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Conceptual Agent based Modeling in Supply Chain: An Economic Perspective

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Abstract
The implementation of government legislation, social responsibility, environmental concerns regarding the reduction of waste, hazardous material and other consumer residuals have made the competition between the firms stricter than ever and nowadays firms that want to survive need a more productive and innovative approach toward the financial aspects of their businesses. This paper presents a conceptual supply chain model integrating financial and physical flows. The main idea of this paper is to identify financial tools and show the usefulness of them in order to increase the competitiveness of the supply chain as a whole in the volatile markets. In doing so, we consider the role of a financial service provider and try to incorporate the effects of supply chain finance concept on the working capital i.e. liquidity of the member entities. So, the main contribution of this research is to address an innovative approach to model financial flows in supply chain and to introduce the financial tools (supply chain finance practices) in the supply chain framework employing Economic Value Added and cash-to-cash cycle as performance measures and finally devise a conceptual agent-based model and show how agent-based modeling can be beneficial in this field.
Keywords: Supply Chain Management, Agent Based Simulation, Supply Chain Finance

Introduction

The implementation of government legislation, social responsibility, environmental concerns regarding the reduction of waste, hazardous material and other consumer residuals have made the competition between the firms stricter than ever and nowadays firms that want to survive need a more productive and innovative approach toward the financial aspects of their businesses. The focus of supply chain management to date has been on the optimization and the design of the flow of goods and information, but the financial flows in the supply chain are often neglected from a supply chain management perspective (More & Basu, 2013). In the meantime, technological

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advances are changing the shape of the overall business ecosystem in which SCF is embedded (Bals, 2018). Ever since the financial crisis in 2008 the development of Supply Chain Finance has increased dramatically. Initially it was developed for small and medium-sized enterprises that were in financial difficulty, but more often large multinational organizations has seen the great potential Supply Chain Finance can unlock (Betts, 2010). Supply Chain Finance was developed as an initiative to create net working capital in the form of cash flow and to act as an alternative to financing from banks with high interest rates. During the economic downturn, a lot of organizations had difficulty generating cash flow in the short term, to optimize working capital and mitigating the risks involved with financing (Wandhofer, 2013). So, availability of the liquidity in the right place and time is important to the firms and insolvency can lead to major problems in the daily activities of the firms in short-term.

Financial flows from accounts receivables, inventory and accounts payables are the main sources of liquidity in a company. To optimize the working capital means to reduce the accounts receivables and to reduce the inventory, and to delay the accounts payables (Tavan, 2012). Without an adequate amount of cash flow companies won’t be able to run operations and could face operational downtime. This type of financial constraint can lead to a major loss in profit or even in the worst-case scenario bankruptcy. Supply Chain Finance (SCF) was developed to overcome these problems and can be used as an alternative cash generating tool that increases liquidity of the firm.

In the meantime, Supply Chains (SCs) are complex and dynamic networks that encounter significant modifications over time. Agents, on the other hand, are independent entities that can act on behalf of real-world actors and thus dynamically support the associated decision-making processes, taking into consideration both local and global knowledge about their environment. The nature of the SC promotes the use of agents as each SC stakeholder can be characterized with an autonomous agent. Agent Based simulation has been identified as a useful tool to the development of certain decision-making processes in SCs mainly due to its somewhat “natural” correspondence between SC stakeholders and agents. The capability of representing the interactions between stakeholders over time, in a dynamic and distributed environment, is unique at the agent society. The AB approach allows for observing the behavior of each supply chain stakeholder over time, as well as of the SC as a whole. Multi-Agent System (MAS) platforms are composed of multiple agents that negotiate and cooperate in order to obtain their goals (O'Hare & Jennings, 1996).

So, an emerging alternative to the supply chain research field is the new modeling approach using agents, the independent small computer programs may be used to represent the individual entities in the simulated world and interact with each other to reveal and help explain the phenomenon that is difficult or impossible to model using the traditional modeling methods. The underling scientific method is simulation. This research uses agent-based modeling as the methodology.

So, the main contribution of this research is to address an innovative approach to model financial flows in the supply chain and assess and evaluate efficiency of the financial tools (supply chain finance) in the supply chain employing Economic Value Added and cash-to-cash cycle as performance measures. In addition, we would like to show that due to nature of supply chain problems, simulation and especially agent-based simulation provides an appropriate ground for exploring the emergent behavior of the system. Using simulation in supply chain enables managers to have a broad perspective toward tradeoffs between different factors and enhances cash flow predictability and management of receivables, payables and forecast future cash inflows and out flows.

Thus, the main questions of this research are as follows:

1) How can we model financial flows in the supply chain along with other flows i.e. physical and information flows, incorporating the dynamic nature of interactions?
2) What are the appropriate tools to measure the overall performance of the supply chain member entities?
3) What are the benefits of agent based simulation modeling in terms of financial performance of supply chain?

The organization of rest of the paper is as in the following. In Section 2, a literature review regarding financial flows in supply chain and simulation methodologies in supply chains is provided. In Section 3 financial issues in Supply Chain Management is explained. Section 4 includes a brief description about the methodology of the research in general. In Section 5, the proposed multi-agent system model is presented. Finally, in Section 6, concluding remarks and possible future research directions are presented.

Literature review

Regarding Supply Chain Management (SCM) models, there have been a considerable number of publications in recent years. The early publications considered supply chains as linear, single-product, single-period, deterministic systems. Later, complex, nonlinear, multiproduct, multi period, stochastic models using more realistic approaches to model the phenomena in more realistic form, emerged. Two main streams of literature are relevant to our research:

1) The studies considering the financial flows in SCM.
2) The researches associated with Agent Based simulation methodology in supply chains.

In the first stream, incorporation of financial flows in SCM can be observed in the literature. Wang, Batta, Bhadury, and Rump (2003) addressed a facility location problem with budget constraints in which the opening of new facilities and the closing of existing facilities are considered. The objective of the model is to minimize the distance from customer subject to the restriction of investment budget and number of facilities. They develop a mathematical programming model and examine its theoretical properties and then develop three heuristic algorithms for this NP-hard problem. Computational testing of these algorithms includes an analysis of the sensitivity of the solution to the budget and the desired number of facilities. Badell, Romero, Huertas, and Puigjaner (2004) presented a Mixed Integer Linear Programming (MILP) model to implement the financial cross functional links with the enterprise value-added chain, where the activities of planning, scheduling, and budgeting are integrated at plant level. The main contribution of this paper is to incorporate the financial issues (i.e. budgeting model) into Advanced Planning and Schedule (APS) enterprise systems. Guillen, Badell, and Puigjaner (2007) presented a mathematical model that optimizes simultaneously activities of scheduling, production planning, and corporate financial planning in a holistic framework. The objective of this paper is to maximize change in equity instead of maximizing profit. The obtained results show the importance of devising broader modeling systems for SCM leading to increased overall earnings and providing further insights on the interactions between operations and finances.

Puigjaner and Guillén-Gosálbez (2008) addressed the supply chain optimization at the operation level in the chemical process industry. An integrated approach was suggested for supply chain management in a multi agent framework. The paper considers supply chain dynamics, the environmental impacts, the business issues, and key performance indicator in the proposed problem. The results show that inclusion of abovementioned aspects in modeling, enlarge the scope of Supply Chain analysis. These advantages are also highlighted in a case study. Hammami, Frein, and Hadj-Alouane (2009) presented a strategic-tactical model for the design of a supply chain network in the delocalization context. The paper considers the logistic decisions, i.e. location of facilities, technology choice, supplier selection, and product flows among chain, as well as the financial decisions, i.e. transfer pricing and transportation costs allocation. Laínez, Puigjaner, and Reklaitis (2009) presented a model for supply chain management with focus on the process operations and the Product Development Pipeline Management (PDPM) problem. The paper addresses the financial and financial engineering considerations with inflow and outflow cash in each period, strategic management of supplier and customer relations by inventory management and option contracts. Protopappa-Sieke and Seifert (2010) presented a mathematical model to integrate the operational and financial supply chain management in the inventory control area. The model decides on the optimal purchasing order quantity with respect to the capital constraints and payment delays while performance measurements of the service level, return on investment, profit margin, and inventory level are analyzed in the relevant supply chain. Longinidis and Georgiadis (2011) proposed a Mixed Integer Linear Programming (MILP) formulation for design of a supply chain network including plants, warehouses, distribution centers, and customers. The paper extends the existing models in the literature by incorporating the financial issues as financial ratios and considering the demand uncertainty. Nickel, Saldanha-da-Gama, and Ziegler (2012) presented a multi-stage supply chain network design problem in which the decisions of the location of the facilities, the flow of commodities and the investments to be made in alternative activities to those directly related with the supply chain design are considered. The goal was to maximize the total financial benefit and an alternative formulation which is based upon the paths in the scenario tree was also proposed. Longinidis and Georgiadis (2013) presented a mathematical model that integrates financial performance and credit solvency modelling with SCN design decisions under economic uncertainty. The multi-objective Mixed Integer Non-Linear Programming (moMINLP) model enchased financial performance through economic value added and credit solvency through a valid credit scoring model. Ramezani, Kimiagari, and Karimi (2015) consider bi-objective logistic design problem integrating the financial and physical flows of a closed-loop supply chain in which the uncertainty of demand and the return rate are described by a finite set of possible scenarios. Golpîra, Zandieh, Najafi, and Sadi-Nezhad (2017) presented a multi-objective, multi-echelon supply chain network design problem. The proposed framework is green, in which it tackles the demand uncertainty of a product, environmental uncertainties, and the downstream risk attitude into the problem formulation. Carnovale, Rogers, and Yeniyurt (2018) consider network power and network cohesion and examine the role of these factors on financial performance of a firm. Meng, Li, Liu, and Chen (2017) present a multi-agent model of four three-level supply chains that apply different types of combined contracts by considering the effects of vertical and horizontal competition between supply chains. Cao and Yu (2018) consider an emission-dependent supply chain comprised of a supplier and a manufacturer who has limited capital and obtains the pledged loan by utilizing the carbon emission permits. The results show that the capital-constrained manufacturer makes more profit by pledging carbon emission permits to obtain a loan compared with having no access to borrowing money.

Regarding the second category, Simulation has in the recent years been adopted in management and social science research and has been regarded as the third way of doing science (Axelrod, 1997). Agent-based simulation which encompasses the simulation technique with the advances in artificial intelligence is characterized by the existence of many agents who interact with each other with little or no central direction, nor human interference.

Only a small number of research papers could be found that adopt agent-based simulation as a methodology in supply chain management literature. One of the important works is by Swaminathan, Smith, and Sadeh (1998), who find that supply chain reengineering (improvement) is critical to the companies exposed to global economy and striving to meet customer expectations regarding cost and service. As the reengineering process is a strategic move, it requires detailed risk analysis. Since quantitative analysis provide insights into current trends but not prescriptive, simulation becomes the only viable platform for detailed analysis for alternative solutions. The authors design a multi-agent framework in which different agents are specified and different control mechanisms are defined. The purpose of this framework is to provide members in the supply chain a customizable decision support tool that can help managers to understand the costs, benefits, and risks associated with various alternatives.

García-Flores and Wang (2002) propose a multi-agent system to model the three flows (money, information, and material) in a chemical supply chain. Their design is very specific for use in the chemical supply chain. The main emphasis of this design is on the processes of paints and coatings production in a plant in additional to certain simplified relationships up- and down-stream. The major addition in the agent design to those by Swaminathan et al. (1998) is that they use one of the common agent communication languages (ACL) to specify in detail the mechanism of communications between agents. A shift of interests is found to move from traditional to net-enabled supply chain (using the Internet or other types of electronic telecommunication media) research. Some researchers name this as e-supply chain (Poirier & Bauer, 2000) or e-chain (Singh, Salam, & Iyer, 2005). The later authors present an agent-enabled architecture that exhibits information transparency (the availability of information throughout the supply chain in an unambiguously interpretable format) and enable enhanced interaction among participants in an e-chain. The focus of the system is largely on the supplier-buyer relationships and processes. The authors describe the process of how a discovery agent matches the buyer and supplier based on the buyer's demand, supplier capacity and reputation, etc.; how transaction is promoted by a transaction agent; and the control mechanism facilitated by the monitoring agent. This platform can be applied to multi-buyer multi-supplier supply chain environment. Some researchers use agent-based simulation to study the traditional SCM topics in a new way. Such example is Lin, Sung, and Lo (2005), who examine the effects of trust mechanisms on supply-chain performance in an e-commerce environment. Their research framework has particular focus of exploring the trust mechanism, based on the integrated view of Mayer, Davis, and Schoorman (1995), in facilitating information flows and transactions within a supply chain. The authors have not described how agents and agent functions are defined and they implement their study on the Swarm platform, one of the agent-based simulation software packages available. Utomo, Onggo, and Eldridge (2018) review the use of agent-based simulation (ABS) in agri-food supply chain research. Their findings include common ABS model structures and modelling approaches.

Financial issues in Supply Chain Management

In practice, the financial aspects of SCM are mostly left to corporate finance and accounting, which 'thinks' in terms of single companies or affiliated groups rather than supply chains (Sargent, 2006). Considering the numerous SCM collaboration initiatives in areas such as procurement, transportation, distribution, R&D, marketing, and sales, it is remarkable how little research is undertaken on collaboration in financial aspects, even more so considering how high the potential cost savings might be.

By embracing Supply Chain Finance, SCM can bridge the customer-oriented demands concerning time, cost, and quality (which are mainly driven by logistics management) with future-, risk-, and market- oriented demands of the providers of capital (Gomm, 2010).

Supply Chain Finance

Supply chain finance (SCF) is the inter-company optimization of financing as well as the integration of financing processes with customers, suppliers, and service providers in order to increase the value of all participating companies (Pfohl & Gomm, 2009). The task of SCF is to save capital cost by means of better mutual adjustment or completely new financing concepts within the supply chain—eventually in combination with a changed role or task sharing.

There are the three different types of SCF that can be used depending on the organization strengths. These three types of SCF are asset-based financing, buyer-led financing and supplier-led financing respectively and are based on the ING Guide to Financial Supply Chain Optimization (Cronie & Sales, 2008). In the next section the three types of SCF and each of their methods are discussed.

Asset-based financing

Asset-based financing is a process that releases working capital through the assets that were created in the supply chain. Selling receivables at a discounted rate to financial institutions are an example of this type of financing. Using asset-based financing you can use different assets like purchase orders, receivables or inventory for loan collateral. Factoring is another asset-based method that will be discussed later.

Buyer-Led Financing

This type of SCF is provided by large buyers to their smaller suppliers. A financial institution is used to leverage the buyer's credit rating to enable early payment to the suppliers. This type of SCF stabilizes the entire supply chain by providing continuous flow of goods from the supplier to the customer.

Reverse Factoring (Approved Payables Finance)

ING Group (Cronie & Sales, 2008) believes that reverse factoring holds the most significant advantages of all the different types of financing tools. During reverse factoring buyers provide financial and information reconciliation to key suppliers based on approved invoices, hence buyer-led financing. Reverse factoring allows a firm to discount a receivable, i.e., receive cash now instead of waiting until the agreed payment delay has elapsed (Van der Vliet, Reindorp, & Fransoo, 2015).

A central technology platform is integrated into the buyer, seller and financial institution to facilitate invoice and credit note reconciliation, invoice trading and settlement between the parties.

Reverse factoring is a solution that aims to reduce the risk of disruption in the collaboration of information flows, physical flow of products, and financial flow (Popa, 2013). The difference between traditional borrowing and factoring is that receivables are rather sold than pledged that results in no liabilities that are credited on the suppliers' balance sheet. Suppliers would typically sell receivables from more than one buyer, thus before factors enter an agreement they have to evaluate buyer portfolios (Seifert & Seifert, 2011).

Reverse factoring has three distinct characteristics from factoring. First, factors do not have to evaluate heterogeneous buyer portfolios, since it is buyer-led, and can charge lower fees. Second, since buyers are usually investment grade companies, factors carry lower risk and can charge lower interest rates. Third, as buyers participate in reverse factoring, factors obtain better information and can release funds earlier (Seifert & Seifert, 2011).

During reverse factoring the buyer issues a purchase order to the supplier and the bank and the supplier delivers the goods and presents the documents. The bank checks documents and notifies the buyer whether all is in order to proceed. The buyer accepts and the bank advises acceptance. The supplier requests to be paid early by the bank, while the buyer pays the bank back on the original due date.

Supplier-Led Financing

This type of financing is the same as buyer-led financing only the financing is provided by large suppliers to smaller buyers, with a financial institution that leverages the suppliers' credit rating. This gives the buyers payment options that suit them better without putting the suppliers' working capital at risk.

The key is to increase liquidity and relieve cash flow stress in the supply chain. This is achieved by a bank or financial service provider that offers early payment to the suppliers based on the approved payables of the buyer. Making use of a technology platform and the adequate infrastructure enhances communication between the parties. Firstly, the buyer issues a purchase order and the supplier delivers the goods and invoices the buyer. The buyer then has to provide the invoices to the bank/financial service provider and should be approved for payment.

The financial service provider gives the suppliers the option of early payment, if the suppliers accept the early payment option the amount that is paid is less by a percentage of the total invoice value. The finance charges are based on the buyer's credit rating which means that the cost of finance is much lower for the suppliers. Smaller suppliers that are having difficulty accessing financing and finding the cost of financing a major problem has identified SCF as a viable solution.

Bank Payment Obligation

Bank payment obligation is defined as: An unchangeable and independent undertaking of an obligor bank to pay or incur a deferred payment obligation and pay a recipient bank a specified amount at maturity following submission of all data sets required by an established baseline (Transaction Matching Application established between banks) resulting in a data match or an acceptance of a data mismatch (Hennah & internationale, 2013).

Economic Value Added

The Economic Value Added (EVA) model was developed for performance management for top managers to signal problems quickly and identify sources for improvement. This method has become an alternative approach for companies as a measure of financial performance at corporate level (Dunbar, 2013).

EVA as defined by Stern, Stewart, and Chew (1995), measures the economic profits earned by a firm during a given period. It is a popular performance measure since it takes into consideration not only the profits generated by the company's resources, but also the cost of those resources (Bahri, St-Pierre, & Sakka, 2011). The difference between EVA and traditional accounting measures is that EVA indicates how well a company performs in relation to the amount of capital employed. The calculation of the EVA is presented below:

$$Economic\ Value\ Added\ (EVA) = NOPAT^{1} - (Capital\ Invested \times\ Cost\ of\ Capital)$$

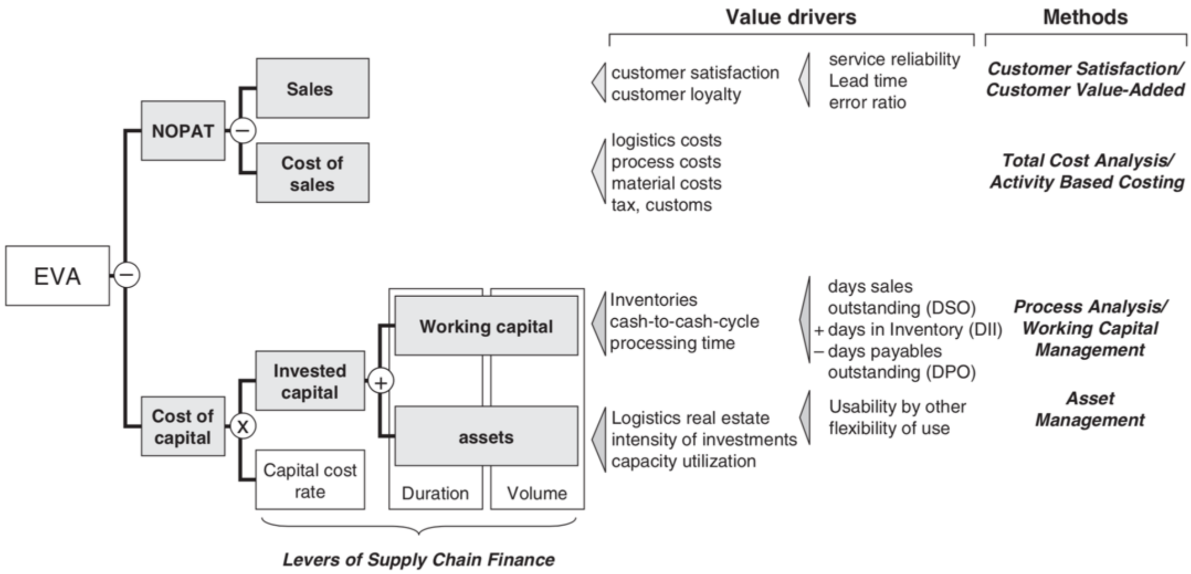

Figure 1. EVA value driver hierarchy and levers of SCF. (Gomm, 2010)

The cash-to-cash cycle time is one of the value drivers that influence EVA directly and forms part of working capital management as seen in figure 2. The cash-to-cash cycle time represents an important part to understand the financial impact of process optimization in the physical and financial flow. In this research we show how effective are SCF tools in improving cash-to-cash cycle and as a result Economic Value Addd measure.

Cash-To-Cash Cycle Time

The time it takes for a financial investment to return to a company after it has been spent for the acquirement of raw materials are known as the cash-to-cash cycle time (Supply Chain Council, 2014). The cash-to-cash cycle time is a measurement tool that is estimated by converting both the inventory days of supply and the number of days outstanding for accounts payable and accounts receivable. After the cash-to-cash cycle has been calculated the result can be interpreted as follows: the longer the cash-to-cash cycle, the more working capital is required (Supply Chain Council,

[1] Net Operating Profit After Tax

2014). The goal is to maximize the days payables outstanding, minimize the sales outstanding and the inventory days of supply.

The inventory days of supply is the amount of inventory expressed in days of sales. The days' sales outstanding is the length of time from when a sale is made until cash for it is received from customers. Days payable outstanding is the length of time from the purchasing materials, labor and/or conversion resources until cash payments must be made expressed in days (Supply Chain Council, 2014).

Based on our researches, nowadays reverse factoring is widely used in many sectors and there are many cloud-based solutions for this method (like Kyriba, ING bank, MIZUHO). So, in the next chapter we try to propose a simulation model in this framework and analysis its efficiency in the different situations and scenarios.

The research methodology

Among the different alternatives, we use agent-based modelling and simulation (ABMS), since this approach has proven to be very suitable for analyzing the complex behavior of supply chains (e.g. Avci and Selim (2017), Dominguez, Cannella, and Framinan (2015), Long (2014), Ponte, Costas, Puche, De la Fuente, and Pino (2016)). Note that a supply chain is a physically distributed system, where each entity has only a partial knowledge of the entire system, which fits perfectly with the agent-based paradigm. ABM means that the actual perceived system is modeled as a set of interacting agents in a defined environment, leading to an agent-based simulation model. The agents are presumed to be acting in what they perceive as their own interests, such as economic benefit (they have personalized missions), and their intelligence regarding the entire system (other agents and environment) is limited.

Agent based modeling has its restrictions, one of which is that, common to all modeling techniques, as Bonabeau (2002) puts it, "a model has to serve a purpose". A general-purpose model is not sufficient to define and deliver such a purpose. The model has to be domain-specific and with just the right amount of details to serve its purpose. How much is "right" remains an art more than a science.

The proposed multi-agent system model

In the proposed model, a two-echelon supply chain is considered, including one supplier and three retailers. We will also consider the role of financial service provider in this process.

The supply chain consists of multiple autonomous plants aiming to maximize their EVA through a collaborative approach. In this regard, we will try to simulate products flows as well as financial flows but our main concern would be the financial aspects of the model. Each day, retailers check their inventory positions. Then, they place orders to corresponding agents if needed. This process continues until the simulation clock reaches to predefined simulation length. In particular, ordering policy and performance measures used by plants are explained in detail, subsequently.

The retailers use a periodic order-up-to policy (s, S). Therefore, each retailer checks its inventory position each day and places and order as soon as the inventory becomes less than s. The same policy is applied in the supplier's raw material inventory.

The supplier and retailers may have very different design objectives due to their unique positions in the business relationship. The supplier holds the product and retailers order product from the supplier. However, the shipment from the supplier may need a prolonged period to arrive i.e. Lead Time.

Agents behavior

Supplier: as defined, a supplier provides products for the retailers to sell. We assume that these products are made by the supplier using three kind of raw material which the price and amount used in each product are determined. (Based on Bill of Material) The supplier receives orders from the retailers when their inventory reaches reorder level(s).

- The supplier needs a fixed amount of time (cycle Time) to make one unit of the product. The value of cycle Time may be customized by a user at runtime.
- The supplier needs a fixed amount of time (Lead Time) to transport the orders to retailers. This value may be customized by a user at runtime.
- We assume there is no Backlog cost for supplier in case of late delivery to Retailers.

Retailers behavior:

- Each retailer receives demand on user specific intervals and each day checks if it has sufficient stock. If it does, it will reduce the stock level by subtracting the demand amount. In case there is not enough inventory Backlog cost is calculated.
- It will check if the stock level is below a preset reorder-level value “s”, if not, it will do nothing, otherwise it will order more stock to order-up-to level “S” from the supplier.

Financial behaviors of supply chain members:

- Each of three retailers and supplier has a specific amount of liquidity as initial working capital which may be customized by user at runtime.
- Selling price of each retailer is specific and each retailer is paid by the customer after a specific time period (in days) which may be customized by user at runtime.
- Unit price of the product sold (supplier to retailers) is fixed and supplier sends the invoices to each retailer along the shipment.
- Maturity date of invoices is specific for every retailer and may be customized by user at runtime.
- Each retailer approves the invoices and uploads the approved invoice data to the SCF electronic platform.
- Supplier decides based on its own working capital level to do nothing and funds will settle directly in the supplier’s bank account on the original maturity date, or the supplier may sell or ‘trade’ his receivables to a funder on the SCF platform in return for advance payment. Rationally it will try to minimize the cost of capital by selecting the receivables with maturity date earlier.
- If traded before maturity, 100 percent of the invoice—less a financing fee or discount in percentage (which can be modified by user at runtime)—is transferred electronically to the supplier’s bank account immediately. Since funds from the financial institution are advanced based on the buyer’s promise to pay on the original maturity date, financing rates are based only on the buyer’s risk, not the supplier’s.
- At maturity, the buyer pays the full invoice amount to the supplier or respective funder on the SCF platform.
- We assume no marketable securities are available in order to provide liquidity for the supply chain members.

- In our model the working capital position in each period (year) cannot exceed a constant and known allowance. We assume that working capital restrictions take place at the end of every period (i.e. each year). When no backorders are in the system, all working capital that exceeds this threshold, in cash, is sent to an external depository in order to avoid an undue and unrealistic accumulation of working capital in the system. The depository cannot be used in the future to finance operations.

Other parameters:

- Demand distribution: Demands arrive on intervals defined by user at runtime, which lower retailers' inventory levels and increase profit account. Demand arrival can be of any distributions as long as it is coded in the simulation implementation. Some commonly used distributions may include normal, uniform, and exponential distributions (Gavirneni, Kapuscinski, & Tayur, 1999). Demand distribution parameters may be set as changeable so that a user can change the parameter values to compare the results under different demand distributions.

Conclusion

In this essay we have devised a conceptual model incorporating supply chain finance practices and using agent-based modeling concept as the methodology. The proposed model along with performance measurement tools can be used to evaluate the supply chain financial performance as availability of the liquidity in the right place and time is one of major problems that many firms are facing in their daily operations.

Using agents to represent the firms in the supply chain enable us to define behaviors and interactions for each agent by applying the existing methods and rules and eventually observe the emergent behavior of the system. The main advantage of using agent-based modeling in comparison with conventional methods is that we can study dynamic nature of transactions in the supply chain and explore and analyze the effects that this aspect has on the evolving behavior of the system as a whole. Along with advances in information technology, nowadays many sophisticated financial tools are available for firms that may seem complicated at first glance and managers can use simulation technics discussed to have a better understanding of the process and explore different scenarios based on if-then planning. In addition, EVA measure enables users to have a better understanding of the costs and benefits regarding the financial and operational performance of the firms involved in the supply chain.

Also, we have shown in this study the potential benefits that supply chain members can utilize by incorporating the value of knowledge and other characteristics of the supply chain (i.e. inventory, trust between members, risk transfer and etc.) to finance their operations and increase the productivity.

In the meantime, by simulating the financial flows in the supply chain, managers will have a realistic perspective about the future cash flows and can efficiently manage receivables or payables, forecast the financial inflows and outflows, leverage financial tools and achieve significant cost savings. Enhanced cash flow predictability can reduce risk-related costs and improve working capital (Anwar, 2004).

The proposed conceptual supply chain finance framework provides a basis for analyzing and interconnecting financial issues and linking finance and SCM to corporate goals. It can also be used to develop new financing models and simulate and analyze them before actually implementing on real cases.

A number of promising areas for future research remains. One can proceed with this methodology and implement the proposed model in a software platform and perform sensitivity analysis of the parameters. Our main concern in this essay are financial flows but one can also incorporate information flows as well to investigate collaborative inventory control effects on the cash-to-cash cycle and overall profit. Our model is a two-echelon supply chain, future research could develop multi-echelon chain and expand discussed paradigms mentioned here and the cost/benefit analysis of other financial concepts. This might enable further insight into the impact of financial tools on supply chain. Considering other supply chain structures such as Closed Loop supply chains and Green supply chains also can enrich the discussion.

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