Overview and Classification of Coordination Contracts within Forward and Reverse Supply Chains

by

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OVERVIEW AND CLASSIFICATION OF COORDINATION CONTRACTS WITHIN FORWARD AND REVERSE SUPPLY CHAINS

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Abstract

Among coordination mechanisms, contracts are valuable tools used in both theory and practice to coordinate various supply chains. The focus of this paper is to present an overview of contracts and a classification of coordination contracts and contracting literature in the form of classification schemes. The two criteria used for contract classification, as resulted from contracting literature, are transfer payment contractual incentives and inventory risk sharing. The overview classification of the existing literature has as criteria the level of detail used in designing the coordination models with applicability on the forward and reverse supply chains.

1. Introduction

Supply chain coordination theory is very broad and it covers different aspects of the existing relationship between supply chain members. A classification scheme of the coordination literature is suggested by Arshinder et al. (2008) and is presented in Figure 1. The scheme shows that, within the literature, coordination is approached from various angles from the role of coordination in supply chains and coordination across the functions of the supply chain and at interfaces to empirical case studies and numerical examples. Furthermore, coordination can be achieved by means of coordination mechanisms used to motivate the members of a decentralized setting to participate in the optimization of the supply chain network. Among the four coordination mechanisms presented in the literature, namely contracts, information technology, information sharing and joint decision making, *the attention of this paper is directed towards coordination by contracts*.

According to Tsay (1999), the *supply chain contract* is "a coordination mechanism that provides incentives to all of its members so that the decentralized supply chain behaves nearly or exactly the same as the integrated one". By specifying contract parameters such as quantity, price, quality and deadlines, contracts are designed to improve supplier-buyer relationship.

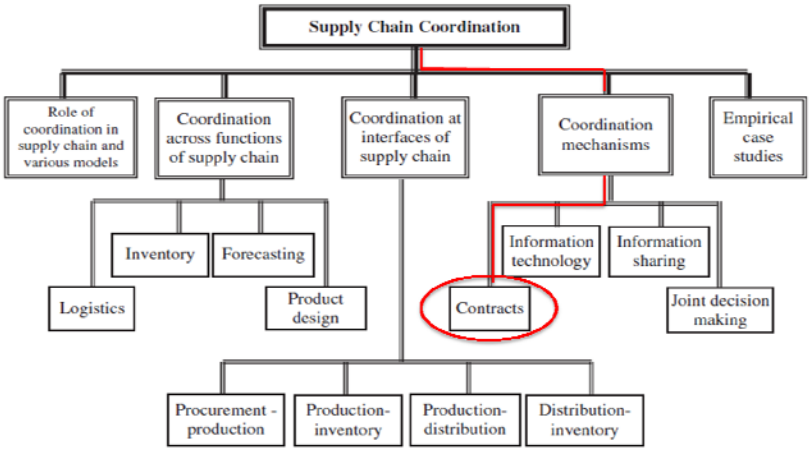


Figure 1. The focus of review [1]

The objectives of these coordinating contracts are (Arshinder et al. 2008):

- Optimization of the total supply chain profit
- Minimization of inventory related costs of salvage (overstock) and goodwill (shortage)
- Fair risk sharing between the parties

Based on the incentives used to motivate the partners, there are different types of coordination contracts analyzed in the literature, presented in detail in section 1.2. These contracts, designed to achieve coordination in the *forward supply chain*, can also be extended and applied to achieve coordination among members of the *reverse supply chain*.

Starting from the general definition of logistics (forward supply chain) - given by The Council of Logistics Management – as "the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements", the reverse logistics (reverse or backward supply chain) can be defined as "the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal" (Rogers and Tibben-Lembke 1998).

Researchers and practitioners have paid a significant attention to coordination contracts on the basis of their positive impact on the supply chain performance. In this regard, this paper is

[1] Source: Supply Chain Coordination Overview extracted from Arshinder et. Al. (2008), p.318

concerned with the overview, classification and interpretation of the literature that addresses the forward and reverse logistics based contracts, incentives and coordination.

2. Research highlights and objectives

In relation to the aspects considered in the introductory part, *the main aim of this paper is to review contracting literature on forward and reverse supply chains*, with divided attention towards the following *objectives*:

- *Review the different types of coordination contracts addressed in the literature;*
- *Understand and appreciate the different types of contracts and their applicability;*
- *Supplement contracting literature by proposing a classification scheme of the existing literature having as criteria the level of detail used in building the different contractual models/set-ups for both forward and reverse supply chains;*
- *Suggest further research directions by making a parallel between existing study and future possible extensions of the theory.*

Starting with the review of coordination contracts, the newness aspect of this paper is brought to the literature by the proposition of two classification schemes in relation to the applicability of coordination contracts on forward and reverse supply chains and by the suggested parallel between existing and further research.

There have been numerous journals used to collect information related to coordination by contracts. The publishers particularly used are Springer, Palgrave Macmillan, JSTOR, Emerald, Inter Science, Science Direct and Elsevier. Furthermore, the selection of the papers has been made based on the addressed issue and according to their content, with focus on: the type of contract that receives attention in the analysis, the assumptions and the setting behind the model, the procedure followed in generating the data and the formulas and the level of detail and contract applicability.

In line with the objectives of the research, the rest of the paper is structured as presented in the following. Section 3 presents an overview of coordination contracts theory, followed by contract classification. Section 4 introduces a classification scheme of the literature based on the setting/level of detail adopted when modeling and analyzing the implications of different types of contracts on the forward supply chain. In section 5, the applicability of contracts on reverse supply

chain theory is considered and classified, ending the paper with concluding remarks and further research directions of section 1.6.

3. Coordination contracts

In this section, the attention is directed on contract characteristics with a closer look at game theory, Nash equilibrium and newsvendor model, followed by contract classification and evaluation criteria for implementation of contracts.

3.1 Contract overview

Supply chain contracts are used in the business relationship between two or more independent participants to the supply chain, as tools for coordination. Game theory analysis plays an important role in the decision making process on whether the participants are better off by cooperation or by non-cooperation. In the cooperative game the participants' responsibility is to decide on which type of contract is worth implementing and to design the contract in such a way that both players are satisfied with the contractual terms. If the parties do not agree on the contractual terms – decided by bargaining - then there is no cooperation and the members of the supply chain will be rivals in the non-cooperative game (Figure 2).

A second option for the players, if they do not agree on a contract and still want to cooperate is the coalition approach where the concepts of cooperative game theory are applied without a predefined procedure to be followed like in the negotiation approach (Guardiola et al. 2007).

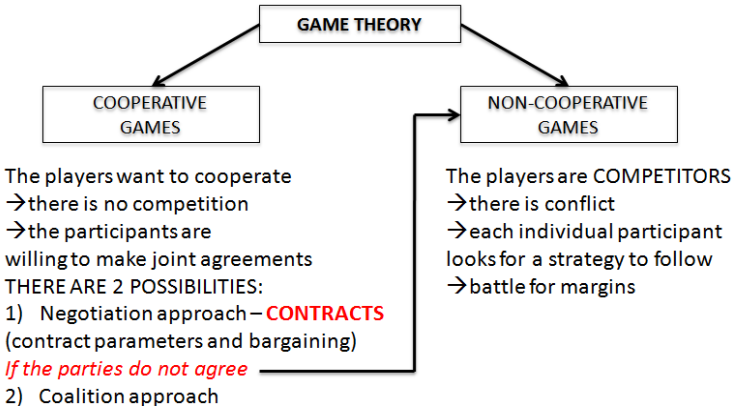


Figure 2. Game theory approach for coordination[2]

[2] Figure 2 has been constructed based on information extracted from Albrecht (2010).

Starting from the assumption of a monopolistic market, Li et al. (2007) addresses the issue of cooperation in a buyer-seller inventory control system. The research methodology used is the *game theoretical model*, where a parallel between the cooperative and the non-cooperative games is made. Considering quantity discount as the mechanism used to achieve cooperation, Li et al. (2007) studies the impact of cooperative transactions between the members and demonstrates that:

- Total system profit is higher at cooperation than at non-cooperation;
- The optimal order quantity of the buyer is higher at cooperation than at non-cooperation;
- The wholesale price of seller to buyer is lower at cooperation than at non-cooperation.

Furthermore, Cachon (2003) emphasizes that "A contract is said to coordinate the supply chain if the set of supply chain optimal actions is a Nash equilibrium, i.e., no firm has a profitable unilateral deviation from the set of supply chain optimal actions. Ideally, the optimal actions should also be a unique Nash equilibrium; otherwise the firms may "coordinate" on a sub-optimal set of actions. In the *newsvendor model* the action to coordinate is the retailer's order quantity". And, since the newsvendor model is the ground setting for coordination contracts, a short introduction of the model is required. More detailed analysis of game theory applicability in supply chain can be found in Cachon and Netessine (2005), Nagarajan (2005) and Nagarajan and Sosic (2008).

The newsvendor model

The basic newsvendor model (Cachon 2003), also called the newsboy model, consists of two firms, a supplier and a retailer facing stochastic demand. The time frame is one selling season and the retailer has a single opportunity to replace his inventory. The newsvendor problem the retailer encounters refers to the decision on the order quantity q that must be taken before the start of the selling season. The demand $D>0$ has distribution function F and density function f, where $F(0)=0$, $\bar{F}(x) = 1 - F(x)$ and $\mu = E[D]$. The costs are c_s – supplier's production cost and c_r – retailer's marginal cost. The retail price is p and $c_s + c_r < p$. There is a goodwill loss for each unit of demand the supplier g_s or the retailer g_r does not satisfy. Alternatively there is a net salvage value v for the leftover inventory at the end of the selling season.

Considering $S(q)$ the expected sales and T the transfer payment from the retailer to the supplier, the profit functions can be written as:

$$\pi_r(q) = (p - v + g_r)S(q) - (c_r - v)q - g_r\mu - T \quad (1)$$

$$\pi_s(q) = g_s S(q) - c_s q - g_s\mu + T \quad (2)$$

The total supply chain profit will be the sum of supplier and retailer profits where $c = c_s + c_r$ and $g = g_s + g_r \quad \longrightarrow \quad \prod(q) = \pi_r(q) + \pi_s(q) = (p - v + g)S(q) - (c - v)q - g\mu$ (3)

There is a vast literature on newsvendor model from which Lariviere (2001) is focusing on prices and supply chain profit and Chen and Seshadri (2006) focuses on demand risk implications. Other extensive treatments can be found in Nahmias and Smith (1994) and Silver et al. (1998).

In relation to the game theory approach, there is a specific sequence of events that takes place in the game, in the case where the parties agree and the retailer accepts the contract offered by the supplier. For a better understanding of the supplier-retailer relationship such a sequence of events - relative to the time frame - is presented in Figure 3.

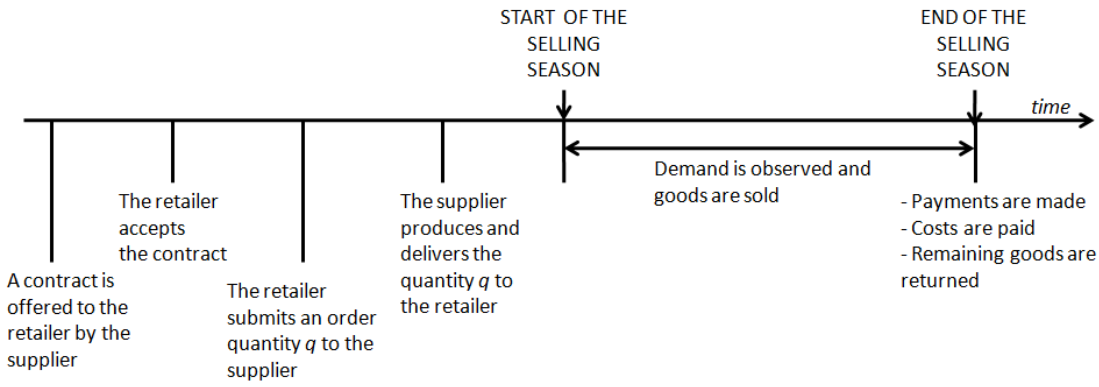


Figure 3. Sequence of events within supplier-retailer relation[3]

Furthermore, referring to the specific coordination problem and to the contract to be adopted for implementation, the sequence of steps to be followed is as shown in Figure 4.

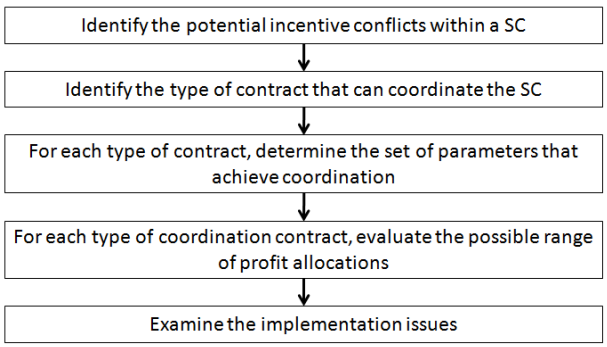


Figure 4. Sequence of steps regarding the decision process of contract implementation[4]

[3] Figure 3 is a graph representation of the sequence of events presented in Cachon (2003), p.8.

3.2. Contract classification

As already specified, there are a series of contracts that coordinate the newsvendor setting. These contracts can be described based on the different criteria used for classification and on the parameters used to create the model.

A. Classification based on transfer payments

As presented in Cachon (2003), optimal performance is possible if the participants coordinate using *transfer payment contractual incentives* such that every firm's objective is aligned to the supply chain's objectives. Based on this criterion, the existing types of contracts are presented in Figure 5 and detailed in the following. An overview of the extensive models and approaches of coordination by contracts, with focus on the most representative papers in the literature can also be found in Table 1.

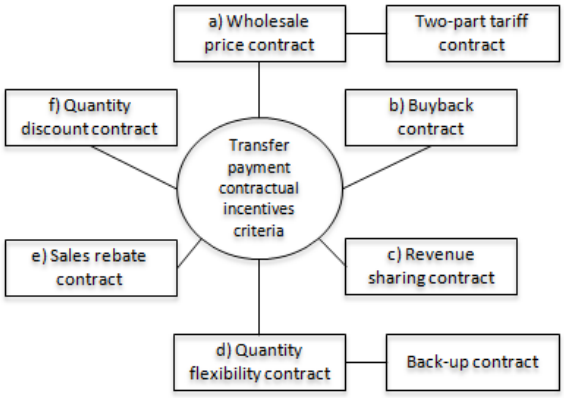


Figure 5. Types of contracts using transfer payments criteria of classification

a) The wholesale price contract

In this setting, the producer/supplier is selling goods to the retailer at a wholesale price *w* as time as the former agrees to buy the goods at the offered amount per unit. The retailer decides on his optimal stocking quantity and sells the goods during the selling season. The retailer keeps the entire revenue, but has no possibility of returning unsold items. The transfer payment takes the form of: $T_w(q, w) = wq$. The wholesale price contract coordinates the supply chain only if the wholesale price is at least equal to supplier's cost of producing the goods.

The wholesale price contract is analyzed by Chen and Li (2007) with focus on double marginalization and demand distribution, while Dong and Zhu (2006) focus on inventory availability within the supply chain and Sabbaghi, Sheffi and Tsitsiklis (2007) focus on the same setting where capacity constraints influence the wholesale price.

[4] Figure 4 of steps regarding the decision process of implementing contracts is based on information extracted from Cachon (2003), p.5.

A particular case of wholesale contract is the *two-part tariff contract*. In this case the wholesale price charged by the supplier is equal with the production cost. After the end of the selling season the retailer pays a fixed franchise fee *F* to the supplier. This fee is agreed by bargaining before the

Table 1. Contracting literature *(personal contribution)*

	Type of contract	References	Applicability
1	Wholesale price	Dong and Zhu (2006), Sabbaghi, Sheffi and Tsitsiklis (2007), Chen and Li (2007), Jinghong and Dingti (2008), Shin and Tunca (2010)	Any selling/buying transaction
2	Two-part tariff	Bonet et al. (2004), Fauli-Oller and Sandonis (2007), San Martin and Saracho (2010)	Patent licensing
3	Buyback	Donohue (2000), He et al. (2006), Hou et al. (2010), Höhn (2010)	Audio, magazines and book industries
4	Revenue sharing	Giannoccaro and Pontrandolfo (2004), Cachon and Lariviere (2005), Chen (2006), Koulamas (2006), Quin and Young (2008), Li and He (2008), Dong and Li (2009), Van der Rhee et al. (2010)	Video rental industry
5	Quantity flexibility	Tsay (1999), Tsay and Lovejoy (1999), Sethi et al. (2004), Brusset (2005), Subramanian et al. (2006), Bassok and Anupindi (2008), Lian and Deshmukh (2009), Li et al. (2010)	Cosmetic industry, electronic and computer industry
6	Back-up	Eppen and Iyer (1997)	Fashion industry
7	Sales rebate	Taylor (2002), Krishnan et al. (2004), Wong (2009)	Hardware, software, auto industries
8	Quantity discount	Burnetas et al. (2005), Beard et al. (2007), Li et al. (2007), Cao et al. (2008)	Products with long lead times and short life cycles: apparel, toys, etc
	Reviews	Lariviere (1999), Tsay et al (1999), Cachon (2003), Albrecht (2010), Höhn (2010), Wang (2002), Gomez-Padilla et al. (2005)	
	Debates	Gerchak and Wang (2004), Arshinder et al (2009a and 2009b), Cachon and Lariviere (2005), Höhn (2010), Wang et al. (2007)	
	Newsvendor model	Nahmias and Smith (1994), Silver et al. (1998), Lariviere (2001), Chen and Seshadri (2006), Rekik et al. (2007)	

demand is observed, assigning all the demand risk to the retailer. The transfer payment is: $T_{w2p}(q, w) = wq + F$.

Regarding the two-part tariff contract Fauli-Oller and Sandonis (2007) and San Martin and Saracho (2010) focus their attention on patent licensing and royalties within the licensing mechanism.

b) The buyback contract

In addition to the wholesale price contract, with a buyback contract the retailer purchases *q* units before the start of the selling season at a price of *w*, but he can return up to *q* unsold units to the

supplier after the end of the season. The price received from the supplier for the unsold items is the buyback price $b<w$.

The transfer payment in this setting is: $T_b(q,w,b) = bS(q) + (w-b)q$.

Donohue (2000) studies the coordination in a buyback contract with improving the demand forecast information in fashion industry. The impact of supply and demand uncertainty along with supply disruption and decision-making under risk on buyback contract is analyzed by Hou et al. (2010) while channel stuffing as inventory problem is studied by Wang and Zipkin (2009).

c) The revenue sharing contract

Under a revenue sharing agreement, the buyer pays the supplier a lower wholesale price w_r per unit purchased. In return, the retailer will share the return realized with the supplier in such a way that the retailer keeps a ϕ fraction of the revenue, while the rest of $(1-\phi)$ is the fraction granted by the supplier. Assuming that all the revenue is shared, the transfer payment is:

$T_r(q,w,\phi) = (w_r + (1-\phi)v)q + (1-\phi)(p-v)S(q)$.

Cachon and Lariviere (2005), Li and He (2008) and Dong and Li (2009) are some of the references that approach revenue sharing contract on different aspects such as inventory, competition, risk adverse retailers, the use of fuzzy variables, etc.

d) The quantity flexibility contract

Within a quantity flexibility agreement, the buyer pays w_q per unit purchased. At the end of the selling season, the supplier compensates the retailer for the unsold inventory I with a credit equal to $(w_q + c_r - v)\ min(I,\delta q)$, where δ is a contract parameter and $\delta \in [0,1]$. This type of contract is mostly used in electronics and computer industry (Lariviere 1999).

With the quantity flexibility, the transfer payment is:

$T_q(q,w_q,\delta) = w_q q - (w_q + c_r - v)\int_{(1-\delta)q}^{q} F(y)dy$.

Among the quantity flexibility approaches, valuable work has been done by Tsay (1999), Bassok and Anupindi (2008), Lian and Deshmukh (2009) and Li et al. (2010).

A particular case of quantity flexibility contract is the *back-up contract*, very similar to the buyback contract. Following this agreement, the supplier commits to buy back any unsold

inventory at the end of the selling season, giving an incentive to the buyer to purchase a larger quantity.

Eppen and Iyer (1997) study the backup agreements and inventory implications within the backup setting within fashion industry.

e) The sales rebate contract

In this setting, the supplier's price is w_s per unit. During the selling season, after the accomplishment of a threshold n, the retailer receives a rebate r for every extra unit that exceeds the threshold value. The transfer payment takes the form of:

$$T_s(q, w_s, r, n) = \begin{cases} w_s q & q < n, \\ (w_s - r)q + r(n + \int_n^q F(y)dy) & q > n. \end{cases}$$

Sales rebates contract is analyzed by Taylor (2002), Krishnan et al. (2004) and Wong et al. (2009).

f) The quantity discount contract

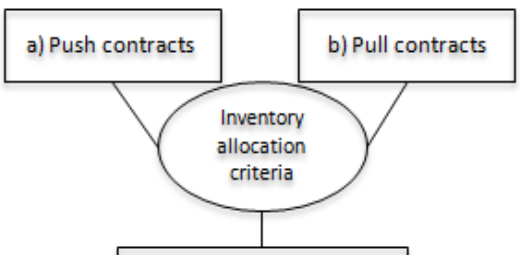
Differentiating between the different types of quantity discounts, the attention is drawn on "all unit" quantity discount contract. Considering $w_d(q)$ the wholesale price charged by the supplier per unit, the transfer payment is: $T_d(q, w_d(q)) = w_d(q)q$, where the per unit wholesale price decreases with quantity q.

Burnetas et al. (2005) studies the quantity discounts contract with asymmetric demand information, while inventory control and buyer-seller cooperation improvement are studied by Li et al (1996).

There can be found numerous reviews on contracting literature such as the ones presented by Cachon (2003), Albrecht (2010) and Höhn (2010). Among others, debates and comparisons between two or more contracts can be found in Gerchak and Wang (2004), Arshinder et al (2009a and 2009b), Cachon and Lariviere (2005) and Höhn (2010).

B. Classification based on inventory risk allocation

Under the consideration that some firms manage to avoid carrying the risk of unsold inventory, Cachon (2004) suggests a *classification of contracts*



according to the allocation of inventory risk between the members of the supply chain. The different types of contracts are as presented in Figure 6.

a) Push contracts

The retailer decides and pre-books quantity q several months before the start of the selling season and pays a wholesale price w_{pull} lower than his retail unit price p: $w_{pull} < p$. Hence, by placing his order before having any information on the demand (only observed within the selling season time frame), the retailer bears the entire supply chain inventory risk.

b) Pull contracts

The setting is similar with push contracts but in this case the supplier is the one that takes the entire supply chain inventory risk because he is the only one holding inventory. The retailer takes no risk as he replenishes according to the demand observed during the selling season.

c) Advance-purchase discount contracts

Compared with the previous two contracts that only have one wholesale price, the advance-purchase discount contract has two wholesale prices. There is a regular price for goods ordered during the selling season while a discounted price is applied for inventory acquired before the start of the season. This being the case, the retailer bears the risk of carrying the inventory purchased before the demand is observed and the supplier bears the risk of holding inventory during the season, ready for any eventual replenishments of the retailer.

3.3. Evaluation criteria for contract implementation

In order to facilitate the decision on which type of contract is worth implementing, Cachon (2003) suggested the following *evaluation criteria for contract implementation*:

- Supply chain coordination, in the sense that the contract must be designed in such a way that none of the participants should have the incentive to deviate from the optimal supply chain decisions and actions;
- Administrative costs implying that the efficiency of any coordination contract is directly related with the administrative costs generated by the level of detail specified in the contract;

- Risk and benefits sharing as an important feature of any contract that should allow for a fair distribution of risk and any division of the total supply chain profit.

Under the consideration of newsvendor model, the setting allows for observations on the above three criteria. It has been shown that most of the contracts achieve coordination and allow for a fair division of risk and profits. As concerning the administrative costs, the contracts that imply one transaction only are simple to describe and are less expensive. In this regard, wholesale price and quantity discount contracts are equally costly, while revenue sharing, buyback and quantity flexibility imply a higher investment as the level of detail is higher and additional material and informational flows are required.

In addition to the newsvendor based contractual models, it is worth mentioning that the newsvendor model with the retailer choosing his order quantity (optimal Q) can be extended according to the degree of liberty the retailer can have in choosing other actions (Cachon 2003) to:

- Newsvendor model where the retailer chooses his retail price along with his stocking quantity;
- Newsvendor model where the retailer is permitted to exert costly effort to increase the demand (i.e. Taylor, 2002);
- Newsvendor model where compensation between multiple retailers is possible.

4. Overview of the classification scheme – forward supply chain

By specifying precise parameters and decision variables, contracts provide incentives to the participants to behave in a manner that provides benefits to the entire supply chain. Based on these parameters and on the level of detail adopted in building the contract, the literature can be structured as presented in Figure 7.

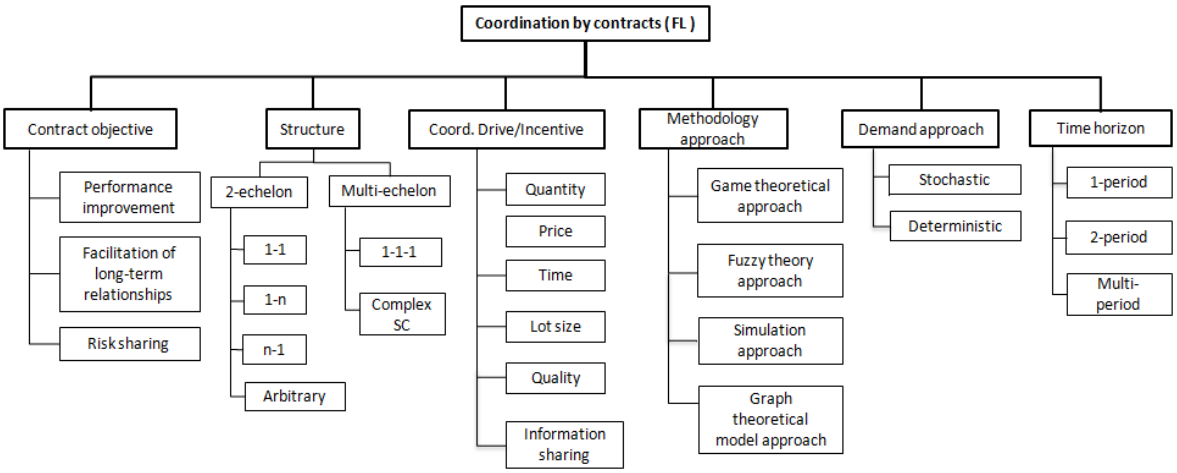


Figure 7. Literature classification scheme within forward logistics (FL) *(personal contribution)*

In generating the overview for contracting literature, there appeared a series of elements to be considered in the classification such as: the objective of the contract, the structure of the supply chain, the incentive/coordination drive that imposes coordination by contracts, the theory applied in analyzing the model, the type of demand and the time horizon. Each of these considerations will be presented in this section.

Contract objective

According to the scope of contract implementation, contracts can be signed between partners having as finality the fulfillment of one or more of the following objectives: *performance improvement* in terms of profit maximization or over/under stock cost reduction (treated by Cachon (2003) and by most of the work in the field), *facilitation of long-term relationships* (Bakos and Brynjolfsson (1993)) and/or *risk sharing* among the supply chain partners (such as inventory risk sharing problem discussed by Yao et al. (2010) and Cachon (2004)). These objectives are further discussed in Tsay (1999) and Hohn (2010).

The structure

Contracts can be designed in such a way to satisfy the needs of the participants to the game given the cases of *two-echelon* supply chains (with the numbers of participants n and with n = 2) and *multi-echelon* supply chains (with $n \geq 3$). Regarding complex structures, Figure 8 is meant to clarify the concept of echelon within contracting literature, where the set of all suppliers represents

one level of the supply chain, the set of manufacturers represents the second level of the supply chain, with the same going for all sets of participants to the chain. The alignment of two sets of participants (consecutive or not i.e. supplier – manufacturer or supplier – retailer) that effectuate direct transactions with one another is referred to be the two-echelon supply chain, while the alignment of multiple sets is called a multi-echelon supply chain.

Regarding the *two-echelon* supply chain there are many papers that concentrate their attention on the direct collaboration between two individual members, *1-1*. This is the case of most of the references found in the coordination by contracts literature that investigate the supplier – retailer or seller – buyer relation: Bernstein and Federgruen (2005) on price discount, Tsay (1999) and Bassok and Anupindi (2008) on quantity flexibility, Pasternack (1985) on buyback, Arshinder et al. (2009a) on buyback, revenue sharing and quantity discount contracts, etc. The *1-n* collaboration can be found in the work of: Plambeck and Taylor (2002) on quantity flexibility, Bernstein and Federgruen (2005) on price discount, Breinstein et al. (2006) on wholesale price,

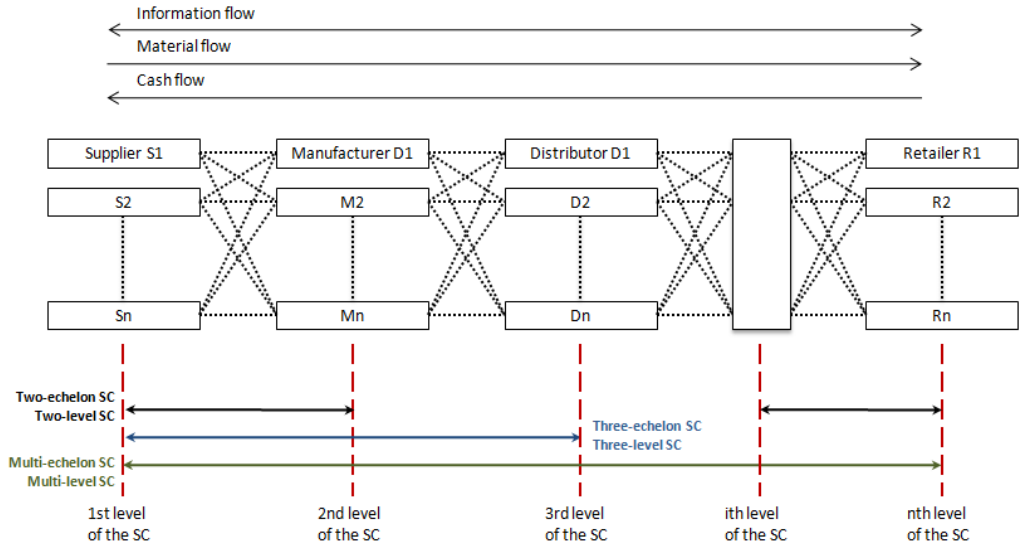


Figure 8. One-echelon/multi-echelon versus two level/multi level supply chains *(personal contribution)*

Cachon and Lariviere (2005) on revenue sharing, etc. The *n-1* single echelon can be found in Gerchak and Wang (2004) on revenue sharing and Bernstein and DeCroix (2006) on transfer payment. The case of multiple suppliers - multiple retailers is approached by Weber and Xiong (2007).

With regards to the *multi-echelon* supply chain, recent work can be found in Arshinder et al. (2009b) which analyze a three-level supply chain with one supplier, one distributor and one retailer. A more complex setting is analyzed by Ganeshan (1999) where multiple suppliers provide goods to multiple retailers through one distributor.

Coordination Drive/Incentives

As presented in the contract overview part, there can be a series of incentives offered by supply chain members to their collaborators in order to achieve coordination. More specifically, these incentives can be: *price discounts, quantity discounts, quantity flexibility, time incentives such as lead times and deadlines, quantity incentives, capacity related incentives or the need for access to information such as sales, forecasts and inventory levels* (literature presented in section 1.2).

Methodology approach

Coordination theory is based on *game theoretical approach* where the success of one individual in making decisions depends on the choices made by the other participants to the game (Myerson, 1991). In this respect, Cachon (2003) refers to the set of supply chain optimal actions as a unique Nash equilibrium and investigates the behavior of different coordination contracts. Albrecht (2010) looks at the mechanisms based on non-cooperative game theory and establishment of coordinating contracts related to drivers such as quantity, time and lot sizes. Other approaches can be found in Cachon (2005), Nagarajan (2005), Taboubi and Zaccour (2005), Guardiola et al. (2007) and Hannet and Arda (2008). *Fuzzy theory* is introduced to coordination contracts by Li and He (2008) and Wang et al. (2008) with focus on revenue sharing contract. The *simulation approach* is used in observing the behavior of coordinating contracts under specific settings and conditions (Arshinder et al., 2009a). Kaur, A., Kanda, A. and Deshmukh, S.G. (2006) looked at graph theoretic approach implemented on different aspects of supply chain coordination, while Arshinder et al. (2009a) apply the concept on quantity flexibility contract as the contract that provides best results under specific assumptions.

Demand approach

The case of *stochastic demand* is approached by Cachon (2003) and most of the contracting literature. The case of *deterministic demand* can be found in Bresnahan and Reiss (1985) on the wholesale price contract and Sobel and Zhang (2001), Ding et al. (2007), Qi et al. (2004) and Song, Ray and Li (2008) on different coordination settings.

Time horizon

The *one-period* approach is adopted in Cachon (2003) and most of the references presented in Table 1. The *two-period* setting can be found in the work of Cachon (2002) and Linh and Hong (2009). Regarding the *multi period* setting, Tsay and Lovejoy (1999) study quantity flexibility contracts having multiple locations, multiple demand periods, lead times and demand forecast updates.

It has been shown that the contracting literature classified in this section is very broad and covers many aspects of the supply chain incentives and coordination, from simple one to one settings and simplifying assumptions to very complex approaches. Next section concentrates on classifying the literature with respect to the reverse supply chain.

5. Overview of the classification scheme – reverse supply chain

In Rogers and Tibben-Lembke (2001) reverse logistics is defined as the movement of products or materials from the downstream to upstream with the purpose of creating or recapturing value, or for proper disposal. Proceeding further with the research, Tibben-Lembke and Rogers (2002) compares and contrasts forward and reverse logistics in a retail environment showing that the differences are considerable and cover a wide variety of aspects of logistics from product recovery to the sales of remanufactured products.

While the reverse logistics covers aspects such as product recovery, network design, inventory management, production planning and control, remanufacturing, repair, recycling, disposal and other related activities, the focus on this section will be on coordination by contracts within forward supply chains. Considering all the aspects of the reverse logistics of equal importance, the attention is directed only towards the literature that proposes models and contracts that achieve coordination between the participants to the reverse logistics game.

There seem to be a large body of work in the literature regarding reverse logistics. Complete overviews can be found in Rogers and Tibben-Lembke (1998), Beullens (2004), Sasikumar and Kannan (2008 and 2009) and Subramoniam et al., 2009. However, less importance seem to be paid to coordination and, in particular, to coordination by contracts within this area of research.

Based on the available literature and focusing on the same selection criteria for the papers as in forward logistics classification (namely: the type of contract/model that receives attention in the

analysis, the assumptions and the setting behind the model, the procedure followed in generating the data and formulas, the level of detail and contract/model applicability) a classification scheme of the coordination models and coordination by contracts within the reverse logistics literature is proposed in Figure 9.

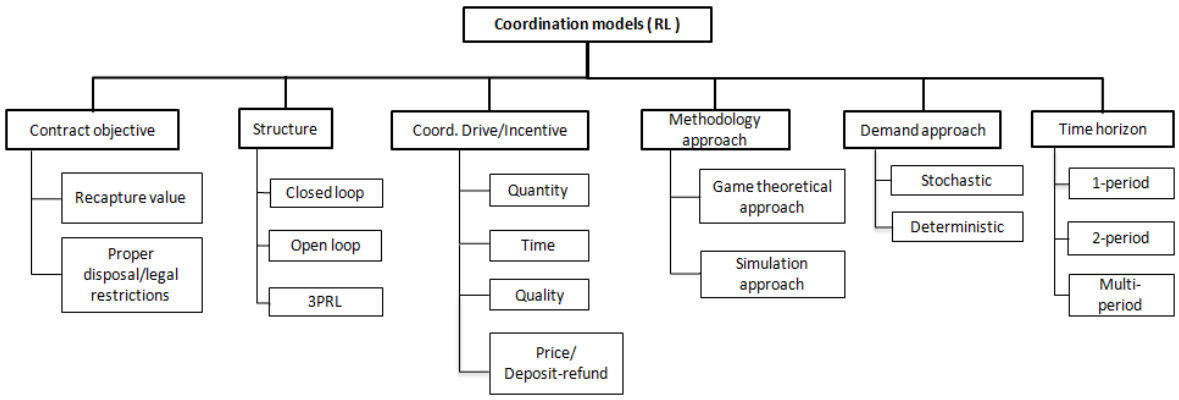


Figure 9. Literature classification scheme within reverse logistics (RL) *(personal contribution)*

Contract objective

The main reasons supply chain members engage in reverse logistics is for *recapturing value* by reuse of recycled materials and end-of-live products or for *proper disposal* imposed by government regulations or by customer sensitivity to environmental issues.

There are two important considerations to be made when it comes to *recapturing value* from used products: product recovery (collection, inspection and separation, disassembly, reuse, remanufacturing and recycling) and inventory management. From the very vast literature, Melissen and Ron (1999) define the practices and relevant terminology of product recovery, while Krikke et al. (1998) looks at the evaluation of product recovery strategies. Recent work on inventory management can be found in Mahavedan et al. (2003) on push policy and Hahn et al. (2004) on perishable products under LIFO and FIFO policies. Baenas et al., (2011) described that the reverse logistics framework will create actions that will not be harming the environment. Korchi, and Millet (2011) proposed a framework which allows generating and assessing different reverse logistics channel structures and the proposed framework is applied to a product remanufacturing case to propose an alternative structures which has less environmental impact and higher economic benefits.

The *disposal* of out-of-use materials (products that cannot be reused) is directly related with waste management and environmental implications. In this respect, Sheu (2007) presents a model that coordinates the reverse chain by minimization of total reverse logistics costs and risks. Krikke et al. (1998) develops a model that optimizes product recovery and disposal considering one product category. Other treatments of waste management can be found in Ritchie et al. (2000) on pharmaceutical products, Hawickhorst (1997) on nuclear waste, Haastrup et al. (1998) on urban waste management and Sharma (2007) on electronic equipment. On the environmental perspective, Bloemhof-Ruwaard et al. (1995) considers the impact of operations research techniques on the value of green supply chain management, Zhu and Sarkis (2004) investigates the existing relation between economic performance and green supply chain management and Vlachos et al. (2007) looks at capacity planning under the consideration of take-back obligation and the 'green image' impact on customer demand.

The structure

The *closed loop* supply chain, as referred to in Figure 10, is the integration of forward channel with the reverse channel having as purpose the achievement of optimal planning and cost reduction. Papers that analyze coordination in closed loop systems are Valachos et al. (2007) on take-back obligation, Gu and Ji (2008) on remanufacturing cost minimization and Shi and Bian (2009) on revenue sharing and quantity discount settings. In an *open loop* system the products do not return to the manufacturer but can be used by different producers in the same or in different industries. Zografos and Samara (1989) focus on disposal and routing risks minimization and travel time reduction, Savaskan and Van Wassenhove (2006) discuss the economic tradeoffs of selecting the optimal reverse chain and Neto et al. (2008) looks at balancing profitability with environmental impact within sustainable logistics network.

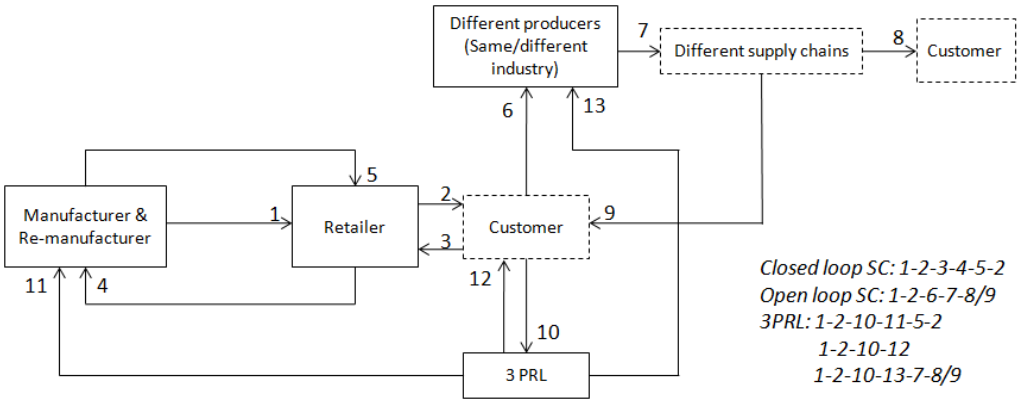


Figure 10. Reverse logistics structure *(personal contribution)*

The *third-party reverse logistics (3PRL)* refer to the reverse logistic taking place through a specialized and viable logistics provider instead of the original network (collection centers, outsourcing). References that focus on 3PRL coordination are Ko and Evens (2007), Sasi kumar and Kannan, 2008a,b; Sasi kumar and Kannan, 2009; Kannan et al., 2009; Kannan, 2009; Farzipoor Saen, 2010; Kannan and Murugesan, 2011 and Du and Evans (2008).

Coordination drive/incentive

There have been proposed some models in the literature meant to coordinate the reverse supply chain. The incentives used are *quantity, time, quality and price/deposit-refund.* However, the relation of the models with the contractual models existing in the forward supply chain literature is limited. In this respect, references to the two-part tariff contract are made by Tirole (1988) and Debo et al. (2002), while Dobos and Richter (2004) look at EOQ and buy-back costs in a production-recycling system and Mostard and Teunter (2006) analyze the newsboy problem with resalable returns. More recent researches have been made by Shi and Bian (2009) which analyze the aspects of revenue sharing and quantity discount contracts on closed loop supply chain and Wang (2009) which studies the coordination with revenue sharing contract under disruption. The price/deposit refund incentive, with influence on the quality, quantity and timing of the returns, seem to be the most preferred policy in terms of the total cost of accomplishing disposal reduction. Papers that focus on deposit refund incentive are Palmer and Walls (1997), Guide and Jayaraman (2000) and Savaskan Van Wassenhove (2006). Practical approaches can be found in Raymond (2001) on car batteries and tires deposit refund and Krikke et al. (2008) on automobile refund systems.

Methodology approach

A *game theoretic model* has been analyzed by Singer et al. (2003), with focus on quality of the disposable items and by Hu et al. (2002) with attention to cost minimization in the case of multi-time-step, multi-type perilous waste management. The *simulation approach* has been applied by Kara et al. (2007) on the collection of end-of-life appliances with focus on collection costs.

Demand approach

The *deterministic* approach has been studied by Koh et al. (2002), Dobos (2003), Dobos and Richter (2004) and Mukhopadhyay and Setoputro (2005).The *stochastic* approach can be found in Minner and Kleber (2001), Hahn et al. (2004) and Wang et al. (2007).

Time horizon

The *one period* approach with focus on order quantities is studied by Vlachos and Dekker (2003), Ferrer (2003), Robotis et al. (2005) and Zikopoulos and Tagaras (2007). The *two period* model is analyzed by Majumder and Groenevelt (2001) and Webster and Mitra (2007). The *multi period* setting is approached by Kiesmuller and Minner (2003) and Debo et al. (2005).

6. *Conclusions and research directions*

In line with the objectives of this research, the paper (1) reviews the contracting literature offering a classification of coordination contracts and models presented in the literature, (2) appreciates the different types of contracts and their applicability and (3) proposes two classification schemes of forward supply chain and reverse supply chain based on the level of detail adopted in setting and analyzing a specific contract/model. These have been investigated and described in detail through sections 2, 3 and 4.

The outcome shows that where some research has been made on achieving coordination in reverse logistics, the reverse supply chain contracting literature is still far behind of the coordination by contracts research made within the forward supply chain. Although many models have been proposed, there seem to be no direct link to contract applicability in the manner they are applied on the forward supply chain. Most of the references considered for the classification of coordination within reverse supply chains focus on simple 1-1 structures with less attention paid to multi-echelon settings. Furthermore, while simulation approach has been considered to test the

coordination models, fuzzy theory and graph theoretical model are theories not considered for applicability on reverse logistics.

It has been observed that the forward supply chain literature presents a high volume of work on contract applicability under models with both specific and more relaxed assumptions. The level of detail varies from very simple models to very complex ones where coordination among multiple actors at different levels of the supply chain can be achieved through contract implementation. Contrary to forward logistics, reverse logistics is a relatively new area for researchers and the analysis of contract implementation among supply chain members is definitely worth increasing attention both in theory and practice, with specific attention to be allocated to the fields covered by contracting literature on reverse supply chain versus the fields covered by forward supply chains as results from Figure 7 and 9.

Regarding the findings of this research a parallel can be made between the existing literature on coordination contracts and further research directions as visualized in Figure 11, where the existing literature refers to the evolution of contracting literature reflecting present situation and further study refers to possible ways of extending the literature through future research.

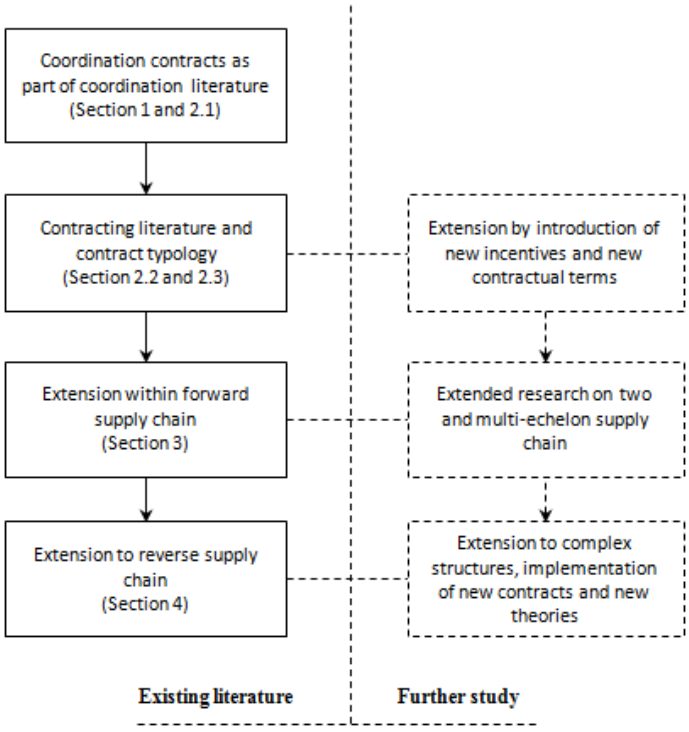


Figure 11. Evolution of contracting literature versus extension possibilities *(personal contribution)*

When it comes to contract typology, the literature can be extended to include:

- Contracts based on incentives less or not yet considered by researchers such as time and information sharing and/or
- The introduction of new contractual terms such as the effort made by the participants or compensations between multiple members (i.e. multiple retailers).

This can generate further research on simple forward supply chain along with extended research on multi-echelon settings (i.e. the applicability of different contractual agreements between sets of members of the same multi-echelon supply chain or the implications brought to the bottom line of a member that decides not to participate to the cooperative supply chain game). The literature on reverse logistics can be extended by focusing the attention on complex closed and open loop supply chains as well as 3PRL. Although there is considerable number of papers proposing models with the scope of achieving coordination within reverse settings, less attention is paid to the implementation of existing contracts and the applicability of new theories (i.e. fuzzy theory).

Contracting literature is an interesting area of research with opportunity for further investigations on both forward and reverse logistics. However, with the rapid extension of different forward supply chains and with the increasing focus on recycling and reverse logistics, the field of research seems to remain far behind the progress made by the industry.

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