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WORKING CAPITAL OPTIMIZATION UNDER LIQUIDITY CONSTRAINTS IN COLLABORATIVE SUPPLY CHAINS

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Abstract: The paper is devoted to development of a working capital management model providing optimal levels of working capital to all individual business partners operating under the liquidity and return constraints through collaborative actions of capital reallocation along the supply chain. As such, we suggest the tool of working optimization through financial terms and cash flows verified on Russian collaborative supply chain data. Mathematical modeling is suggested as a method to upgrade existing collaborative cash conversion cycle model by optimizing it in terms of total financial costs minimization for a three-stage supply chain in the context of constrained liquidity and specified target return levels. The application of the suggested optimization model to focal supply chain provided significant acceleration of individual cash conversion cycles and investments in working capital by combining the extension of days of accounts payable, reduction in days of inventories and reduction in days of accounts receivable in different proportions for supply chain participants. The theoretical contribution consists of integrating collaboration and working capital concepts, adding a holistic perspective to extant working capital management models. The suggested model illustrates financially the motivation of supply chain partners to cooperate in order to simultaneously achieve target levels of WC investments and improve individual financial performance through collaborative operations.

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1. Introduction

In the field of supply chain management (SCM), collaboration of business partners (basic raw materials and components suppliers, manufacturers, distributors, transporters, retailers, banks and financial institutions, etc.), linked through the flows of goods, information and finance is a core concept. Research on supply chains (SCs) has mainly focused on inventory cost, transportation cost and cost related to goods procurement. However, there has been very little research work focusing on the flow of money (Kouvelis et al., 2006). In terms of a swiftly changing business environment, Gupta and Dutta (2011, p.47) state that "for an effective supply chain system, the management of upstream flow of money is as important as the management of downstream flow of goods." From this perspective, working capital management (WCM) as an essential element of financial supply chain management (FSCM) has gained a lot of attention (Deloof, 2003; García-Teruel and Martínez-Solano, 2007; Johnson and Templar, 2011; Viskari et al., 2011; Viskari and Karri, 2012; Matyac, 2015) due to the fact that it is a way to accelerate the cycle time of working capital (WC) and increase the profitability of the company in response to financial volatility in the business environment, e.g. the enacted Basel II, restraining external financing from banks. Consequently, the demand for capital from within the SC, e.g. from companies directly involved in supply chain finance (SCF) schemes or acting as financial service providers (FSPs) has increased (Hofmann and Kotzab, 2010; Song, Yu and Lu, 2018; Protopappa-Sieke and Seifert, 2017; Talonpoika et al., 2016). For this reason, the importance of effective WCM has raised dramatically, especially for SCs from emerging markets, which faced difficulties with access to capital, limited financial infrastructure and legal, regulatory and accounting uncertainties in the first place (ACCA, 2014).

Apart from that, the focus of the study on emerging markets is also prompted by the fact that SCs stretch across the globe with a diverse range of suppliers in emerging markets, and the failure of a supplier can impact most severely the whole production process, threatening the viability and continuity of an entire SC. So, WCM is increasingly transcending boundaries of mature markets and has the potential for economic stabilization, however most emerging market companies have not yet fully realized its benefits.

Likewise, the coordinating mechanisms of WCM and SCF in SCs have received little attention because the role of financial coordinators (FSPs, banks, FinTech companies and other financial intermediaries) as core participants in facilitating and enabling SCF has only recently been identified in academic literature (Silvestro and Lustrato, 2014; Song, Yu and Lu, 2018; Martin and Hofmann, 2017; Protopappa-Sieke and Seifert, 2017).

Additionally, the research is motivated by the call for a more holistic approach to SCM on the grounds of merging financial and operational SC measures, since the existing literature either considers them separately or does not give insights on financial flows (Kroes and Manikas, 2014; Protopappa-Sieke and Seifert, 2010).

We address these gaps and aim to develop a WCM model providing optimal levels of working capital to every business partner through collaborative actions of capital reallocation along the SC. As such, the main aim of the research is to suggest a tool for working capital optimization under constraints of profitability-liquidity tradeoff verified on Russian collaborative SC data. The paper begins with a review of SC collaboration and WCM literature leading to the research question:

RQ. How to improve the working capital position of each SC business partner by improving the integral performance of the SC at the same time?

The selected methodology aiming at responding to the research question represents the upgrading of the approach proposed by Hofmann and Kotzab (2010). In response to the RQ, a model is developed; this is followed by numerical analysis and discussion of the findings. The paper closes with a conclusion, identifying further research directions.

2. Literature review

2.1. Supply chain collaboration

From the strategic management point of view, one of the most challenging collaboration perspectives is to extend the concept from collaboration within an organization to the level between organizations, since they do not exist in isolation (Gadde and Snehota, 2000; Håkansson and Snehota, 2006; Simatupang and Sridharan, 2002). Any organization, whether a large corporation, public body, or a small business, aims to meet the needs of its various customers and stakeholders, will need resources to do this, and will acquire many of its materials, equipment, facilities and supplies from other organizations. The performance of an organization is thus influenced by the actions of the organizations that make up the supply chain (Frohlich and Westbrook, 2001; Barratt, 2004; Kim, 2009, Kirca et al., 2005). Therefore, focus has moved from competition between firms at the same level in the production process to competition between supply chains, from raw materials to end customers (Beamon, 1998; Håkansson and Ford, 2002). A company's ability to create trust-based and long-term business relationships with customers, suppliers, and other strategic partners becomes a crucial competitive parameter. Though it is accepted that external relationships in SCM are strategically important, still many questions concerning operations integration with suppliers and customers in SC remain unanswered (Blome et al., 2014; Chen and Paulraj, 2004; Fairchild, 2005; Frochlich and Westbrook, 2001; Sabath and Fontanella, 2002; Wuttke et al., 2013).

SC collaboration is especially important to manage external relationships with suppliers and customers (Fawcett and Magnan, 2002). The empirical results indicate that SC collaboration considerably improves the collaborative advantage (Cao and Zhang, 2011), which in turn, has a significant positive effect on firms' financial performance (in particular, the mediator role of collaborative advantage is stronger for small firms than medium and large firms (Shi and Yu, 2013). Furthermore, a lack of collaboration may result in poor performance of the whole SC (Gunasekaran et al., 2004), such as: inaccurate forecasts, low capacity utilization, excessive inventory, inadequate customer service, inventory turns, inventory costs, time to market, order fulfillment response, quality, customer focus and customer satisfaction (Hendricks and Singhal, 2003; Ramdas and Spekman, 2000; Coyle et al., 2013), not to mention the perspective representing the "dark side" of inter-firm collaboration, which characterizes many buyer-supplier relationships (Rokkan, Heide and Wathne, 2003; Noordhoff et al., 2011; Seggie, Griffith and Jap, 2013).

It has been well documented by operations management scholars and practitioners, that communication between business partners is the essence of organizational life (Rokkan, Heide and Wathne, 2003; Galaskiewicz, 2011). However, in empirical studies, researchers have typically considered inter-organizational communication as a part of a broader construct or have examined the extent to which the use of selected communication strategies by buyer firms enhances supplier firm operational performance. Furthermore, the majority of research focuses on the economic value for buyers or for suppliers; few studies investigate how strategic orientations of buyers and suppliers affect the relative relationship performance for the individual dyad members (Flynn, Huo and Zhao, 2010; Paulraj et al., 2008). This being said, traditional perspectives that suppliers and buyers act as independent economic agents are being replaced with the understanding that these exchange partners are co-producers of value, and thus their performances are interlinked (Blackman, Holland and Westcott, 2013; Malshe and Agarwal, 2015; Silvestro and Lustrato, 2014; Stevens and Johnson, 2016). Cachon and Lariviere (2005) published a paper analyzing the role of revenue sharing contracts in coordinating a supply chain. The idea is straightforward: organizations are self-serving entities maximizing individual profits, but sometimes this might result in a sub-optimal overall performance. However, a focal company can contractually coordinate the actions of other players in the supply chain in order to achieve optimal profit.

With this in mind, in the next paragraph we will mainly leave out of consideration a large body of working capital and cash management literature providing, solutions aimed at improving working capital position for a single company and thus neglecting the inter-organizational perspective of the issue (e.g. Deloof et al., 2003, García-Teruel and Martínez-Solano, 2007; Enqvist et al., 2014; Vázquez et al., 2016; Chauhan and Banerjee, 2017). Instead, we will focus on the recent papers outlining approaches to working capital management in the context of collaboration of business partners in a supply chain.

2.2. Working capital management

Finance literature captures financial flows as working capital (WC). There are two main perspectives of working capital. The first one defines it as the ability of the company to cover its short-term debt with current assets. Jones (2006) defines the concept of this working capital perspective and describes it with the Eq. 1.

$$Working\ capital = Current\ Assets - Current\ Liabilities. \tag{1}$$

According to Jones (2006), current assets consist of cash, total inventory, accounts receivable, securities and cash equivalents. On the other side, current liabilities refer to accounts payable, accruals, notes payable and short-term debt. A positive result of working capital means that the amount of cash the company will receive in the next 12 months is bigger than what company needs to cover its liabilities. A negative result of working capital means that the company will not be able to cover its short-term debt.

Another perspective of working capital is widely used in most of the studies dedicated to operating working capital and consists of the total level of inventory, accounts receivable (A/R) and accounts payable (A/P). According to Pirttilä (2014) the equation is following (Eq. 2):

$$Working\ capital = Inventories\ +\ AR\ -\ AP. \tag{2}$$

The study by Talonpoika et al. (2014) included accrued expenses (A/E) as a separate component into the working capital cycle (usually is a part of A/P). Pirttilä (2014) states that the working capital cycle describes the main parts of the company's performance associated with financial flows.

The operational approach to evaluate working capital is a time-based measure of cash conversion cycle (CCC) introduced by Richards and Laughlin (1980) for measuring and controlling the effectiveness of working capital management on the basis of relative ratios. Shin and Soenen (1998), Deloof (2003) and Hutchison et al. (2007) have agreed that CCC is an adequate proxy for working capital management. The CCC presents the length (in days) of time a firm has funds tied up in working capital, starting from the payment of purchases to the supplier and ending when remittance of sales is received from the customers. In other words, the CCC is a collection of three sub-cycles: the cycle time of inventories (*DIO*) plus the cycle time of accounts receivable (*DRO*) minus the cycle time of accounts payable (*DPO*).

$$CCC = DIO + DRO - DPO. \tag{3}$$

CCC as working capital can be either negative or positive. Negative CCC means that the company has a low amount of inventory and the company receives money from its customers before it has to pay its A/R. In other words, in a negative CCC scenario, a company receives its A/R before it should pay A/P. A large number of researchers believe that the lower CCC is the better a company can manage it cycles efficiently, although a too low CCC can cause problems with each component of the CCC.

Considering the problem of identifying the CCC optimal value, there arises the issue of achieving target rates of return and, at the same time, maintaining the necessary level of liquidity (Garanina and Belova, 2015; Talonpoika et al., 2016; Yazdanfar and Öhman, 2014). In recent years the number of studies devoted to this issue has boomed, though the results are controversial and incomparable due to a number of reasons with research method selection

among them (case studies – Farris and Hutchison, 2002, Randall and Farris, 2009; regression analysis of annual financial statements – Deloof, 2003; Garcia-Teruel and Martinez-Solano, 2007; Kroes and Manikas, 2014; optimization modeling – Hofmann and Kotzab, 2010). As far as it goes, there are mixed evidences on the inverse relation between CCC and its components and profitability (Deloof, 2003; Garcia-Teruel and Martinez-Solano, 2007; Lazaridis and Tryfonidis, 2006; Randall and Farris, 2009; Shin and Soenen, 1998) as well as direct relation between CCC and its components and liquidity (Filbeck and Krueger, 2005). However, the conviction is the following: an increase of CCC will reduce risk and profitability on the one hand and will improve liquidity on the other.

Clearly, each company pursuing its target levels of liquidity and profitability implements a set of working capital policies (Kroes and Manikas, 2014) usually referred to as conservative, moderate or aggressive. The aggressive working capital policy implies estimation of current assets at the lowest possible level resulting in lower working capital requirements and higher risks. Conservative policy, on the contrary, is aimed at avoiding the maximum possible risks and guarantees smooth operations of the company, though the higher level of current assets leads to lower profitability. Moderate policy is assumed to be a tradeoff between the aggressive and conservative policies providing reasonable accordance in profitability and liquidity.

In line with this classification, the contribution by Talonpoika et al. (2016) suggests the theoretical typology of various financial working capital management strategies focusing on maximization or minimization of CCC components aiming to improve the financial working capital. Authors claim these strategies are to be pursued during the economic downturn, which make them possible to apply for companies from emerging markets, as they faced difficulties with access to capital, limited financial infrastructure and legal, regulatory and accounting uncertainties (ACCA, 2014) well before spreading volatility in the business environment as well as the enacted Basel II restrained getting financing from banks and in turn increased demand for capital from within the SC (Hofmann and Kotzab, 2010; Song, Yu and Lu, 2018; Protopappa-Sieke and Seifert, 2017; Talonpoika et al., 2016). For this reasons, the practitioners' interest to effective WCM on inter-organizational level has increased dramatically, which resulted in a wave of publications (Marttonen, Monto and Kärri, 2013; Protopappa-Sieke and Seifert, 2010; Protopappa-Sieke and Seifert, 2017; Pirttilä et al., 2014; Talonpoika at al., 2014; Talonpoika et al., 2016; Viskari et al., 2011; Viskari et al., 2012b; Viskari et al., 2012c; Ylä-Kujala et al., 2016).

Motivation behind these research, besides the mentioned post-crisis challenges is the idea, that finance research on WCM has been focusing on company profitability instead of supply chain contribution, consequently, companies seek to optimize their individual performance; however, none of its elements can be truly managed by a company individually, but only in collaboration with business partners. It is important to note that individual financial performance optimization is to be considered in terms of a more holistic approach taking into account each participant's interests as well as the abilities to collaborate, or, in other words, supply chain orientation of a company.

With this consideration in mind, an initial assumption for further optimization is, following Cachon and Lariviere (2005), collaboration of supply chain partners already motivated to maximize total profit of the chain. Alternatively, this motivation can be reformulated in terms of total financial costs minimization, and specifically financial costs associated with WCM.

3. Model

3.1. Base model

Building on earlier research, this study attempts to address the gaps from extant body of WCM literature by suggesting an upgrading of the collaborative cash conversion cycle

(CCCC) model originally introduced by Hofmann and Kotzab (2010). Authors denote CCCC as a sum of the cash conversion cycles of all exchange partners. They show by the means of optimization modeling, that a reduction of cash conversion cycle for a single company in a chain (possibly on the expense of suppliers or customers) does not add value to other SC partners. While resulting in short-term balance-sheet improvements, it eventually triggers higher risk supplier base and, consequently, increased total cost of running business in long-term. The study provides clear argumentation, why the true optimization approach to the problem of finding optimal cash conversion cycle length lies in the area of collaborative actions of all affiliated members.

As such, for the purposes of our study we consider a collaborative wholesaler's three-stage SC with *N* suppliers and *M* retailers at first and third stages respectively (see Fig. 1).

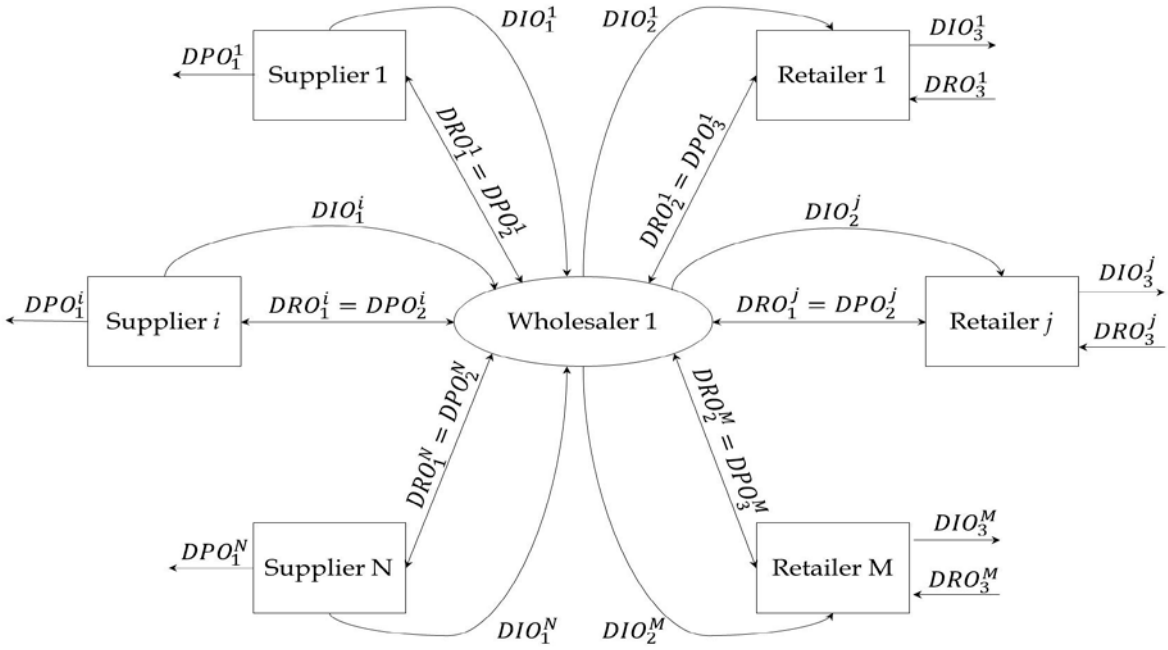

Fig. 1. Collaborative supply chain.

To capture the financial costs associated with each SC stage, we consider the formula (Eq. 5) introduced by Viskari et al. (2013). Consequently, the objective function of our model is collaborative financial costs (*CFC*), which sums financial costs of all supply chain participants (Eq. 4):

$$CFC = \sum_{l=1}^{3} \sum_{k=1}^{K_l} FC_l^k, \tag{4}$$

$$FC_l^k\left(DIO_l^k, DRO_l^k, DPO_l^k, INV_l^k, AR_l^k, AP_l^k\right) =$$
$$= INV_l^k\left[\left(1+c_l^k\right)^{\frac{DIO_l^k}{365}} - 1\right] + AR_l^k\left[\left(1+c_l^k\right)^{\frac{DRO_l^k}{365}} - 1\right] - AP_l^k\left[\left(1+c_l^k\right)^{\frac{DPO_l^k}{365}} - 1\right]. \tag{5}$$

As mentioned before, our approach to solving the problem of working capital optimization is grounded within the supply chain collaboration stream of research. We imply that minimization of total financial costs associated with certain supply stages is of common interest for all SC members and they are financially motivated for collaborative actions; the rationale behind such a collaboration (Eq. 6) is that financial costs of each participant operating in collaboration (FC_l^k) do not exceed their values while operating independently (FC_l^{0k}):

$$FC_l^k \le FC_l^{0k}. \tag{6}$$

For this SC structure and following Hofmann and Kotzab (2010), we define collaborative cash conversion cycle (CCCC) as the sum of CCCs of all participants (Eq. 7):

$$CCCC = \sum_{l=1}^{3} \sum_{k=1}^{K_l} CCC_l^k, \tag{7}$$

$$CCC_l^k = DIO_l^k + DRO_l^k - DPO_l^k. \quad (8)$$

Concerning the liquidity-return trade-off, we suppose companies in a focal supply chain are pursuing a moderate approach to working capital management. Our aim is to ensure companies' current ratio is higher than the industry average rate of return and at the same time is below the value at which the relation between liquidity and rate of return becomes inverse (Garanina and Belova, 2015); hence we denote individual cash conversion cycles (CCC_l^k) to confine to recommended industry specific stability interval CCC_{low}, CCC^{up}, providing favorable balance between return and liquidity (Eq. 9):

$$CCC_{low} \leq CCC_l^k \leq CCC^{up}. \quad (9)$$

Introducing constraints on CCCC components (Eq. 10 and Eq. 11), we aim to incorporate the inward-oriented approach to optimization stemming from two assumptions (Hofmann and Kotzab, 2010). Firstly, we assume the nature of relations between the exchange partners in the supply chain (Fig. 1). We are fully aware of an underlying simplification of the focal supply chain structure as real-life supply chains (or rather multidimensional networks) show greater degree of complexity. However, we denote internal payment periods among SC players do not have impact on CCCC:

$$DRO_l^k = DPO_{l+1}^k, \quad \text{where } l = \overline{1,\ 2},\ k = \overline{1,\ K_l}. \quad (10)$$

Secondly, we assume companies pursuing inward-oriented optimization to restrain from exploiting the capacities of contractors outside the specified supply chain perimeter (Eq. 11). As such, we denote values of days of payables outstanding at the suppliers stage (DPO_1^k) and days of receivables outstanding at the retailers stage (DRO_3^k) after optimization should equal their values before optimization (DPO_1^{0k} and DRO_3^{0k} consequently):

$$\begin{aligned} DPO_1^k &= DPO_1^{0k},\ k = \overline{1,\ N}, \\ DRO_3^k &= DRO_3^{0k},\ k = \overline{1,\ M}. \end{aligned} \quad (11)$$

Although the literature suggests the shorter the inventory holding period is, the better the liquidity position of the company, we aim to limit the dramatic reductions in inventory as a result of optimization procedures possibly leading to decreased customer service due to stock-outs and increased bullwhip effect (Kroes and Manikas, 2014); hence we assume that each company in a chain pursues individual inventory management policy with specific stock level requirements (Eq. 12):

$$DIO_l^k \geq DIO_{low}. \quad (12)$$

Furthermore, we suppose CCCC components to be nonnegative and continuous (Eq. 13):

$$DIO_l^k, DRO_l^k, DPO_l^k \geq 0. \quad (13)$$

Table 1 provides the notations of our model.

Table 1. Model parameters.

Indices	
l	Stage; $l = \overline{1,\ 3}$ (1 – supplier stage, 2 – wholesaler stage, 3 – retailer stage)
k	Company; $k = \overline{1,\ K_l}$, $K_l = \begin{cases} N, & l = 1, \\ 1, & l = 2, \\ M, & l = 3. \end{cases}$

Objective function	
CFC	Collaborative financial costs
Parameters	
INV_l^k	Level of inventory of company *k* at stage *l* at year-end *l*
AR_l^k	Level of accounts receivable of company *k* at stage *l* at year-end *l*
AP_l^k	Level of accounts payable of company *k* at stage *l* at year-end *l*
WC_l^k	Working capital position of company *k* at stage *l*
$COGS_l^k$	Value of annual cost of goods sold of company *k* at stage *l*
$Revenue_l^k$	Value of annual revenue of company *k* at stage *l*
c_l^k	Annual cost of capital for company *k* at stage *l*
CCC_l^k	Cash conversion cycle of company *k* at stage *l*
CCC_{low}, CCC^{up}	Target stability levels of cash conversion cycle of company *k* at stage *l*
FC_l^k	Financial costs of company *k* at stage *l*
FC_l^{0k}	Financial costs of company *k* at stage *l* at year-beginning
DIO_{low}	Minimal stock level
Variables	
DIO_l^k	Days of inventory outstanding for company *k* at stage *l*
DRO_l^k	Days of accounts receivable outstanding for company *k* at stage *l*
DPO_l^k	Days of accounts payable outstanding for company *k* at stage *l*

We construct the optimization model as follows: to minimize collaborative financial costs (4) under constraints (6), (9) – (13). Therefore, we find the optimal cycle times of inventories (DIO_l^k), accounts receivable (DRO_l^k) and accounts payable (DPO_l^k) minimizing overall financial costs of a supply chain under specific liquidity, profitability and inventory constraints for its members over a planning period of a year.

The objective function and constraints are separable functions; hence for solving this nonlinear separable programming problem we employ general algorithm of gradient method (Stefanov, 2013). As the developed model represents a nonlinear programming problem, it is impossible to receive its solution in closed form and the next section provides numerical analysis of the model applied to a case of ICT supply chain from Russia.

4. Numerical analysis

In this section, we present our findings of optimization modeling by illustrative numerical example. The choice of a SC operating in information and communication technology (ICT) industry for numerical analysis is motivated by the fact that it is characterized by a highly integrated business environment and fast technology development (Pirttilä et al., 2014). It is service-oriented, and has a large variety of end products and customers. Besides, even though individual companies in the ICT industry have been used in many case studies, and the SCs of single products have been examined, the ICT chains at the industry level have been rarely addressed (Lind et al., 2012).

We consider a chain consisting of a single supplier, wholesaler and retailer (Fig. 2).

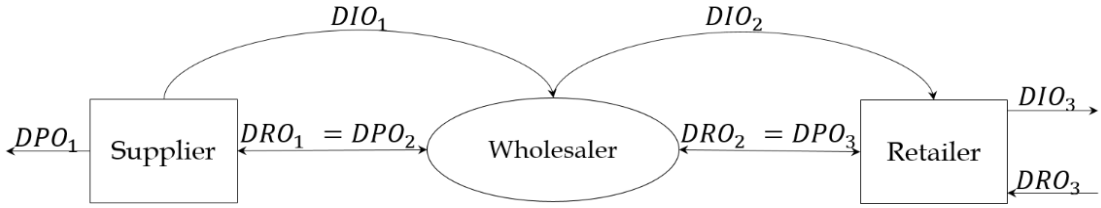

Fig. 2. The financial flows of a focal SC.

The focal company of the chain (Wholesaler) is a Russian public telecommunication services provider holding licenses for local, long-distance and mobile telephone services, data, TV and value-added solutions to residential, corporate and governmental subscribers and third-party operators across all regions of the Russian Federation, Europe and Asia[1]. According to the Wholesaler's strategy[2], it aims to move from fixed line operator to integrated digital service provider based on technological, service and efficiency enhancement aspects. For the latter, optimization of capital expenditure with focus on return on investment is one of the main directions considered, as such, the company is applying operational efficiency upgrading programs, procurement optimization being one of them. Thereby, the Wholesaler states transparency, freedom from discrimination and unwarranted competition-blocking for all its potential suppliers, including small and medium enterprises[3], pursuing procurement on electronic communications networks[4].

The Supplier (Fig. 2) is one of the large domestic system integrators, involved in the Wholesaler's procurement process[5], operating in Russia, CIS countries and Europe. The Supplier's business profile is realization of large scale, socially significant projects on the implementation, development and outsourcing of telecom infrastructure, information security systems, energy and engineering systems, and industrial application platforms.

The Retailer in the considered SC (Fig. 2) is a mobile phone company integrated with Wholesaler, providing a wide range of services, including high-speed mobile Internet, across the Russian Federation. The Retailer' business is based on a unique and efficient model: high-quality services at low costs. Cost control and focus on highly demanded products help the company outpace the growth of other mobile operators showing considerable growth rates of the subscriber base. However, the Retailer's financial performance is weak due to extremely high leverage resulting from recent telecom network construction.

The model parameters we consider are based on data (Tab. 1) retrieved from the Wholesaler's Annual Report and interviews with Supplier's and Retailer's financial managers.

Table 2. Year-beginning data (before optimization)

	Supplier	***Wholesaler***	***Retailer***	***Total (SC)***
$\boldsymbol{INV_l^0}$	1,342.0	11,593.0	972.0	13,907.0
$\boldsymbol{AR_l^0}$	1,374.0	458.1	119.0	1,951.1
$\boldsymbol{AP_l^0}$	901.0	4,256.1	85.0	5,242.1
$\boldsymbol{WC_l^0}$	***1,815.0***	***7,795.0***	***1,006.0***	***10,616.0***
$\boldsymbol{COGS_l^0}$	6,345.0	22,981.0	5,528.0	X
$\boldsymbol{Revenue_l^0}$	7,419.0	29,792.0	6,588.0	X
$\boldsymbol{c_l}$	8.2%	4.7%	3.4%	X
$\boldsymbol{DIO_l^0}$	77.2	184.1	64.2	X
$\boldsymbol{DRO_l^0}$	67.6	5.6	6.6	X
$\boldsymbol{DPO_l^0}$	51.8	67.6	5.6	X
$\boldsymbol{CCC_l^0}$	***93.0***	***122.1***	***65.2***	***280.3***
$\boldsymbol{FC_l^0}$	***32.5***	***237.7***	***5.7***	***276.0***

We investigate two modeling scenarios. In the scenario of initial performance within the CCC stability range, we assume the members of the supply chain each have achieved the tar-

get levels of CCC providing suitable balance between return and liquidity in previous time period. In the scenario of initial performance outside the CCC stability range, the members of the supply chain each have the target CCC values to be achieved in current planning period. However, we assume in both scenarios supply chain members each have sufficient motivation to proceed to working capital optimization on the grounds of total financial costs minimization. Our results demonstrate significant benefits of working capital re-allocation on the grounds of financial costs minimization.

4.1. Initial performance outside the CCC stability range

Without changing the inventories levels

The base model implies the optimization of collaborative CCC components for supply chain members directly inside the specified SC perimeter. For this reason we are testing the case of not changing the initial levels of inventories in the scenario of companies performing outside the CCC stability range. This condition and outlined model parameters provided us with a result of missing feasible solution, meaning that for this case optimization based solely on changing payment terms for supply chain partners is impossible.

However, optimization is possible (Tab. 3a and Tab. 3b) if the range of CCC providing acceptable return-liquidity trade-off is broadened from (-16.18, 61.50) as recommended by Garanina and Belova (2015) for companies from ICT industry to (-16.18, 116.53). The results also illustrate inadequate results, as the obtained marginal reduction in working capital requirements demands harsh changes to payment policies on the expense of the Retailer. It is highly questionable that, being the weaker member of the chain, he will tolerate this approach to repayment.

Table 3a. Year-end data (after optimization)

	Supplier	***Wholesaler***	***Retailer***	***Total (SC)***
$\boldsymbol{INV_l^k}$	1,342.0	11,593.0	972.0	13,907.0
$\boldsymbol{AR_l^k}$	1,374.0	0.0	119.0	1,493.0
$\boldsymbol{AP_l^k}$	901.0	4,256.1	0.0	5,157.1
$\boldsymbol{WC_l^k}$	***1,815.0***	***7,336.9***	***1,091.0***	***10,242.9***
$\boldsymbol{COGS_l^k}$	6,345.0	22,981.0	5,528.0	X
$\boldsymbol{Revenue_l^k}$	7,419.0	29,792.0	6,588.0	X
$\boldsymbol{c_l}$	8.2%	4.7%	3.4%	X
$\boldsymbol{DIO_l^k}$	77.2	184.1	64.2	X
$\boldsymbol{DRO_l^k}$	67.6	0.0	6.6	X
$\boldsymbol{DPO_l^k}$	51.8	67.6	0.0	X
$\boldsymbol{CCC_l^k}$	***93.0***	***116.5***	***70.8***	***280.3***
$\boldsymbol{FC_l^k}$	***32.5***	***237.4***	***5.8***	***275.7***

Table 3b. Comparative change

	Supplier	***Wholesaler***	***Retailer***	***Total (SC)***
$\boldsymbol{INV_l^k}$	0%	0%	0%	0%
$\boldsymbol{AR_l^k}$	0%	-100%	0%	-23%
$\boldsymbol{AP_l^k}$	0%	0%	-100%	-2%
$\boldsymbol{WC_l^k}$	***0%***	***-6%***	***8%***	***-4%***
$\boldsymbol{DIO_l^k}$	0%	0%	0%	X
$\boldsymbol{DRO_l^k}$	0%	-100%	0%	X
$\boldsymbol{DPO_l^k}$	0%	0%	-100%	X
$\boldsymbol{CCC_l^k}$	***0%***	***-5%***	***9%***	***0%***
$\boldsymbol{FC_l^k}$	***0%***	***0%***	***1%***	***0%***

Changing the inventories levels

Building on earlier results of modeling, we observed the need to collaborative inventories management of all SC partners as well as payment terms in order to achieve satisfying and practically reasonable working capital re-allocation along the supply chain. However, the result obtained (Tab. 4a and Tab. 4b) is hardly practically achievable even through usage of all the spectrum of SCF solutions and instruments. The optimization here requires reallocation of roughly 80% of the inventories to the 3PL provider providing inventories financing instruments. Moreover, it demands payment delay to customers downstream. Technically, this will lead to a significant improvement both in overall working capital position as well as in total financial costs decline, though the solution does not take into the account costs of such an inventory financing scheme and the possible outcomes of the payment re-scheduling.

Table 4a. Year-end data (after optimization)

	Supplier	***Wholesaler***	***Retailer***	***Total (SC)***
$\boldsymbol{INV_l^k}$	0.1	2,705.5	203.4	2,908.9
$\boldsymbol{AR_l^k}$	1,938.1	2,954.7	119.0	5,011.8
$\boldsymbol{AP_l^k}$	901.0	6,003.4	548.3	7,452.7
$\boldsymbol{WC_l^k}$	***1,037.2***	***-343.2***	***-225.9***	***468.1***
$\boldsymbol{COGS_l^k}$	6,345.0	22,981.0	5,528.0	X
$\boldsymbol{Revenue_l^k}$	7,419.0	29,792.0	6,588.0	X
$\boldsymbol{c_l}$	8.2%	4.7%	3.4%	X
$\boldsymbol{DIO_l^k}$	0.0	43.0	13.4	X
$\boldsymbol{DRO_l^k}$	95.4	36.2	6.6	X
$\boldsymbol{DPO_l^k}$	51.8	95.4	36.2	X
$\boldsymbol{CCC_l^k}$	***43.5***	***-16.2***	***-16.2***	***11.2***
$\boldsymbol{FC_l^k}$	***30.1***	***-44.7***	***-1.5***	***-16.1***

Table 4b. Comparative change

	Supplier	***Wholesaler***	***Retailer***	***Total (SC)***
$\boldsymbol{INV_l^k}$	-100%	-77%	-79%	-79%
$\boldsymbol{AR_l^k}$	41%	545%	0%	157%
$\boldsymbol{AP_l^k}$	0%	41%	545%	42%
$\boldsymbol{WC_l^k}$	***-43%***	***-104%***	***-122%***	***-96%***
$\boldsymbol{DIO_l^k}$	-100%	-77%	-79%	X
$\boldsymbol{DRO_l^k}$	41%	545%	0%	X
$\boldsymbol{DPO_l^k}$	0%	41%	545%	X
$\boldsymbol{CCC_l^k}$	***-53%***	***-113%***	***-125%***	***-96%***
$\boldsymbol{FC_l^k}$	***-7%***	***-119%***	***-126%***	***-106%***

The illustrative examples lead us to the conclusion that working capital optimization is complicated for the case of relatively high stock levels. However, the scheme of proportional reduction of inventories for at least one business partner in conjunction with usage of SCF instruments has a potential of providing optimal solutions to the problem of working capital re-allocation (Tab. 5a and Tab. 5b).

Table 5a. Year-end data (after optimization)

	Supplier	***Wholesaler***	***Retailer***	***Total (SC)***
$\boldsymbol{INV_l^k}$	878.8	7,591.7	636.5	9,107.0
$\boldsymbol{AR_l^k}$	1,276.0	0.0	119.0	1,395.0
$\boldsymbol{AP_l^k}$	901.0	3,952.5	0.0	4,853.5
$\boldsymbol{WC_l^k}$	***1,253.8***	***3,639.2***	***755.5***	***5,648.5***

	Supplier	*Wholesaler*	*Retailer*	*Total (SC)*
$COGS_l^k$	6,345.0	22,981.0	5,528.0	X
$Revenue_l^k$	7,419.0	29,792.0	6,588.0	X
c_l	8.2%	4.7%	3.4%	X
DIO_l^k	50.6	120.6	42.0	X
DRO_l^k	62.8	0.0	6.6	X
DPO_l^k	51.8	62.8	0.0	X
CCC_l^k	***61.5***	***57.8***	***48.6***	***167.9***
FC_l^k	***16.9***	***85.4***	***2.5***	***104.8***

Table 5b. Comparative change

	Supplier	*Wholesaler*	*Retailer*	*Total (SC)*
INV_l^k	-35%	-35%	-35%	-35%
AR_l^k	-7%	-100%	0%	-29%
AP_l^k	0%	-7%	-100%	-7%
WC_l^k	***-31%***	***-53%***	***-25%***	***-47%***
DIO_l^k	-35%	-35%	-35%	X
DRO_l^k	-7%	-100%	0%	X
DPO_l^k	0%	-7%	-100%	X
CCC_l^k	***-34%***	***-53%***	***-25%***	***-40%***
FC_l^k	***-48%***	***-64%***	***-56%***	***-62%***

For example, proportional reduction of inventories cycle for all members of the focal chain by at least 35% and speed up of DRO cycle for suppler and distributor by 7.13% provides the decrease of total financial costs by 62%. In other words, for the case of high initial levels of inventories one of the members of the chain is to take the initiative of managing and coordinating the inventories along the whole chain, keeping them at lowest cost possible. At the same time, managing the inventories along the chain implies the task of synchronization of individual inventory management and supply chain strategy.

4.2. Initial performance within the CCC stability range

Assuming the supply chain partners have already reached the levels (Tab. 6a) when each company's current ratio is higher than the industry average rate of return and at the same time is below the value at which the relation between liquidity and rate of return becomes inverse (Garanina and Belova, 2015), we found out that working capital reallocation through the use of SCF instruments can entail the decrease in total financial costs of the whole supply chain.

Table 6a. Case of year-beginning data within the CCC stability range (before optimization).

	Supplier	*Wholesaler*	*Retailer*	*Total (SC)*
INV_l^0	869.2	5,666.5	757.3	7,293.0
AR_l^0	1,219.6	816.2	119.0	2,154.8
AP_l^0	901.0	3,777.7	151.5	4,830.2
WC_l^0	***1,187.7***	***2,705.1***	***724.8***	***4,617.6***
$COGS_l$	6,345.0	22,981.0	5,528.0	X
$Revenue_l$	7,419.0	29,792.0	6,588.0	X
c_l	8.2%	4.7%	3.4%	X
DIO_l^0	50.0	90.0	50.0	X
DRO_l^0	60.0	10.0	6.6	X
DPO_l^0	51.8	60.0	10.0	X
CCC_l^0	***58.2***	***40.0***	***46.6***	***144.8***

	Supplier	*Wholesaler*	*Retailer*	*Total (SC)*
FC_l^0	***15.2***	***37.2***	***3.4***	***55.8***

Table 6b. Year-end data (after optimization).

	Supplier	*Wholesaler*	*Retailer*	*Total (SC)*
INV_l^k	869.2	5,666.5	757.3	7,293.0
AR_l^k	1,219.6	0.0	119.0	1,338.6
AP_l^k	901.0	3,777.7	0.0	4,678.7
WC_l^k	***1,187.7***	***1,888.8***	***876.3***	***3,952.8***
$COGS_l^k$	6,345.0	22,981.0	5,528.0	X
$Revenue_l^k$	7,419.0	29,792.0	6,588.0	X
c_l	8.2%	4.7%	3.4%	X
DIO_l^k	50.0	90.0	50.0	X
DRO_l^k	60.0	0.0	6.6	X
DPO_l^k	51.8	60.0	0.0	X
CCC_l^k	***58.2***	***30.0***	***56.6***	***144.8***
FC_l^k	***15.2***	***36.2***	***3.5***	***54.9***

Table 6c. Comparative change

	Supplier	*Wholesaler*	*Retailer*	*Total (SC)*
INV_l^k	0%	0%	0%	0%
AR_l^k	0%	-100%	0%	-38%
AP_l^k	0%	0%	-100%	-3%
WC_l^k	***0%***	***-30%***	***21%***	***-14%***
DIO_l^k	0%	0%	0%	X
DRO_l^k	0%	-100%	0%	X
DPO_l^k	0%	0%	-100%	X
CCC_l^k	***0%***	***-25%***	***21%***	***0%***
FC_l^k	***0%***	***-3%***	***4%***	***-2%***

However, Table 6b and Table 6c illustrate the decrease observed is comparatively inconsiderable and can only be achieved with unrealistic change in trade credit terms requiring immediate repayments.

5. Discussion and conclusions

The main goal of this paper was to develop a model of working capital optimization in collaborative supply chains and to describe how companies can benefit from collaboratively managing their financial flows at the supply chain level. The study indicates that companies do not yet use available opportunities adequately. By identifying possible ways of implementing CFC optimization within and outside the stability intervals of CCCs, the research illustrates approaches and targets for companies to overcome existing challenges by simultaneously using SCF instruments and inventory management practices.

The research contributes to existing SCM literature by focusing on financial flows and studying its optimization. The research integrates financial and supply chain perspectives on the involvement of WCM on the supply chain level.

Managerial actions towards working capital in collaborative supply chains are critical at the operational level for such operations as supply chain management, production, procurement and finance. The companies have gained knowledge how to assess the cycle time of working capital at the intra-organizational level, but estimation of this at the inter-organizational level still causes difficulties for the companies involved in collaborative supply chains. This paper provides insights into collaborative approach to WCM using an optimiza-

tion CFC model by accurately assessing the length of the cycle time of working capital and the total financial costs associated with it. The paper provides mathematical justification of collaborative minimization of CFC on the grounds of using SCF solutions and implementing thorough inventories management in the context of each company in a chain performance is constrained by liquidity and return target levels. The paper provides base for further research on behavior of supply chain partners implementing specific SCF solutions by addressing the questions of strategic cooperation in pursuing shared objectives of total cost minimization and effective coalition structure.

There are two main theoretical implications of the paper that correspond to the main objectives justified by the empirical study. Current studies outline the importance of working capital management in supply chains because companies need to adjust their operations to the volatile economic and financial environment. Firstly, the gap in research that connects the CCC approach and the three-stage collaborative supply chains is filled by the development of the CFC concept. Secondly, the authors contributed to an improvement in the methodology of working capital assessment in collaborative supply chains by introducing the optimization model that provides a holistic view to the collaborative supply chains. The developed methodology is suitable for a three-stage collaborative supply chain and is applicable for usage for business, consultancy, 3PL or bank as an intermediary or the decision maker. Despite the fact, that the model provides static solution to the problem of collaborative working capital management, it has potential for further development of dynamic algorithm.

Future research should seek to extend the context of this paper by investigating the possible imputation options for gained costs reduction on the grounds of cooperative games with coalition structure as there is power asymmetry among players leading to possible lack of motivation to cooperate in the process of collaborative working capital management.

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