Cost-benefit Analysis of a Blockchain-based Supply Chain Finance Solution

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ABSTRACT
Topic Areas: Supply Chain Finance, Blockchain Technology

During the past few years, blockchain technology has shown great potential to disrupt existing supply chain finance solutions, as it could increase the efficiency of invoice processing and provide a more transparent and secure transactions. However, the costs and benefits of implementing blockchain technology in supply chain finance for involved parties are still unclear, since research on the topic is scarce. This thesis explores the net value of implementing blockchain technology in supply chain finance arrangement by using cost-benefit analysis. A cost-benefit model and the operating processes of traditional and blockchain-based supply chain finance solutions are proposed and applied to a real-world case study. We prove that blockchain technology increases the total net benefit among involved parties participating in the supply chain finance arrangement as a result of improved efficiency of invoice processing. We also find that suppliers would benefit from blockchain-based supply chain finance if the benefit from the unlocked working capital outweighs the cost of the platform fee. Another finding is that the buyer does not benefit from the technology in terms of unlocked working capital.

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1 Introduction

In a business world, companies, especially buyers, tend to use trade credit as a tool for financial growth. Trade credit is a business-to-business arrangement that a supplier allows a buyer to extend a payment date and to purchase on account without paying prompt payments (Kumar & Shrivastava, 2013). While the buyer gains benefit from the extended due date, the supplier is affected by a negative working capital situation from the delayed payment. To mitigate this situation, supply chain finance (SCF) becomes a useful financial tool not just for suppliers but also for buyers for enhancing working capital (Hofmann & Belin, 2011). With SCF funding from funders such as financial institutions, the suppliers can access to immediate cash they need, and the buyers might get extended payment term. More importantly, SCF helps provide suppliers with financial and operational liquidity, allowing them to operate their businesses efficiently (Dalen, Reindorp, & Kok, 2015),

Meanwhile, digital transformation has disrupted different industries and transformed businesses and societies over the past decade including SCF. During the past few years, distributed ledger technology such as blockchain technology become one of the most popular headlines in many industries. With its unique capabilities in ensuring transparency, enhancing security, improving traceability, and increasing efficiency and speed, the promising technology reveals its potential to disrupt existing SCF landscape (Hofmann & Strewe, 2018; Omran, Henke, Heines, & Hofmann, 2017). Although the benefits of applying blockchain technology in SCF is obvious, many businesses are reluctant to adopt the blockchain technology in SCF.

One of the most prominent ongoing questions for applying blockchain technology in SCF is whether it is cost-effective for involved parties to use the technology instead of the traditional SCF using a paper-based invoice or traditional platforms. The topic is very crucial towards decisions of blockchain adoption. Although there are some potential cost savings and tangible benefits of using blockchain technology such as the efficiency of invoice processing, there are some potential costs associated to the technology such as a fee to use the blockchain platform. It is crucial for involved parties such as suppliers, buyers, and financial institutions to understand the net value of blockchain-based SCF before they make a decision to implement the technology. From this, the research question of the thesis is "what is the net value of implementing a blockchain-based SCF solution for involved parties". This thesis contributes to research on SCF theoretically and practically. The thesis not only is the first academic paper to propose a cost-benefit model for evaluating the net value of blockchain-based SCF solution, but it also applied the model to a real-world use case.

2. Literature Review

2.1 Supply Chain Finance

The definition of SCF does not appear until the 2000s (Xu et al., 2018). Before the 2010s, SCF was typically defined as a term related to financial management in supply chain management. Hofmann (2005) describes SCF as an approach, located at the intersection of logistics, supply chain management, collaboration, and finance, for organizations involved in a supply chain to collectively create value through means of planning, steering, and controlling the financial resource flow at inter-organizational level. These definitions represent a broad term of financial management in supply chain processes. However, most recent researchers and business sectors have defined SCF in more specific terms. Recently, SCF has been typically defined as financial solutions to optimize the working capital in supply chain processes. Bryant and Camerinelli (2013) define SCF as the use of financial instruments, practices, and technologies to optimize the management of the working capital and liquidity tied up in supply chain processes for collaborating business partners. Omran, Henke, Heines, and Hofmann (2017) identify that SCF nowadays is an isolated series of actions taken to optimize financial flows and working capital through supply chains. Kouvelis, Dong, and Turcic, (2017) explains that SCF focus in on creating liquidity in the supply chain through various buyer or seller-led solutions to optimize both the availability and cost of capital within the supply chain. All in all, SCF is a financial solution that connects the various parties in a transaction — buyers, suppliers, and funders, and it creates win-win scenarios for involving parties by allowing buyers and suppliers short-term credit to optimize their working capital, lower financing costs, and improve business efficiency.

Reverse factoring (RF) is a financial solution that funders, such as financial institutions, offer to pay a supplier's account receivable prior to its due date at a discounted rate. Typically, RF is commonly managed and implemented by banks with their credible buyers and the buyers' suppliers, who might not have a financial record for banks to perform credit evaluation, as they have limited assets that can serve as collateral (Swinderen & Grace, 2015). In the arrangement of RF, the creditworthy buyer typically initiates the process and promises the bank that they will promptly pay the invoice issued by the supplier (Lekkakos & Serrano, 2016). If the supplier desires to get early payment (earlier than the invoice due date), they can sell the invoice to the bank at a discount based on the buyer's credit rating (Lekkakos & Serrano, 2016). In RF, the funders such as banks only need to collect credit information and calculate the credit risk of selected buyers, such as large, internationally accredited firms (Swinderen & Grace, 2015).

In principle, RF is gaining popularity because its well-design program provides benefits to all three main parties involved: suppliers, buyers, and banks (Lekkakos & Serrano, 2016). Suppliers benefit from RF by transferring their credit risk. Suppliers get their receivables financed based on the credit risk of their creditworthy buyers, allowing them to enhance working capital at a better interest rate than they normally are offered (Klapper, 2006). In other words, the credit risk is equal to the default risk of the high-quality buyer, and not the risky suppliers. Similarly, the buyer can benefit financially through an extension in payment term and operationally through improvement in service level (Dalen, Reindorp, et al., 2015). Finally, RF allows the bank to earn a profit through service fees and creates opportunities for cross-selling financial services to the suppliers. It also decreases the bank's overall portfolio risk, meaning that the bank requires fewer capital reserves to meet central bank solvency requirements (Lekkakos & Serrano, 2016).

SCF can be categorized in pre-shipment and post-shipment financing solution. As presented in Figure 1, reverse factoring (RF) can be regarded as a subcategory of SCF within the post-shipment phase under the umbrella term of FSCM (Liebl, Hartmann, & Feisel, 2016). The term Financial Supply Chain Management (FSCM) is defined as optimized planning, managing, and controlling of supply chain cash flows to facilitate efficient supply chain material flows (Wuttke, Blome, & Henke, 2013). However, in recent publications, SCF is frequently referred to as RF (Kleemann, 2018; PwC, 2017; van der Vliet, Reindorp, & Fransoo, 2015). This thesis uses the terms SCF and RF interchangeably.

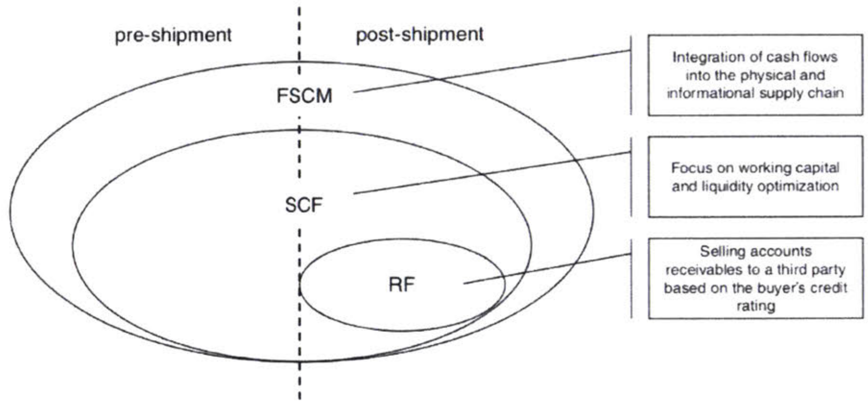

Figure 1: Landscape of reverse factoring (Liebl et al., 2016)

SCF activities are typically enabled by technology platforms that connect buyers, suppliers, and funders together to facilitate the process of reconciliation and exchanging POs, invoices, credit notes, and relevant information among the parties (Hofmann & Belin, 2011). The technology platform is a key enabler of SCF solutions because it makes processes and information sharing more efficient and transparent (Omran et al., 2017). However, the current SCF platform needs digital transformation to increase more speed and effectiveness, to access to real-time visibility and validation of invoices, and to create more trust and collaborative network.

Although there are many parties involved in SCF arrangement, the most popular area of academic research in SCF is supplier-focused, and a supplier participating in an SCF scheme is typically a small and medium enterprise (SME). With the fact that they supply products and services to bigger and more established companies, SME as a supplier can reap benefits from participating in an SCF scheme. There are some studies that investigate SCF specifically on the case of SMEs (Abbasi, Wang, & Alsakarneh, 2018; International Finance Corporation, 2017; Klapper, 2006; Swinderen & Grace, 2015). The research conducted by Klapper (2006) scrutinized the role of SCF in financing SMEs in Mexico, finding that SCF may mitigate the problem of suppliers' credit obscurity only if their buyers are more creditworthy than the suppliers themselves (Klapper, 2006). Swinderen and Grace (2015) published a technical note discussing problems that SMEs in Kenya face within their supply chain and how SCF can help solving these issues. Some scholars have developed formal analytical models to determine the value of SCF for SMEs. Fehmi (2012) claims that his research is the first one applying a mathematical model to demonstrate the operational and financial benefits of RF between a large corporation and SMEs. Grüter and Wuttke (2017) use a real option approach to explore the value of SCF, finding that, in some cases, buyers should ask payment extension instead of price reductions to gain direct benefits from SCF. Both the researches by Fehmi (2012) and Hofmann & Belin (2011) compare the value of SCF between scenarios where SMEs use traditional external financing and where they use SCF. In addition, Lekkakos and Serrano (2016) model a supplier's inventory replenishment issue as a multi-stage dynamic program, and they found that SCF unlocks more than 10 percent of the supplier's working capital.

2.2 Blockchain technology

Blockchain technology, which is one form of distributed ledger technology, is a decentralized data structure that maintains a continuously-growing list of data records and is stored in and shared among the members of a network. A blockchain not only allows to add new data to the database but it also ensures that everyone on the network has similar data, thus ensuring a distributed and decentralized linked data that is immutable to any modification (Muzammal, Qu, & Nasrulin, 2018). In addition, the blockchain is an ideal technology supporting the implementation of smart contracts, computer protocols that allow a contract to be automatically executed and enforced on predefined conditions (Reyna, Martín, Chen, Soler, & Díaz, 2018). When a set of preconditions are met among participants in a smart contract, the contractual agreement can automatically initiate transactions without intermediaries such as banks and lawyers (Omran et al., 2017). The smart contracts enable transactions between different users faster and more effective (Casado-Vara, Prieto, la Prieta, & Corchado, 2018), provide transparency and traceability of the transactions, and ensures visibility and resilience of the network (Varghese & Goyal, 2017).

In addition, one of the potential areas that blockchain can improve is a "Know Your Customer" (KYC) process, an onboarding activity for the suppliers at the banks (Hofmann & Strewe, 2018; McNamara, 2016; Omran et al., 2017). Typically, a KYC request might take as long as 30 – 50 days to turn around using standard industry measures (Fintech Features, 2014). Callahan (2018) reports that 10% of the world's top financial institutions pay at least $100 million each year on KYC and compliance process and that average annual spending (including labor and third-party costs) of the activities is $48 million. Omran et al. (2017) point out that, if the system is underlying by blockchain technology, a KYC process is not necessary anymore, since credit ratings and supplier evaluations will be stored and cryptographically secured in the blockchain. In the same way, McNamara (2016) also explains that the technology could remove the redundancy of carrying out KYC activities and provide a historical record of compliance activities for each client, unlocking benefits by automation and thus reducing compliance errors.

From these advantages, blockchain technology shows great potential to disrupt existing supply chain finance solutions especially in terms of the efficiency of invoice processing and a transparent and secure transaction (Omran et al., 2017). Blockchain can digitise the documents involved in SCF and store them in a form of smart contract. With the immutable characteristics and automation of smart contract, a blockchain-based SCF has potential to disrupt existing SCF solution.

Regarding qualitative literature about blockchain-based SCF, there are some academic studies and white papers that propose operating processes of blockchain-based SCF as shown in Table 1. To illustrate, TradeIX Ltd (2017) proposed the blockchain-based operating process of the blockchain-based SCF where there are single supplier, buyer, and funder with insurance company as a credit guarantee provider. Similarly, Varghese & Goyal (2017) presents the operating process of the blockchain-based SCF where there is a single main party but with an insurance company as a credit guarantee provider. However, the processes proposed by both papers still rely on the traditional invoice. XinFin (2018) Huertas, Liu, & Robinson (2018) and Hofmann & Strewe (2018) present the operating processes of SCF using smart contract instead of a traditional invoice.

	Type of blockchain-based financing	**SCF model (Number of participants)**			**Credit guarantee provider**	**Invoicing type**
		Supplier	**Buyer**	**Funder**		
XinFin (2018)	Project financing	Multiple	Single	Single	Beneficiary	Smart contract
TradeIX Ltd (2017)	SCF (Reverse factoring)	Single	Single	Single	Insurance Company	Traditional Invoice
Cognizant (Varghese & Goyal, 2018)	SCF (Reverse Factoring)	Single	Single	Single	Buyer	Traditional Invoice
EximChain (Huertas et al., 2018)	SCF (Distributor Financing)	Single	Single	Single	Supplier	Smart contract
Hofmann & Strewe (2018)	SCF (Reverse securitization)	Multiple	Multiple	Multiple	Multiple buyers	Smart contract
AZHOS (Rudolf, Kuhs, Baer, & Zintl, 2018)	SCF (Reverse Factoring) using IoT & blockchain-based platform	Single	Single	Single	Buyer	Smart Contract

Table 1: Scope of blockchain-based SCF proposed in white papers and academic studies

Regarding quantitative literature about the blockchain-based SCF, although there are academic papers supporting the claim that blockchain technology is able to reduce cost, improve efficiency, and increase transparency for SCF solutions (Hofmann & Strewe, 2018; Omran et al., 2017), there is no academic literature that quantifies how much blockchain can save cost or provide tangible benefits for parties involved. In order to expand knowledge about SCF and blockchain technology, quantitative research on the aforementioned gap is needed. Cost-benefit analysis is an appropriate quantitative method for this purpose, as this method is a systematic approach to estimate costs against value associated with a solution or project. By determining all the direct, indirect costs and benefits associated with the solution, the business can add the net gains or losses of the solution and make an appropriate business decision based on the analysis. In other words, it is an approach to consider which alternative makes financial sense. Even though cost-benefit analysis has been widely used by scholars in many sectors, it has been seen very limited in the SCF area. Li (2010) analyzes the cost-benefit structure of SCF based on uniform credit mode. Hofmann and Belin (2011) apply cost-benefit analysis to assess the saving potential, for suppliers and buyers, of implementing SCF solution against without SCF solutions. Using the methodology of system dynamics together with the cost-benefit model, Dello Iacono, Reindorp, & Dellaert (2015) shows that market dynamics significantly influence the lifecycle and value of SCF solution. Elliot & Lindblom (2018) presents the cost-benefit model to quantify the benefits and costs of SCF and discuss the case of SCF in Scandinavian banks. However, none applies cost-benefit analysis to evaluate blockchain-based SCF solution.

3. Methodology and data

3.1 Methodology

This research develops a cost-benefit analysis of blockchain-based supply chain financing solutions. To conduct the analysis, a cost-benefit model to quantify the net value of blockchain-based SCF and the operating processes of the traditional and blockchain-based SCF was proposed. Then the model and the processes were applied in a real-world case study.

To develop the new cost-benefit model to quantify the value of blockchain-based SCF, a review of relevant quantitative academic literature in areas of traditional SCF was conducted to find a cost-benefit model as a base-case model. Since an application of blockchain in SCF has been considered a novel concept in recent years, there is a paucity of academic literature on quantifying costs and benefits of blockchain-based SCF. Interviews with practitioners were therefore necessary to revise the base-case model and produce an appropriate cost-benefit model with fixed and variable parameters for blockchain-based SCF.

Once the new model was completed, the next step was to map out operating processes for traditional and blockchain-based SCF solution, to get best-estimated parameters to plug in the model. The thesis analyzes the operating processes in 3 scenarios: (1) traditional SCF solution without blockchain technology, (2) SCF solution using smart contract, and (3) SCF solution using internet-of-things (IoT) & blockchain system. For the first scenario, we began by mapping out the overall operating process of a traditional SCF solution from an academic paper. Then we conducted interviews with practitioners to figure out detail in every step of the processes and came up with the final detailed operating processes for traditional SCF solution. For the second scenario, as mentioned in the literature review, we researched white papers published by companies propose an operating process of a smart contract-based SCF solution. We then introduce the new operating process of smart contract-based SCF solution, which was developed based on the previously proposed processes by the companies together with interviews with experts in SCF and blockchain technology. For the third scenario, we researched one use case of an operating framework of the SCF process via IoT & blockchain-based platform proposed by a prominent fintech company. We then explain the operating process in detail step-by-step and describe how the IoT infrastructures and blockchain system collectively work in the SCF arrangement.

We then applied the cost-benefit model and the operating processes in 3 scenarios to a real-world case study. We use assumptions and parameters from actual financial terms among the involved parties in the SCF arrangement. We also estimated variable parameters from the proposed operating processes in scenario 2 and 3. In the end, the thesis summarizes the key findings and the net value of applying blockchain technology in SCF for the case study.

3.2 Data

For primary data collection, we interviewed a number of industries experts to gather more detailed information on supply chain finance, blockchain technology, and cost-benefit model and to verify our proposed operating processes and all the assumptions we set for the cost-benefit model. The subjects that we interviewed are from different companies such as commercial banks, blockchain consulting firms, law firms, and blockchain start-ups. The list of primary data is provided in Table 2.

No.	Date	Topic	Position of Interviewee	Organization
1	08/25/2018	Trade credit	Product Manager	TMB Bank
2	12/20/2018	Smart Contract	CTO	SmartContract Thailand
3	01/07/2019	Supply Chain Finance	Assistance Vice President	Krungthai Bank Plc
4	01/27/2019	Trade credit	Credit Analyst	Siam Commercial Bank
5	02/19/2019	Supply Chain Finance (Operations)	Senior Vice President	Krungthai Bank Plc
6	02/26/2019	Blockchain-based SCF	Lawyer	Singapore Law Firm*
7	02/27/2019	Supply Chain Finance	Product Manager	Krungsri Bank

8	03/03/2019	Blockchain-based SCF	CEO	Blockchain-based platform provider*
9	03/04/2019	Supply Chain Finance (Commercial)	Senior Analyst	Krung Thai Bank Plc
10	03/10/2019	Operating process	Relationship Manager	Krungsri Bank
11	03/26/2019	Smart Contract	CTO	SmartContract Thailand

*The subjects prefer not to disclose the organization name

Table 2: List of primary data

For secondary data collection, as there is limited academic literature blockchain-based SCF solution, we used white papers proposed by fintech companies and books written by well-known professors and researchers. The list of secondary data is shown in Table 3.

Name of writings	Writers	Type of writings
Blockchain for trade finance	XinFin (2018)	Business white paper
Case study: receivable finance	TradeIX Ltd (2017)	Business white paper
Blockchain for trade finance: payment instrument tokenization	Cognizant (Varghese & Goyal, 2018)	Business white paper
Eximchain: Supply Chain Finance solutions on a secured public, permissioned blockchain hybrid	EximChain (Huertas et al., 2018)	Business white paper
Supply chain finance and blockchain technology: the case of reverse securitisation	Hofmann & Strewe (2018)	Book
AZHOS: Proof of existence for supply chain finance	AZHOS (Rudolf et al., 2018)	Business white paper
Blockchain-driven supply chain finance: Towards a conceptual framework from a buyer perspective	(Omran et al., 2017)	Academic paper

Table 3: List of secondary data

4. The cost benefit model

4.1 Evaluating benefits of SCF solutions

There are many aspects of SCF's benefits from blockchain technology including the efficiency of invoice processing, real-time validation of invoice, irreversible transaction or efficient trust, and easy & fast supplier onboarding (Omran et al., 2017). Among those benefits, this thesis focuses on evaluating the benefit of SCF solutions in the aspect of efficiency of invoice processing, which is directly related to unlocked working capital. The unlocked working capital is the tangible benefit of a supplier and a buyer participating in the SCF arrangement (Gelsomino, de Boer, Steeman, & Perego, 2018). To elaborate, the faster the process is, the more working capital can be unlocked.

For the supplier, the unlocked working capital is the implied financial gain from reduced day sales outstanding (DSO). In the real world, the supplier would possibly have different trade credit agreements other than SCF, in which the agreements affect the supplier's DSO. To clearly determine which costs and benefits arise from the SCF solution, we evaluate the net benefit of unlocked working capital for a single SCF agreement for three involved parties: supplier, buyer, and funder.

The supplier's rate of getting early funding from the funder is R_{scf} or SCF interest rate. The total amount of early funding is calculated based on the invoice amount and the duration financed. Another important assumption is that the supplier is able to access the external short-term financing at R_s, which is equal to the supplier's cost of debt. Giving the situation without information asymmetry and market imperfection, the actual opportunity financing costs of the suppliers and the buyers in SCF would be represented by R_s and R_b, respectively, (Elliot & Lindblom, 2018). Typically, R_s is higher than R_{scf}, since the funder assesses R_{scf} based on the creditworthiness of the buyer, who is generally a large company and is the funder's customer with high credit rating. Therefore, given the fact that $R_{scf} > R_s$ for typical SCF arrangement, a supplier, such as SME, has incentives to get financing through SCF solution instead of a short-term loan from external working capital financing.

Similarly, the buyer benefits from SCF due to unlocked working capital. However, unlike the case of a supplier, the buyer's unlocked working capital is an implied financial gain from increased day payable outstanding (DPO). In other words, in an SCF arrangement, the funder sometimes allows the buyer to extend credit term to attract the buyer to participate in the SCF scheme. The extended payment term enables the buyer to improve its working capital. We also assume that the buyer has only one SCF agreement to accurately determine the net benefits of the SCF solution and that the buyer can access external working capital financing at R_b, the buyer's cost of debt.

A tangible benefit of the funder in an SCF scheme is the interest that the supplier pays for the financing. With its cost of funding is R_f, the funder provides the supplier early financing at R_{scf}. The duration of the financing provided by the funder under an SCF arrangement is the same as the duration that the supplier benefits from the SCF scheme.

Another key involved party is a platform provider, who provides a blockchain platform to facilitate the blockchain-based SCF activities. A tangible benefit of the platform provider is a platform fee, F_i, that they charge the supplier. The fee is charged in the form of a percentage of the total amount of the invoice.

4.2 Cost-benefit model

Following the method used by Dello Iacono, Reindorp, and Dellaert (2015), the tangible benefit of supply chain financing for the buyer can be calculated by the base model as described below.

$$Benefit_{\text{buyer}} = A * R_{\text{b}} * (\frac{T_{\text{ext}}}{365})$$

$$Benefit_{\text{supplier}} = A * (R_{\text{s}} - R_{\text{scf}}) * \left(\frac{T_{\text{scf}}}{365}\right)$$

$$Benefit_{\text{funder}} = A * (R_{\text{scf}} - R_{\text{f}}) * (\frac{T_{\text{scf}}}{365})$$

The base model calculates the benefits from the difference in gain between the scenario of no SCF solution (trade credit) and that of SCF solution. A trade credit is an arrangement between a supplier and a buyer, in which the buyer can purchase and utilize goods or services and pay the supplier at a later date. The buyer and the supplier mutually set a duration of the trade credit T_{ini}, also known as a due date, which is typically determined in a specific number of days. The buyer has to pay the supplier within an agreed trade credit period or within T_{ini} day, in which the last day of the trade credit is known as a due date. For the buyer and the supplier, the direct benefits of a supply chain finance arrangement calculated by the model are reductions in working capital costs. On the other hand, the funder gains income by interest/fee charged from the supplier.

However, according to the interviews, the base model does not provide realistic benefits since the SCF solution in actual business cases has different arrangement and contains some parameters other than what the models provides.

First, the base model assumes that the duration of supply chain finance solution provided by the funder, during which the supplier gains benefit, is T_{scf}, which is based on the extended credit term that the buyer agrees on with the funder. However, according to the interview with subject no.3, one popular arrangement of supply chain finance is that the funder allows the supplier the early funding with the original payment period. In other words, the duration in which the supplier earns benefits from SCF solution is not until the extended date but from the day when the supplier is able to get early funding (T_i) until the original due date (T_{ini}), making the SCF length for this case is T_{ini} - T_i. Therefore, we adjust the model:

$$Benefit_{\text{buyer}} = A * R_{\text{b}} * (\frac{T_{\text{ext}}}{365})$$

$$Benefit_{\text{supplier}} = A * (R_{\text{s}} - R_{\text{scf}}) * \left(\frac{T_{\text{ini}} - T_{\text{i}}}{365}\right)$$

$$Benefit_{\text{funder}} = A * (R_{\text{scf}} - R_{\text{f}}) * (\frac{T_{\text{ini}} - T_{\text{i}}}{365})$$

Second, the base-case model assumes that the funder agrees to provide early funding for full amount of the invoice. However, according to the interviews with subjects no. 3 and 7, a funder typically does not allow the supplier the full amount of invoice for early funding, but the discounted amount based on credibility of the buyer and the supplier. In other words, the amount financed by the funder is the discount factor (D) multiply by the full amount of the original invoice (A). To include the factor in the model, we adjust the model:

$$Benefit_{\text{buyer,i}} = A * R_{\text{b}} * (\frac{T_{\text{ext}}}{365})$$

$$Benefit_{\text{supplier,i}} = D * A * (R_{\text{s}} - R_{\text{scf}}) * \left(\frac{T_{\text{ini}} - T_{\text{i}}}{365}\right)$$

$$Benefit_{\text{funder,i}} = D * A * (R_{\text{scf}} - R_{\text{f}}) * (\frac{T_{\text{ini}} - T_{\text{i}}}{365})$$

Finally, the base model assumes that there is no service fee charged for using the platform. The assumption is valid in case the SCF activities are done via an internal platform developed and operated by the funder. However, in case the blockchain-based SCF provided by a third-party platform provider, the supplier usually has to pay a platform service fee (F_i) charged by the platform provider. SCF platform provider usually charges the platform fee in form of percentage of amount financed. Thus, we add the benefit of the platform provider and adjust the model. The final cost-benefit model is shown below:

$$Benefit_{\text{buyer,i}} = A * R_{\text{b}} * (\frac{T_{\text{ext}}}{365})$$

$$Benefit_{\text{supplier,i}} = D * A * (R_{\text{s}} - R_{\text{scf}} - F_{\text{i}}) * \left(\frac{T_{\text{ini}} - T_{\text{i}}}{365}\right)$$

$$Benefit_{\text{funder,i}} = D * A * (R_{\text{scf}} - R_{\text{f}}) * (\frac{T_{\text{ini}} - T_{\text{i}}}{365})$$

$$Benefit_{platform,i} = D * A * (F_i) * (\frac{T_{ini} - T_i}{365})$$

Variable	Unit	Description
A	$	Amount of the invoice
R_s	% / year	Supplier's interest rate
R_b	% / year	Buyer's interest rate
R_f	% / year	Funder's cost of funding
R_{scf}	% / year	Interest rate of SCF
i	-	Number of scenarios
T_{ini}	Days	Original payment term
T_{ext}	Days	Extended payment term
F_i	% / Transaction	Service fee charged by the platform provider
T_i	Days	Period from invoice approval to early payment receipt

Table 4: Variables explanation

The final model is based on assumptions that:

(1) No relevant operational costs

(2) A supplier and a buyer are already onboard by a funder

(3) A buyer does not default the payment

(4) No transaction cost

(5) No exchange fee between cryptocurrency and traditional currency

(6) No setup costs

5. The operating processes

The operating processes on 3 three scenarios are formulated to evaluate to be a framework for analyzing operational characteristics of traditional and blockchain-based SCF solution. The 1st scenario is when the buyer and the supplier participate in the traditional SCF arrangement provided and financed by the funder. In the 2nd scenario, the buyer and the supplier take part in the smart contract-based SCF solution via the blockchain platform and financed by the funder. Lastly, the 3rd scenario is when the buyer and the supplier adopt the blockchain and IoT infrastructure and participate in blockchain-based SCF program offered by the blockchain platform and funded by the funder.

5.1 Scenario 1: SCF solution using traditional invoice

Prior to the traditional SCF process, the buyer has to create a purchase order (PO) and submit the PO to the supplier. After receiving and processing the PO internally, the supplier prepares and delivers goods and invoice to the buyer. The buyer and the supplier also agree on the amount A and the payment term of T_{ini} days. The process of SCF begins when the buyer receives the invoice from the supplier (Day 0). We assume that the supplier requires the funding with a lowest interest rate immediately or as soon as possible after the buyer receives the invoice. In doing so, the supplier has two options: get funding from external financing at R_s or get early funding SCF solution at rate R_{scf}. Thus, given that both options are available for the supplier and that $R_{scf} < R_s$, the supplier choose to participate in the SCF arrangement to maximize its benefits.

Liebl, Hartmann, and Feisel (2016) proposed the process of supply chain financing. It starts when (1) the supplier sends an invoice to the buyer. (2) The buyer then approves and submits the invoice to the funder via the platform. (3) The supplier then gets access to immediate discounted cash from the funder based on the creditworthiness of the buyer. In the end, (4) the buyer makes the funder the invoice payment at the due date. The operating flow is shown in Figure 2.

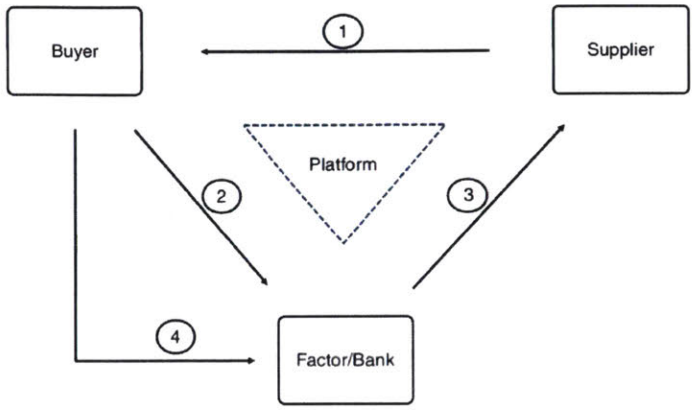

Figure 2: Traditional process of SCF (Liebl et al., 2016)

However, like that in other academic papers, the process flow does not provide a description, bottlenecks, and inefficiencies of the process. To analyze the costs and benefits of supply chain finance solution for involved parties and clearly evaluate the parameter T_i, we need to understand the process flow for every party in detail. According to the interviews with subject number 3,7 and 10, we propose the detailed process flow derived from real-world cases as shown in Figure 3.

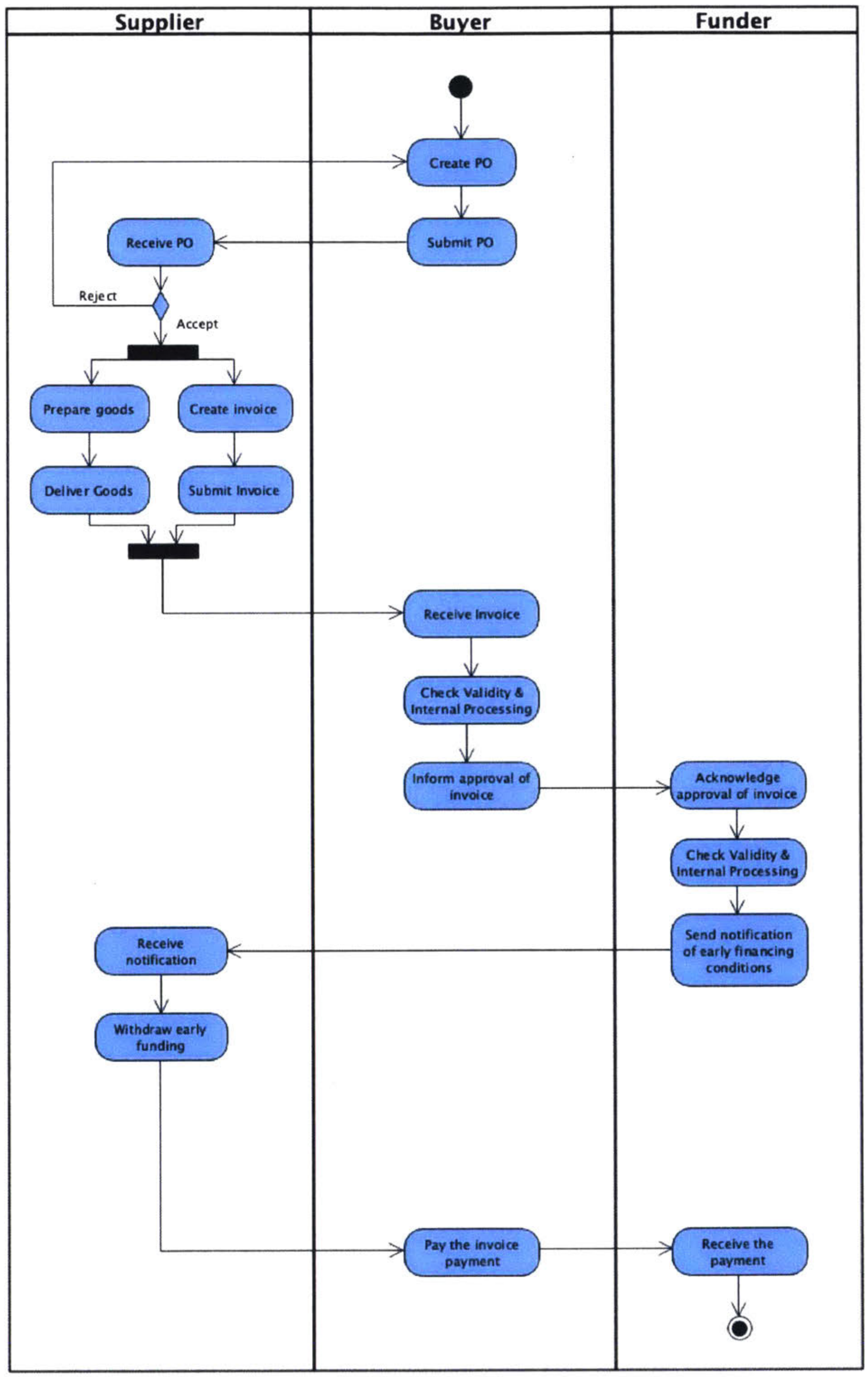

Figure 3: Our proposed traditional SCF operating process

As seen in the figure, the supplier, whom the funder has already onboarded, participates in the SCF scheme initiated by the buyer and solely funded by the funder. The funder and the buyer jointly agree to extend the payment term for T_{ext} days. Thus, the total payment term that the buyer needs to repay the funder is within T_{ini} + T_{ext} days. After receiving the invoice on day 0, the buyer spends T_2 days as an administrative time to process and check the validity of the invoice. We assume that the buyer maximizes its own benefits by paying the amount to the funder at the end of extended period, while the supplier does so by acquiring external financing at R_s from day 0 to day T_2 and then get early discounted funding through SCF solution at rate R_{scf} from day T_2 to the extended due date or day T_{ini} + T_{ext}. The declaration of the approved invoice allows the funder to view the transaction at "buyer risk".

5.2 Scenario 2: Supply chain finance solution using Smart Contract

In this scenario, instead of traditional invoices, a smart contract is used in the SCF process. Unlike ordinary contractual documents such as an invoice, smart contracts have three key characteristics: autonomy, self-sufficiency, and decentralization (Swan, 2015). A smart contract can automatically run by itself without triggering from its initiating agent, is flexible to establish specific conditions to trigger the execution and is securely stored in a decentralized blockchain network. In general, a smart contract for invoicing is designed to satisfy common contractual obligations such as payment terms. A smart contract provides efficiency and transparency through automation, significantly reducing the processing time for each party to submit, verify, and approve the invoice. The currency used in smart contracts is called cryptocurrency or tokenized currency, which represents an asset for exchanging in the blockchain network.

There are some white papers written by researchers and fintech companies on the block-chain-based SCF arrangement. However, as shown in Table 1, there is no paper proposing an operating flow of smart contract-based SCF that has all the following characteristics:

- The type of financing is SCF (reverse factoring)
- The SCF model is a single supplier, a single buyer, and a single funder
- The credit guarantee provider is the buyer
- The invoicing type is the smart contract

Our proposed smart contract-based SCF has the aforementioned characteristics and involves 4 parties: a buyer, a supplier, a funder, and a platform provider. To begin, the platform provider creates and operates the SCF platform that runs on the blockchain network, allowing the involved parties to implement smart contract-based SCF. The supplier, the buyer, and the funder create their own cryptocurrency wallets in the blockchain platform. The buyer and the supplier need to submit onboarding data including historical financial records.

Once the supplier agrees on the PO initiated by the buyer, the supplier prepares and delivers the goods. The supplier then initiates the smart contract as if it were an invoice (Step 1). The initial data stored in the smart contract include supplier ID, buyer ID, funder ID, amount of the invoice, and original due date. The smart contract verifies whether the supplier and buyer are already onboarded by the funder. If it fails in this condition, the smart contract cannot be created. If the verification is positive, the smart contract is fully created and tokenized, and the initial status is set to "W" (Waiting for approval), finishing step 1.

The notification is then automatically sent to the buyer to verify and approve (Step 2). If the buyer declines or wants to change the terms of the smart contract, the buyer needs to discuss it with the supplier, and the supplier has to re-create the smart contract. Once receiving the goods, the buyer approves the smart contract, altering the status to "A" (Approved), thus triggering the approved smart contract to store in the blockchain. The buyer might set the condition to automatically approve the smart contract by linking the blockchain network with its internal ERP system. For example, once the buyer's procurement team confirms the receipt of inventory from the supplier in their ERP system, the ERP system will send the notification to the platform, automatically triggering the smart contract, changing the status from "W" to "A", and sending the notification to the funder. This is the end of step 2.

In the next step, the funder has to input three financing conditions: discount, interest rate, and extended due date (Step 3). Similarly, the funder might set conditions to fill in these three items automatically, given the supplier ID and the buyer ID shown in the smart contract. In order to do so, the funder needs to set the conditions for each supplier and buyer for the three parameters in advance. An example of such conditions is shown below.

		Amount of Invoice					
Buyer ID	Supplier ID	Less than $10,000			More than $10,000		
		Discount (%)	Interest rate (%)	Extended Due date (days)	Discount (%)	Interest rate (%)	Extended Due date (days)
0x558a...	0x61a2....	X1	Y1	Z1	X2	Y2	Z2
	0x71ag....	X3	Y3	Z3	X4	Y4	Z4
	0x112h....	X5	Y5	Z5	X6	Y6	Z6
0x6s25...	0x41hq....	...	...	...	...	...	...
	0xj57k....	...	...	...	...	...	...
	0x6n8y....	...	...	...	...	...	...

Table 5: Example of the conditions set by the funder

When the funder confirms the three parameters, a notification is then sent to the funder, allowing the supplier to request early funding from the funder and altering the status from "A" to "R" (Ready for financing), ending step 3.

For step 4, the supplier has the choice to trigger the smart contract to transfer early funding from the funder's wallet to the supplier's wallet whenever the supplier needs. In this case, we assume that the supplier maximizes its benefit by triggering the contract on the day after it receives the notification from the funder. Once the transaction is completed, the status of the smart contract changes to "P" (Paid).

For the last step (step 5), on the extended due date specified in the smart contract, the money is transferred from the buyer's to the funder's wallet to pay the invoice, changing the status of the smart contract to "C" (Completed). Figure 4 shows the information stored in the blockchain for each step. The bold information in the tables represents updated information stored in the blockchain in each step.

(Step 1) The supplier creates the smart contract

Type of information	Stored information
Invoice ID (Primary Key)	**0x1v98….**
Buyer ID (Encrypt)	**0x558a…**
Supplier ID (Encrypt)	**0x61a2….**
Funder ID (Encrypt)	**0xq3f2….**
Amount of invoice	**10,000,000**
Description	**Chemical materials**
Due date	**12/Jan/2019**
Status	**W**

(Step 2) The buyer approves the smart contract

Type of information	Stored information
Invoice ID (Primary Key)	0x1v98….
Buyer ID (Encrypt)	0x558a…
Supplier ID (Encrypt)	0x61a2….
Funder ID (Encrypt)	0xq3f2….
Amount of invoice	10,000,000
Description	Chemical materials
Due date	12/Jan/2019
Status	**A**

(Step 3) The funder input the three parameters

Type of information	Stored information
Invoice ID (Primary Key)	0x1v98….
Buyer ID (Encrypt)	0x558a…
Supplier ID (Encrypt)	0x61a2….
Funder ID (Encrypt)	0xq3f2….
Amount of invoice	10,000,000
Description	Chemical materials
Due date	12/Jan/2019
Status	**R**
Discount	**90%**
Interest rate	**5%**
Extended due date	**12/Feb/2019**

(Step 4) The supplier triggers the payment

Type of information	Stored information
Invoice ID (Primary Key)	0x1v98….
Buyer ID (Encrypt)	0x558a…
Supplier ID (Encrypt)	0x61a2….
Funder ID (Encrypt)	0xq3f2….
Amount of invoice	10,000,000
Description	Chemical materials
Due date	12/Jan/2019
Status	**P**
Discount	90%
Interest rate	5%
Extended due date	12/Feb/2019

(Step 5) The buyer pays the funder at extended due date

Type of information	Stored information
Invoice ID (Primary Key)	0x1v98….

Buyer ID (Encrypt)	0x558a...
Supplier ID (Encrypt)	0x61a2....
Funder ID (Encrypt)	0xq3f2....
Amount of invoice	10,000,000
Description	Chemical materials
Due date	12/Jan/2019
Status	**C**
Discount	90%
Interest rate	5%
Extended due date	12/Feb/2019

Figure 4: Information stored in smart contract in each step

5.3 Scenario 3: Supply chain finance solution using blockchain & IoT system

In December 2018, AZHOS launched a whitepaper proposing an SCF solution using blockchain and IoT system (Rudolf et al., 2018). AZHOS is a blockchain-based SCF platform on the Ethereum-based Quorum Blockchain. The platform enables an automated SCF process by utilizing data stored in blockchain by real-time monitoring sensors in supply chain processes; it uses such data for the automation and digitalization of SCF process, allowing simplified processes and releasing tied-up working capital. In other words, AZHOS enables suppliers to receive an instant payment to reduce tied-up working capital upon fulfilment of conditions in a smart contract by an IoT system. The signal flow is shown in Figure 5.

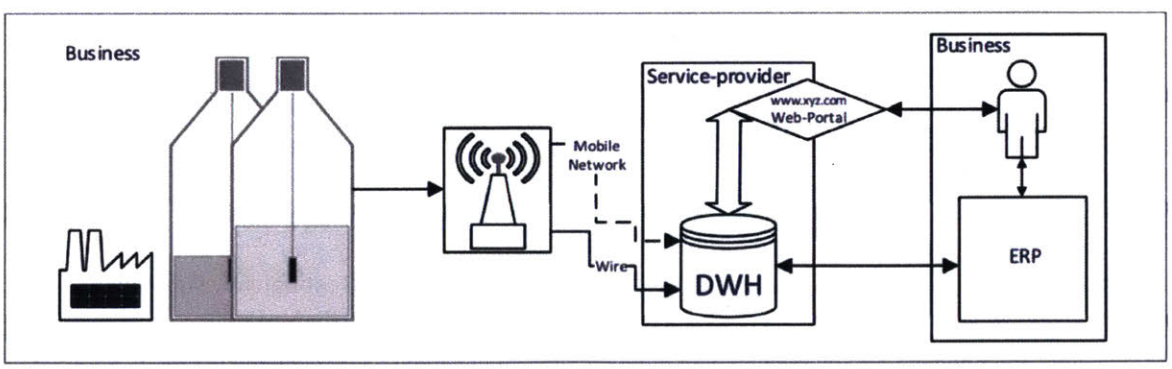

Figure 5: Signal flow of real-time inventory monitoring (Rudolf et al., 2018)

The white paper also proposes the operating process SCF via AZHOS's system. To elaborate, AZHOS's system includes sensor technology at the buyer's location to store the data on the blockchain system to monitor the stock levels of inventory. Thus, the integration of ERP systems between the supplier and the buyer through AZHOS is necessary. When there is a need for goods, a PO is proposed through ERP from the buyer to the supplier. After accepting the PO, the supplier makes an order response to the buyer and issues a Shipment Notice (SN) with planned shipment time to AZHOS. The SCF process is triggered in the smart contract when AZHOS receives the SN. The financial institution then transfers the on-hold tokenized money to the supplier. Before the buyer records the Delivery Receipt (DR), the sensor monitors the stock level. The Delivery Receipt (DR), which has been recorded and sent from the buyer to AZHOS, communicates with the corresponding Smart Contract to create the Proof-of-Inventory (POI). Once the POI is stored in the smart contract, the supplier is able to withdraw the on-hold financing. The buyer pays the amount directly to the funder on the extended due date. The smart contract of the funder then sends the fee request to the supplier. Finally, the funder splits the fee collected from the supplier with AZHOS. The cryptocurrency used in the platform is the AOS token.

5.4 Summary of the three scenarios

As shown by using parameters from the cost-benefit model in Figure 6, we present the three scenarios in comparable to a base-case scenario. The base case scenario is the case when the buyer and the supplier do not participate in the SCF program and decide to pursue the original trade credit term. As explained in section 4, the tangible benefit to a supplier from participating in the SCF program is the unlocked working capital from early payment. The unlocked working capital for supplier increases inversely proportional to T_i, which is the period from invoice approval to early payment receipt by the supplier. As a result of increased efficiency by blockchain technology, the processing time required from the first day that the supplier submits the invoice (Day 0) to the day that the supplier is able to get early funding (Day T_i) decreases from scenario 1,2 and 3 respectively, meaning that $T_1 > T_2 > T_3$. Therefore, considering only the unlocked working capital perspective, the supplier's tangible benefit from unlocked working capital is more in scenario 3 than in scenario 2 and 1 respectively, and that of the buyer is the same among three scenarios.

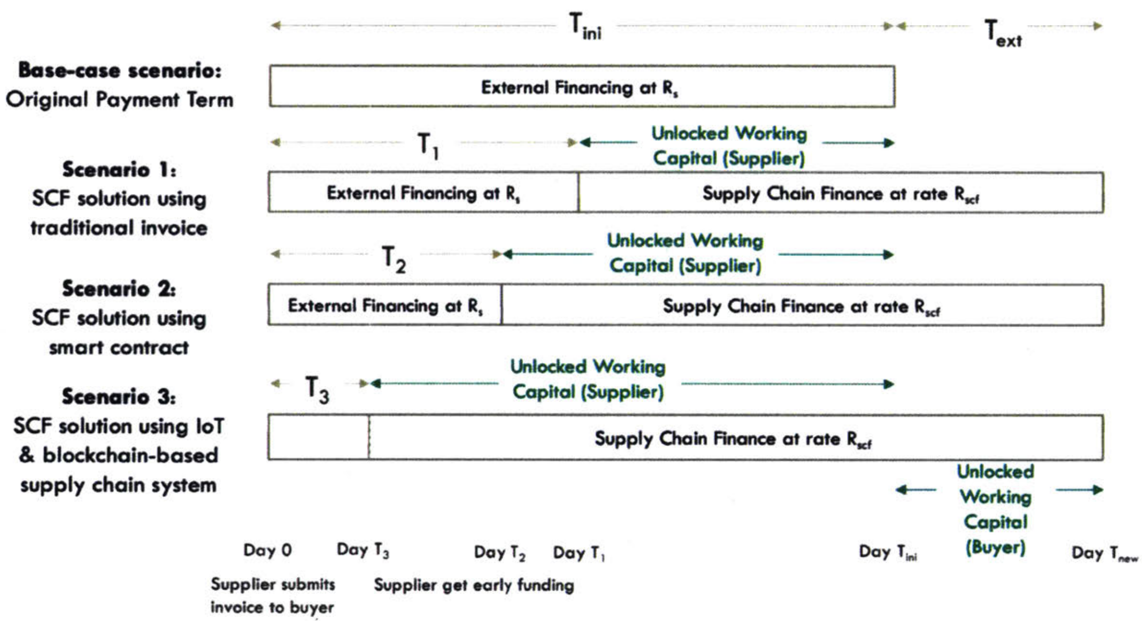

Figure 6: Three scenarios of SCF arrangement

6. Case study

6.1 Case overview

The case study used in the thesis is real-world data from one of the leading commercial banks in Thailand ("the funder"). The raw data includes the operating processes and financial arrangement of SCF solutions among the bank and its customer ("the buyer") in the hypermarket industry. The funder is one of the leading banks in Thailand, which offers financial services including SCF solutions. The buyer is a leading European supermarket company that has had an operation in Thailand for more than 20 years. The buyer offers a wide range of products and services including food, beverages, mobile phone services, ticket services, bill payments, and online shopping. Together with its own in-house brands, the buyer has thousands of SKUs provided by a number of suppliers. The supplier in the case study sells foods and beverages to the buyer with the credit term and utilize the SCF scheme provided by the funder to improve working capital. The collected raw data include invoices, operating process, financing terms, and supplier information, and buyer information. Due to the non-disclosure agreement, this thesis does not disclose the organization names of the involved parties and keep them anonymous.

6.2 Parameter extraction

Among the raw data, we extracted only the necessary data for the cost-benefit model. To begin, for the financial conditions of SCF, the funder allows all the suppliers to be financed at 95% of the total amount of the invoice. One of the suppliers participating in the SCF program, for which we were given data, was allowed to have a maximum amount of loan at 10,000,000 THB or 302,114.8 USD, calculated based on the exchange rate at 0.03021. Although the credit terms between the buyer and its suppliers vary depending on the deals, the average credit term is 30 days. The funder agrees with the buyer to extend the due date for 20 days maximum.

In addition, the funder's cost of funding, or R_f, is set at Thailand's policy rate, which is the rate that the central bank or Bank of Thailand announces as a benchmark for other monetary variables in the economy. According to the bank of Thailand, the policy rate as of Mar 2019 is 1.75%. Besides, for all suppliers of this buyer, the funder set the same interest rate for SCF solution (R_{scf}) at Minimum Overdraft Rate (MOR) minus 2.5%. In Thailand, the MOR is the common interest rate for reference when the funder offers a working capital loan. Almost every financial institution in Thailand publicly announces its own MOR. For the sake of confidentiality, this thesis uses average MOR of the top 7 banks in Thailand, instead of the actual MOR of the funder. As shown in Table 6, the average MOR is 7.159%. According to the interview with the case holder, a benchmark rate for the supplier's cost of debt or R_s is at MOR and for the buyer's cost of debt is MOR – 2.5%. Therefore, we conclude that R_s = 7.150%, R_b is 4.659%, R_f = 1.75%, R_{scf} = 4.659%. The summary of the parameters extracted from the case study is shown in Table 7.

Name of Bank	MOR
Bangkok Bank	7.125
Siam Commercial Bank	6.870
Krungthai Bank	7.120
Kasikorn Bank	7.120
Government Saving Bank	7.000
TMB Bank	7.675
Krungsri Bank	7.200
Average	**7.159**

Table 6: Average MOR as of 27th Mar 2019 (Source: Multiple banks)

Parameters	Unit	Amount
A	$	302,114.80
D	%	95%
R_s	% / year	7.159%
R_b	% / year	4.659%
R_f	% / year	1.750%
R_{scf}	% / year	4.659%
T_{ini}	Days	30
T_{ext}	Days	20

Table 7: Summary of the parameters extracted from the case study

In order to clearly evaluate the tangible benefits of blockchain technology in SCF, we apply the same data from SCF arrangement among the supplier, the buyer, and the funder in all three scenarios.

While the 1st scenario or the traditional SCF arrangement is the real-world case that they implement, the 2nd and 3rd scenarios are created based on the assumptions as explained in section 5. Given that the same financial terms and financial conditions of involved parties are applied, the set of the fixed parameters for each scenario is similar, while the control parameters vary from scenario to scenario. The fixed parameters include A, D, R_s, R_b, R_{scf}, T_{ini}, and T_{ext}, and the control parameters include T_i and F_i. One of the two key control parameters that are used to determine tangible benefits from the improved efficiency of the process is T_i, which represents the total duration of invoice processing and approval process of each involved parties. In other words, the parameter represents the number of days that the working capital is stuck in the SCF process so that the supplier cannot get early funding. The lower the parameter is, the more working capital the supplier can be unlocked. In addition, another control parameter is F_i, which represents the service fee that the platform provider charges to operating the blockchain-based SCF platform. For the 1st scenario, the SCF arrangement is implemented via the funder's internal platform. However, for the blockchain-based SCF such as the 2nd and 3rd scenario, the SCF process is typically implemented in the blockchain-based platform where there is a platform provider that manages and operate the platform, and the supplier has to pay a platform fee to the platform provider to use the SCF solution. Therefore, the key variable parameters among the three scenarios are T_i and F_i. The following parts explain the parameters of the three scenarios.

For scenario 1, according to the interview with the case holder, it takes around 10 days on average after the buyer receives the invoice from the supplier until the supplier could withdraw the early funding from the funder. Along the way, the most important bottleneck is the period required by the buyer to process and submit the invoice to the funder. The bottleneck is partly due to the buyer's inefficiency process and internal policy. For example, a buyer might have the policy to process all invoices once at the end of each week, thus delaying the process for about 7 days. The delay is partly because the buyer lacks an incentive to submit the invoice early. As the buyer's incentive is the extended due date which is not related to how quickly they process the invoice, they feel that the invoice processing process is a burden for them. After receiving the invoice approval from the buyer, the funder takes approximately 2 days to process the document, perform a validity check, and then is able to send the notification to the supplier to get early funding. The supplier usually withdraws the money the day after receiving the notification. In brief, the process takes about 10 days (T_1 = 10) on average from the first day of the process until the day the supplier withdraws the money. In addition, since there is no platform provider in this scenario, the parameter F_i equals to zero. To sum up, the parameters of scenario 2 are shown below in Table 8.

Parameters	Unit	Scenario 1
A	$	302,114.80
D	%	95%
R_s	% / year	7.159%
R_b	% / year	4.659%
R_f	% / year	1.750%
R_{scf}	% / year	4.659%
T_{ini}	Days	30
T_{ext}	Days	20
T_i	Days	10
F_i	% / Transaction	-

Table 8: Parameters for cost-benefit model of scenario 1

For scenario 2, by replacing a traditional invoice, the smart contract-based invoice reduces processing time (T_i), allowing the supplier to get earlier payment than in scenario 1. As explained in scenario 1, the supplier needs to wait around 10 days on average until they get early finance from the SCF arrangement due to inefficiencies in the manual operating and approval processes. However, in the operating process proposed in scenario 2 powered by a smart contract, many bottlenecks have been eliminated. For example, time-consuming operations such as manual validation of the invoice can be eliminated, allowing the invoice to be financed faster, releasing tied-up working capital for the supplier and increasing revenue for the funder from a longer duration of financing. However, some simple manual operations are required. To elaborate, the supplier, the buyer, and the funder still need to input or approve some information manually, although the majority of the processing time required is reduced. For example, in step 2, the buyer does not need 7 days on average, as it does in scenario 1, to process the invoice for a validity check and bulk approval of the invoices manually. The smart contract allows the buyer to automatically check the identity of the supplier and to create and approve the invoice electronically without paperwork. According to the interviews with subject no.10 and 11, our proposed operating process is estimated to reduce T_i from 10 to 5 days (T_2 = 5). Moreover, since there is a platform provider involved in the smart contract-based SCF solution, the platform fee is charged by the platform provider. According to the interview with subject no.8, their blockchain-based platform charges 15% of the supply chain financing rate that the funder charges to the supplier. In our case study, the supply chain financing rate of R_{scf} is 4.659% as calculated in section 4.2, resulting in the platform fee equal to 15% * 4.659% = 0.699% of the amount financed (F_2 = 0.699%). Therefore, according to the data from the case study described in section 4.2, the parameters for scenario 2 are shown in Table 9.

Parameters	Unit	Scenario 2
A	$	302,114.80
D	%	95%
$\mathbf{R_s}$	% / year	7.159%
$\mathbf{R_b}$	% / year	4.659%
$\mathbf{R_f}$	% / year	1.750%
$\mathbf{R_{scf}}$	% / year	4.659%
$\mathbf{T_{ini}}$	Days	30
$\mathbf{T_{ext}}$	Days	20

T_i	Days	5
F_i	% / Transaction	0.699%

Table 9: Parameters for cost-benefit model of scenario 2

For scenario 3, many inefficiencies such as manual creation of the PO by the buyer, creation of invoice by the supplier, and invoice validation and approval by the buyer and the funder can be removed. Instead of the buyer, the platform provider is the party that triggers the approval of early funding after receiving SN from the supplier. In addition, the funder can start processing even before the materials are shipped to the buyer. While the funder needs to wait for the buyer to approve the invoice or smart contract until the funder can process it in scenario 1 and 2, the funder in scenario 3 can start working on the tasks after receiving SN, during which the goods are on the way to the buyer. In scenario 1 and 2, we set the delivery date of the goods, and the invoice submission by the supplier is the beginning of SCF process or as day 0. Given that each scenario is the same case study with similar goods and that the SN is issued before the DR is triggered, we set the day that the DR is created as day 0. Therefore, once the DR triggers the POI, it allows the supplier to get the funding. Similar to the previous scenarios, we assume that the supplier withdraws the funding the day after. Thus, for scenario 3, T_3 is 1 day. Moreover, according to an interview with subject number 8, the platform fee is 15% of the supply chain financing rate, which is 4.659%. Therefore, the F_3 equal to 15% * 4.659% or 0.699%, which is the same as in scenario 2. All in all, according to the data from the case study described in section 4.2, the parameters used in the cost-benefit model for scenario 3 are shown in Table 10

Parameters	Unit	Scenario 3
A	$	302,114.80
D	%	95%

R_s	% / year	7.159%
R_b	% / year	4.659%
R_f	% / year	1.750%
R_{scf}	% / year	4.659%
T_{ini}	Days	30
T_{ext}	Days	20
T_i	Days	1
F_i	% / Transaction	0.699%

Table 10: Parameters for cost-benefit model of scenario 3

7. Results and discussion

The results from the analysis are calculated in the form of benefits to involved parties including the supplier, the buyer, the funder, and the platform provider; they are illustrated in Appendix A-G. Each Appendix shows the benefits to each party in USD in any given T_i (Column) and F_i (Row). From these results, there are four key findings from the analysis.

To begin, the first key finding from the analysis is that blockchain technology increases the total net benefits of the SCF solution. The total net benefits were calculated from the sum of benefits to involved parties. As can see in Table 11, the total net benefits in our cast study are $1,621.77, $1,841.65, and $2,012.92 for scenario 1,2, and 3 respectively. Therefore, the net benefits from shifting from scenario 1 to scenario 2 are $1,841.65 - $1,621.77 = $210.88 and to scenario 3 is $2,012.92 - $1,621.77 = $391.15. To illustrate this in the real-world situation, if involved parties converted from the SCF solution using a traditional invoice (scenario 1) to the SCF solution using smart contract (scenario 2) and to SCF solution using blockchain-based & IoT platform (scenario 3), the total net benefits for involved parties would increase $210.88 or 13% and $391.15 or 24% respectively.

Result	Scenario 1	Scenario 2	Scenario 3
Benefit to Supplier	$ 393.16	$ 354.09	$ 410.74
Benefit to Buyer	$ 771.19	$ 771.19	$ 771.19
Benefit to Funder	$ 457.42	$ 571.77	$ 663.25
Benefit to Platform	$ -	$ 144.60	$ 167.73
Total net benefit	$ 1,621.77	$ 1,841.65	$ 2,012.92

Table 11: Benefits to involved parties in each scenario

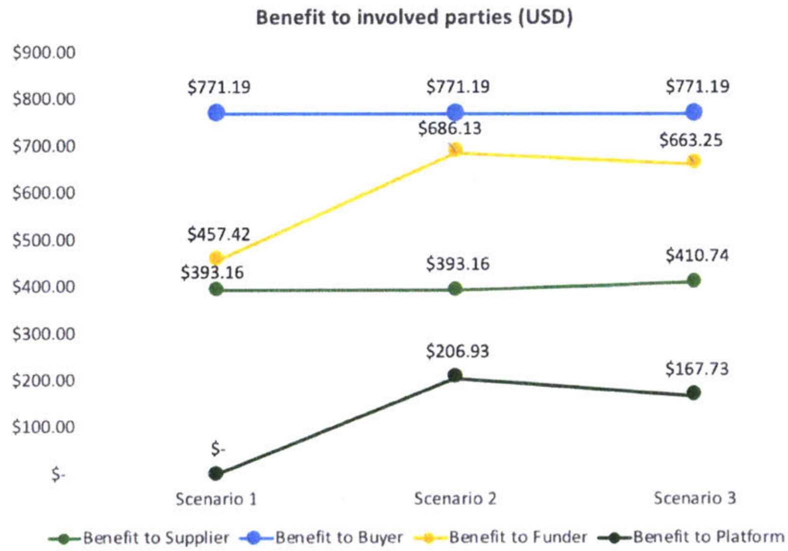

Figure 7: Benefit to involved parties in USD

In addition, considering the benefit allocation among involved parties, the second key finding is that the benefit allocation of supplier and the buyer decreases, while that of funder and platform provider increases from blockchain technology. In more detail, the percentages of the supplier slightly decrease from 24.24% in scenario 1 to 19.23% and 20.41% in scenario 2 and 3 respectively, and those of the buyer also slightly decline from 47.55% in scenario 1 to 41.88% and 38.31% in scenario 2 and 3 respectively. On the other hand, the percentages of funders and platform providers increase from 28.2% to 31.05% and 32.95% and from 0.00% to 7.85% and 8.33% respectively. The summary of benefit allocation among involved parties in each scenario is shown in Table 12.

Result	Scenario 1	Scenario 2	Scenario 3
%Supplier	24.24%	19.23%	20.41%
%Buyer	47.55%	41.88%	38.31%
%Funder	28.20%	31.05%	32.95%
%Platform	0.00%	7.85%	8.33%
Total net benefit	100.00%	100.00%	100.00%

Table 12: Benefit allocation among involved parties

The third key finding is that, unlike other parties, the supplier is the only party whose net benefit might be either positive or negative. Regarding the supplier's perspective, one interesting result from the analysis is that, in scenario 2, the net benefit to the supplier is less than that in scenario 1, even though the supplier gets faster funding for 5 days through increase efficiency from blockchain technology. This is because the benefits that they gain in scenario 2 through getting faster funding are outweighed by the platform fee, which is the compensation that they have to pay to use the platform. Therefore, we calculate the break-even platform fee as can see in Figure 8.

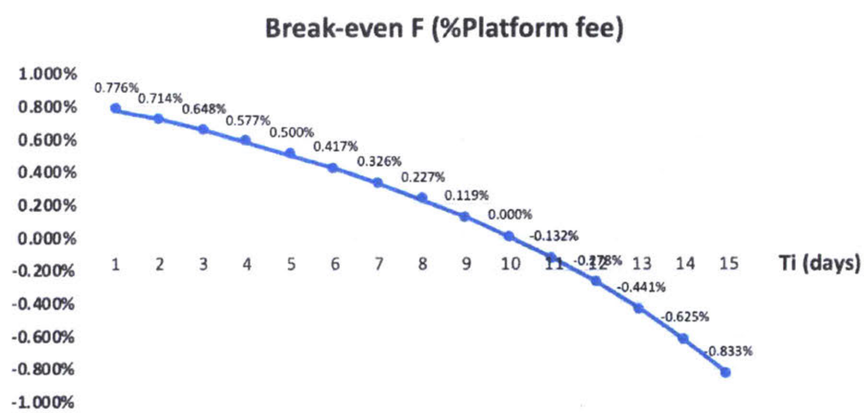

Figure 8: Break-even platform fee for different T_i

In scenario 2, in which T_2 = 5 days, the break-even platform fee = 0.500%, meaning that, the maximum platform fee that makes the supplier positive net benefit is 0.500%. In other words, if the supplier pays the platform at more than 0.500%, the net benefit is negative. In scenario 2, given that the platform provider charges platform fee (F_i) at 0.699% which is higher than the break-even fee, the supplier therefore loses \$393.16 – \$354.09 = \$39.07. However, in scenario 3, the benefits from unlocked working capital outweigh the platform fee, providing the supplier benefits at \$410.74 – \$393.16 = \$17.58.

The fourth key finding is that the buyer does not gain benefits from unlocked working capital from faster processes through blockchain technology. To elaborate, with blockchain technology in scenario 2 and 3, the duration between the day that the invoice is created and the day that the supplier gets the funding is reduced. However, the duration does not affect the benefit to the buyer, which instead depends on the extended due date for the buyer to pay the invoice. This is why the buyer does not benefit from the blockchain technology in the aspect of efficiency of invoice processing.

We compare the results with a benchmark from a previous study by the Association of Chartered Certified Accountants (ACCA). The study presents the allocation of benefits among SCF players. ACCA conducted the calculation based on expert interviews in 4 groups: banks, financial services operators, solution provider, and corporations (Camerinelli, 2014). According to Table 13, overall, our results for the buyer and the funder are within the benchmark range presented by ACCA. However, our result of benefit allocation for the supplier is a bit lower and for the platform provider is higher than the benchmark. The most important factor that directly affects this mismatch is a platform fee (F_i), which is the amount that the supplier has to pay the platform provider for scenario 2 and 3. In our analysis for these two scenarios, the platform fee is set at 0.699%, which is calculated based on the actual rate that the platform provider charges as per the conditions in the case study. However, in real life, a platform provider might charge a platform fee at another rate, which might be higher or lower than 0.699%. If the fee is lower than 0.699%, the benefit allocation will be more in line with the benchmark by ACCA.

	Benchmark	**Result from our analysis**		
	Traditional SCF xf	Traditional SCF (Scenario 1)	Smart contract-based SCF (Scenario 2)	Blockchain & IoT-based SCF (Scenario 3)
Supplier	25-45%	24.24%	19.23%	20.41%
Buyer	35-50%	47.55%	41.88%	38.31%
Funder	25-45%	28.20%	31.05%	32.95%
Platform provider	2-5%	0.00%	7.85%	8.33%

Table 13: Benefit allocation comparison

This thesis is among the first quantitative works on blockchain technology in SCF. We provide insights about costs and benefits of implementing blockchain technology in SCF, contributing to the academic literature. Nevertheless, we should acknowledge some limitations of this study. First, unlike those of scenario 1 that are from real-world implementation, the assumptions and parameters used in scenario 2 and 3 are estimated from our proposed operating processes in section 5. The results in both scenarios might be different if the assumptions and parameters change. Second, the structure of our cost-benefit model and the case study concerns one player for each involved party (one supplier, one buyer, one funder, and one platform provider). In real-world SCF arrangements, there are some other combinations of SCF arrangement that might have more than a single player for each involved party or have other parties involved such as insurance companies. Third, the platform fee (F_i) in our cost-benefit model is structured as a percentage of the total amount of financing, which is the most popular structure of SCF arrangement. However, in the real-world case, there are many other ways of setting the fee including the fixed fee per invoice, free usage with one-time setup cost, and subscription fee. Finally, in a realistic case of applying blockchain technology in SCF, there are other relevant costs than the platform fee (F_i) that is associated to the adoption of blockchain technology in SCF such as human costs, transaction costs, exchange fees, and set up cost.

8. Conclusion

Understanding the costs and benefits of implementing blockchain-based SCF solution is crucial for businesses. We developed a cost-benefit model to quantify a net value of implementing blockchain-based SCF solution and proposed operating processes for analyzing the parameters used in the model in 3 scenarios. We also applied the real-world case study to showcase the calculation from our cost-benefit model. The results presented in this thesis suggest that blockchain technology might increase the total net benefit of involved parties in SCF as a result of improved efficiency of invoice processing.

Considering the supplier's point of view, they would enjoy the benefit if the amount that they pay for the platform fee is less than the benefit from unlocked working capital that they earn. Therefore, the supplier needs to carefully consider the platform fee that they have to pay, whether the net benefit that they gain makes sense financially. In our case study, the net benefit of supplier using smart contract-based SCF solution (scenario 2) is lower than that of supplier using traditional SCF solution (scenario 1), meaning that it does not make financial sense for the supplier to switch from traditional to the smart contract-based SCF solution. However, it is financially viable to switch from the traditional (scenario 1) to the blockchain-based & IoT SCF system.

From the buyer's point of view, they do not directly benefit from unlocked working capital through blockchain technology. As the buyer is the important party in the SCF arrangement who usually initiates and facilitate the SCF deal between the supplier and the funder, the buyer might use bargaining power to negotiate the extended due date with the funder, so that they can earn benefits from switching from the traditional to blockchain-based SCF solution.

From the funder's perspective, given that the financial conditions with the supplier and the buyer is similar among scenarios, they gain more money from a longer duration of financing due to shorter processing time from blockchain technology. In the case study, the result shows that the funder's benefits from switching from the traditional SCF solution (scenario 1) to blockchain-based SCF solutions (scenario 2 and 3) are positive.

Regarding the blockchain-based platform provider perspective, they directly benefit from the platform fee paid by the supplier. Given that the supplier is able to calculate the benefits arise from blockchain technology and the break-even point as shown in this thesis, the platform provider might consider setting the platform fee at a lower value than the break-even point to attract the supplier to use the blockchain-based SCF platform.

Apart from the quantitative benefits derived from efficiency described in this thesis, there are other qualitative benefits that make the blockchain technologies even more attractive. The benefits might include transparency, auditability, and real-time visibility. Although it is challenging to quantify those benefits, businesses should take into account those qualitative benefits when considering a feasibility study of adopting blockchain-based SCF solution.

This thesis is in a nascent field and is among the first contributions to the quantitative research area of blockchain technology in supply chain finance. As the scope of this thesis focuses on quantifying the net value of blockchain-based supply chain finance in terms of efficiency in invoice processing, there are some potential areas for future research. For example, future research might focus on quantifying net value from blockchain technology in SCF in other aspects such as supplier onboarding process and fraud reduction. In addition, future research may consider developing a new cost-benefit model that include other relevant costs and other combinations of involved parties as explain in the last paragraph of section 7. Finally, future research might apply our cost-benefit model and the operating processes to real-world case studies in other industries with different SCF conditions and financial terms and compare the results with ours to study how blockchain technology impacts SCF arrangement in different industries.

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APPENDIX

Appendix A: Benefit to the supplier (USD)

F \ Ti	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.000%	$ 589.74	$ 570.09	$ 550.43	$ 530.77	$ 511.11	$ 491.45	$ 471.80	$ 452.14	$ 432.48	$ 412.82	$ 393.16	$ 373.50	$ 353.85	$ 334.19	$ 314.53	$ 294.87
0.100%	$ 566.15	$ 547.28	$ 528.41	$ 509.54	$ 490.67	$ 471.80	$ 452.92	$ 434.05	$ 415.18	$ 396.31	$ 377.44	$ 358.56	$ 339.69	$ 320.82	$ 301.95	$ 283.08
0.200%	$ 542.57	$ 524.48	$ 506.39	$ 488.31	$ 470.22	$ 452.14	$ 434.05	$ 415.97	$ 397.88	$ 379.80	$ 361.71	$ 343.62	$ 325.54	$ 307.45	$ 289.37	$ 271.28
0.300%	$ 518.98	$ 501.68	$ 484.38	$ 467.08	$ 449.78	$ 432.48	$ 415.18	$ 397.88	$ 380.58	$ 363.28	$ 345.98	$ 328.68	$ 311.39	$ 294.09	$ 276.79	$ 259.49
0.400%	$ 495.39	$ 478.87	$ 462.36	$ 445.85	$ 429.33	$ 412.82	$ 396.31	$ 379.80	$ 363.28	$ 346.77	$ 330.26	$ 313.74	$ 297.23	$ 280.72	$ 264.21	$ 247.69
0.500%	$ 471.80	$ 456.07	$ 440.34	$ 424.62	$ 408.89	$ 393.16	$ 377.44	$ 361.71	$ 345.98	$ 330.26	$ 314.53	$ 298.80	$ 283.08	$ 267.35	$ 251.62	$ 235.90
0.600%	$ 448.21	$ 433.27	$ 418.33	$ 403.39	$ 388.45	$ 373.50	$ 358.56	$ 343.62	$ 328.68	$ 313.74	$ 298.80	$ 283.86	$ 268.92	$ 253.98	$ 239.04	$ 224.10
0.699%	$ 424.85	$ 410.69	$ 396.53	$ 382.37	$ 368.21	$ 354.04	$ 339.88	$ 325.72	$ 311.56	$ 297.40	$ 283.23	$ 269.07	$ 254.91	$ 240.75	$ 226.59	$ 212.43
0.700%	$ 424.62	$ 410.46	$ 396.31	$ 382.15	$ 368.00	$ 353.85	$ 339.69	$ 325.54	$ 311.39	$ 297.23	$ 283.08	$ 268.92	$ 254.77	$ 240.62	$ 226.46	$ 212.31
0.800%	$ 401.03	$ 387.66	$ 374.29	$ 360.92	$ 347.56	$ 334.19	$ 320.82	$ 307.45	$ 294.09	$ 280.72	$ 267.35	$ 253.98	$ 240.62	$ 227.25	$ 213.88	$ 200.51
0.900%	$ 377.44	$ 364.86	$ 352.27	$ 339.69	$ 327.11	$ 314.53	$ 301.95	$ 289.37	$ 276.79	$ 264.21	$ 251.62	$ 239.04	$ 226.46	$ 213.88	$ 201.30	$ 188.72
1.000%	$ 353.85	$ 342.05	$ 330.26	$ 318.46	$ 306.67	$ 294.87	$ 283.08	$ 271.28	$ 259.49	$ 247.69	$ 235.90	$ 224.10	$ 212.31	$ 200.51	$ 188.72	$ 176.92

Appendix B: Benefit to the supplier (Percentage)

F \ Ti	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.000%	50.00%	45.00%	40.00%	35.00%	30.00%	25.00%	20.00%	15.00%	10.00%	5.00%	0.00%	-5.00%	-10.00%	-15.00%	-20.00%	-25.00%
0.100%	44.00%	39.20%	34.40%	29.60%	24.80%	20.00%	15.20%	10.40%	5.60%	0.80%	-4.00%	-8.80%	-13.60%	-18.40%	-23.20%	-28.00%
0.200%	38.00%	33.40%	28.80%	24.20%	19.60%	15.00%	10.40%	5.80%	1.20%	-3.40%	-8.00%	-12.60%	-17.20%	-21.80%	-26.40%	-31.00%
0.300%	32.00%	27.60%	23.20%	18.80%	14.40%	10.00%	5.60%	1.20%	-3.20%	-7.60%	-12.00%	-16.40%	-20.80%	-25.20%	-29.60%	-34.00%
0.400%	26.00%	21.80%	17.60%	13.40%	9.20%	5.00%	0.80%	-3.40%	-7.60%	-11.80%	-16.00%	-20.20%	-24.40%	-28.60%	-32.80%	-37.00%
0.500%	20.00%	16.00%	12.00%	8.00%	4.00%	0.00%	-4.00%	-8.00%	-12.00%	-16.00%	-20.00%	-24.00%	-28.00%	-32.00%	-36.00%	-40.00%
0.600%	14.00%	10.20%	6.40%	2.60%	-1.20%	-5.00%	-8.80%	-12.60%	-16.40%	-20.20%	-24.00%	-27.80%	-31.60%	-35.40%	-39.20%	-43.00%
0.699%	8.06%	4.46%	0.86%	-2.75%	-6.35%	-9.95%	-13.55%	-17.15%	-20.76%	-24.36%	-27.96%	-31.56%	-35.16%	-38.77%	-42.37%	-45.97%
0.700%	8.00%	4.40%	0.80%	-2.80%	-6.40%	-10.00%	-13.60%	-17.20%	-20.80%	-24.40%	-28.00%	-31.60%	-35.20%	-38.80%	-42.40%	-46.00%
0.800%	2.00%	-1.40%	-4.80%	-8.20%	-11.60%	-15.00%	-18.40%	-21.80%	-25.20%	-28.60%	-32.00%	-35.40%	-38.80%	-42.20%	-45.60%	-49.00%
0.900%	-4.00%	-7.20%	-10.40%	-13.60%	-16.80%	-20.00%	-23.20%	-26.40%	-29.60%	-32.80%	-36.00%	-39.20%	-42.40%	-45.60%	-48.80%	-52.00%
1.000%	-10.00%	-13.00%	-16.00%	-19.00%	-22.00%	-25.00%	-28.00%	-31.00%	-34.00%	-37.00%	-40.00%	-43.00%	-46.00%	-49.00%	-52.00%	-55.00%

Appendix C: Benefit to the buyer (USD)

F \ T_i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.000%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.400%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.500%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.600%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.699%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.700%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.800%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.900%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1.000%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Appendix D: Benefit to the buyer (Percentage)

F \ T_i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.000%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
0.100%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
0.200%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
0.300%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
0.400%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
0.500%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
0.600%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
0.699%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
0.700%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
0.800%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
0.900%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19
1.000%	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19	$ 771.19

Appendix E: Benefit to the funder (USD)

F \ T_i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.000%	26.22%	23.60%	20.98%	18.36%	15.73%	13.11%	10.49%	7.87%	5.24%	2.62%	0.00%	-2.62%	-5.24%	-7.87%	-10.49%	-13.11%
0.100%	26.30%	23.68%	21.05%	18.43%	15.80%	13.18%	10.55%	7.93%	5.30%	2.68%	0.05%	-2.57%	-5.20%	-7.82%	-10.45%	-13.07%
0.200%	26.38%	23.75%	21.12%	18.49%	15.87%	13.24%	10.61%	7.98%	5.36%	2.73%	0.10%	-2.53%	-5.15%	-7.78%	-10.41%	-13.04%
0.300%	26.45%	23.82%	21.19%	18.56%	15.93%	13.30%	10.67%	8.04%	5.41%	2.78%	0.15%	-2.48%	-5.11%	-7.74%	-10.37%	-13.00%
0.400%	26.53%	23.90%	21.26%	18.63%	16.00%	13.37%	10.73%	8.10%	5.47%	2.84%	0.20%	-2.43%	-5.06%	-7.69%	-10.33%	-12.96%
0.500%	26.61%	23.97%	21.34%	18.70%	16.07%	13.43%	10.80%	8.16%	5.53%	2.89%	0.26%	-2.38%	-5.02%	-7.65%	-10.29%	-12.92%
0.600%	26.68%	24.05%	21.41%	18.77%	16.13%	13.49%	10.86%	8.22%	5.58%	2.94%	0.31%	-2.33%	-4.97%	-7.61%	-10.24%	-12.88%
0.699%	26.76%	24.12%	21.48%	18.84%	16.20%	13.56%	10.92%	8.28%	5.64%	3.00%	0.36%	-2.28%	-4.92%	-7.56%	-10.20%	-12.84%
0.700%	26.76%	24.12%	21.48%	18.84%	16.20%	13.56%	10.92%	8.28%	5.64%	3.00%	0.36%	-2.28%	-4.92%	-7.56%	-10.20%	-12.84%
0.800%	26.84%	24.19%	21.55%	18.91%	16.27%	13.62%	10.98%	8.34%	5.69%	3.05%	0.41%	-2.23%	-4.88%	-7.52%	-10.16%	-12.81%
0.900%	26.91%	24.27%	21.62%	18.98%	16.33%	13.69%	11.04%	8.40%	5.75%	3.10%	0.46%	-2.19%	-4.83%	-7.48%	-10.12%	-12.77%
1.000%	26.99%	24.34%	21.69%	19.05%	16.40%	13.75%	11.10%	8.45%	5.81%	3.16%	0.51%	-2.14%	-4.79%	-7.43%	-10.08%	-12.73%

Appendix F: Benefit to the funder (Percentage)

F \ Ti	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.000%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
0.100%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
0.200%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
0.300%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
0.400%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
0.500%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
0.600%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
0.699%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
0.700%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
0.800%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
0.900%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06
1.000%	686.13	663.25	640.38	617.51	594.64	571.77	548.90	526.03	503.16	480.29	457.42	434.55	411.68	388.80	365.93	343.06

Appendix G: Benefit to the funder (USD)

F \ T	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.000%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.100%	24.83	24.00	23.18	22.35	21.52	20.69	19.87	19.04	18.21	17.38	16.55	15.73	14.90	14.07	13.24	12.42
0.200%	49.66	48.01	46.35	44.70	43.04	41.39	39.73	38.07	36.42	34.76	33.11	31.45	29.80	28.14	26.49	24.83
0.300%	74.49	72.01	69.53	67.04	64.56	62.08	59.60	57.11	54.63	52.15	49.66	47.18	44.70	42.21	39.73	37.25
0.400%	99.33	96.01	92.70	89.39	86.08	82.77	79.46	76.15	72.84	69.53	66.22	62.91	59.60	56.28	52.97	49.66
0.500%	124.16	120.02	115.88	111.74	107.60	103.46	99.33	95.19	91.05	86.91	82.77	78.63	74.49	70.36	66.22	62.08
0.600%	148.99	144.02	139.06	134.09	129.12	124.16	119.19	114.22	109.26	104.29	99.33	94.36	89.39	84.43	79.46	74.49
0.699%	173.57	167.79	162.00	156.21	150.43	144.64	138.86	133.07	127.29	121.50	115.71	109.93	104.14	98.36	92.57	86.79
0.700%	173.82	168.03	162.23	156.44	150.64	144.85	139.06	133.26	127.47	121.67	115.88	110.09	104.29	98.50	92.70	86.91
0.800%	198.65	192.03	185.41	178.79	172.16	165.54	158.92	152.30	145.68	139.06	132.43	125.81	119.19	112.57	105.95	99.33
0.900%	223.48	216.03	208.58	201.13	193.68	186.24	178.79	171.34	163.89	156.44	148.99	141.54	134.09	126.64	119.19	111.74
1.000%	248.31	240.04	231.76	223.48	215.21	206.93	198.65	190.37	182.10	173.82	165.54	157.27	148.99	140.71	132.43	124.16