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INVITED SURVEY

A selective survey of game-theoretic models of closed-loop supply chains

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Abstract
This paper surveys two key issues in closed-loop supply chain (CLSC) research: return functions and coordination mechanisms. The return function provides the rule according to which end-of-life/use products are returned to a collector. The coordination mechanisms consist of the adoption of a certain mechanism (e.g., a contract) to align the closed-loop supply chain members' objectives. We describe latest thinking in these two major CLSC-related fields and suggest future research directions to be undertaken.

Keywords Closed-loop supply chain · CLSC game · Survey · Return functions · Coordination mechanisms

1 Introduction

A supply chain (SC) is defined as a set of entities (organizations or individuals) directly involved in the upstream and downstream flows of products, service, finances and/or information from a source to consumers (Mentzer et al. 2001). Accordingly, supply chain management (SCM) consists of a set of practices, processes and mechanisms through which firms enter in long-term agreements and manage the related flows having an SC perspective instead of a single-firm perspective (Lambert 2008). Firms belonging to an SC set their strategies to maximize the total payoff and look for Pareto-improving solutions (Colicev et al. 2016). As displayed in Fig. 1, an SC consists of a focal company, who is the SC leader, while upstream and downstream suppliers are organized in tiers (Lambert and Cooper 2000).

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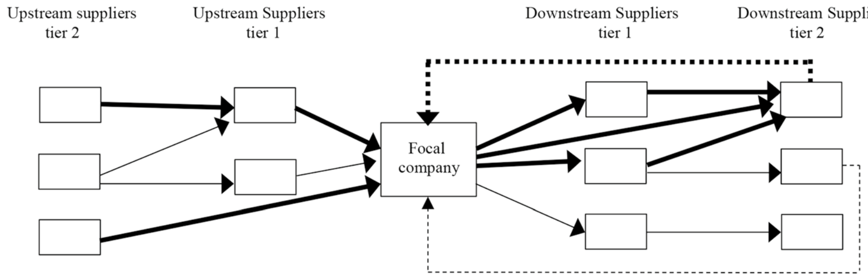

Fig. 1 Typical supply chain structure with managed-process links (bold lines), monitored-process links (non-bold lines), forward flows (continuous lines) and backward flows (dotted lines)

When an SC integrates and coordinates the backward flow of goods along with the forward flows, it takes the form of a closed-loop supply chain (CLSC). While a traditional SC focuses on the management of forward flows going from upstream (e.g., suppliers of raw materials) to downstream agents (e.g., consumers), a CLSC also manages the backward flows from the downstream to the upstream suppliers. Product returns from consumers to producers or to another party characterize the main difference between a classical supply chain, which focuses on forward flows of goods, and a CLSC.

A CSLC integrates forward and reverse activities into a single system, to pursue environmental objectives (Krikke et al. 2004), create new economic opportunities, and provide competitive advantages to participants (Ferrer and Whybark 2001). Forward activities include new product development, product design and engineering, procurement and production, marketing, sales, distribution, and after-sale service (Tabolt et al. 2007). Reverse activities refer to product acquisition, reverse logistics, points of use and of disposal, testing, sorting, refurbishing, recovery, recycling, remarketing, and reselling (Guide and Van Wassenhove 2009; Fleischmann et al. 2001). The integration of these activities makes it possible to recover a residual value from used products, thereby reducing the amount of resources needed for production while also conserving landfill space and reducing air pollution (Atasu et al. 2008).

There are economic and non-economic reasons for focal companies to establish CLSCs. First, the backward activities imply that goods reaching their end-of-use or their end-of-life stage are returned to the focal company and used for remanufacturing or recycling purposes. For example, Kodak was used to carefully manage the return process of single-use cameras because the mechanical parts could be used seven times in the production process, thus generating important cost savings. Second, the focal company offers a collection service to consumers who might have difficulties in getting rid of end-of-use/life goods. For example, disposing of a fridge can be problematic for consumers; therefore, a return process that is directly managed by the manufacturer is appreciated by consumers. Third, consumers who return goods are most likely interested in repurchasing as well a new good to continue to satisfy their needs. Therefore, returns generate demand on the top of cost savings.

There are also non-economic motivations for a focal company to manage the return flows. By managing the return flows, the focal company makes sure that both end-of-use and their end-of-life goods are not disposed-off in the landfill; therefore, the CLSC mitigates the negative environmental externalities due to its business. Further, governments can also establish some specific collection targets by charging some fees when such targets are not achieved. Since the backward flows require the implementation of some atypical processes (e.g., collection, refurbish, inspection, etc..), the focal company needs to offer more jobs to its community (e.g., Dell-Reconnect project), thus also achieving some social benefits. Finally, managing the collection process allows the focal company to avoid that competitors collect their products, acquire the operational and economic values out of the returns, and use the returns to gain positions especially in the second-hand market.

This paper surveys the game-theoretic literature in closed-loop supply chains (CLSCs), with a focus on two elements: (i) the return function, that is, the process by which past-sold products are returned to one member of the supply chain for remanufacturing or recycling, and (ii) the coordination mechanisms put forward by the CLSC members to improve their payoffs.

The first focus of this survey is based on the various return functions used in the CLSC literature. The return flow has been modeled as an exogenous (deterministic or stochastic) parameter, a control variable, or a function of some decision variables, in both static and dynamic settings. Independent of the return approach that is used, closing the loop is beneficial whenever producing with used components is less costly than manufacturing with new materials (Savaskan et al. 2004). Otherwise, the government may intervene to reduce the environmental damages resulting from products ending up in nature. Several empirical works and case studies (see, e.g., Fleischmann et al. 2002; Tabolt et al. 2007) have already highlighted the relevance of CLSC for business and government. The reviews in Fleischmann et al. (1997), Dekker et al. (2004) and Atasu et al. (2008) report on what has so far been achieved and on the issues still needing to be addressed. Regarding government intervention, Pazoki and Zaccour (2019) introduce a mechanism to promote product recovery and environmental performance, which combines different forms of regulation, i.e., taxes and subsidies, and targets for collection, recycling, and remanufacturing. Regulation often takes the form of extended producer responsibility (EPR), implying that the SC's activities go beyond producing and selling to include the reverse flows. Pazoki and Zaccour (2018) compare the economic and environmental performance of various rules for the sharing of physical and financial responsibilities among the partners in a CLSC, to provide the regulator a tool to simulate the impact of different feasible policies.

The literature distinguishes between two types of returns. End-of-use returns refer to reverse flows of goods that still have some residual value but no longer satisfy the consumer's needs. (Think of returning your still-functioning iPhone t to buy an iPhone $t+1$.) Goods returned at end-of-use can be either remanufactured or refurbished for sale as used goods in, e.g., domestic secondary market or in developing countries' markets. By contrast, end-of-life returns have no residual value; therefore, no further operations can be performed to restore their functionality for reselling. Rather, the returns allow manufacturers to exploit recycling opportunities;

Table 1 List of journals

Journal	Number of papers
International Journal of Production Economics	23
European Journal of Operational Research	16
Journal of Cleaner Production	11
Transportation Research	5
Annals of Operations Research	4
International Journal of Production Research	4
Journal of Operational Research Society	2
Management Science	2
Omega	2
Computers and Operations Research	1
Dynamic Games and Applications	1
International Transactions of Operations Research	1
Annals of Dynamic Games	1
Total	73

otherwise, these products are discarded in landfills. The returns are resold either as new or used/refurbished/reconditioned goods if they are end-of-use returns, or they are recycled to save on virgin materials in production.

The second focus of this survey is CLSC coordination in the presence of forward and backward flows. The typical framework involves first determining the outcomes of a noncoordinated CLSC (a benchmark case) and next to design and implement a mechanism that is Pareto-improving. Consequently, the supply chain as a whole is also better off. In this sense, we follow Cachon (2003), who defines coordination as "...contracting on a set of transfer payments such that each firm's objective becomes aligned with the supply chain's objectives." The literature has proposed several mechanisms: contracts (e.g., revenue-sharing contract, vendor management inventory), cooperative green activities programs, government subsidies, incentive strategies, per-return and two-part tariff incentives (e.g., incentives based on the collector's performance), and combinations of reward–penalty mechanisms.

To further clarify the universe of this survey, we stress that for a paper to be included, it must satisfy the following three conditions: (i) it explicitly specifies a return function (which can be exogenous or endogenous) and considers forward and backward flows; (ii) it includes at least two firms that exist in at least two layers of the CLSC (typically a manufacturer and a retailer, or a supplier and a manufacturer), with the players having interdependent payoffs, that is, they are involved in a game; and (iii) it includes a mechanism that aims at partially or fully coordinating the CLSC. Table 1 gives the list of journals and the number of papers in each of them that meet the above criteria.[1]

[1] We were somehow surprised that no papers were found in some operations research journals. To be on the safe side, we double checked by searching each of the following journals individually : *Manufacturing and Service Operations Management, Decision Science, Production Planning and Control, Transportation Science, 4OR, Operations Research, Production and Operations Management* and *OR Spectrum.*

We believe that our survey provides a distinctive contribution with respect to the available literature reviews in San and Pujawan (2012), Souza (2013), Aravendan and Panneerselvam (2014), Guo et al. (2017), and Sundari and Vijayalakshmi (2016). San and Pujawan (2012) divide the literature into two subsets of papers dealing with managerial aspects (leadership and organization, strategy and policy, performance assessment, and business) and technical aspects (networking design, inventory management, production planning, and capacity planning), respectively. Souza (2013) does a review based on strategic and tactical decisions, taking a close look at the models' assumptions and results. Strategic decisions refer to, e.g., the motivations for remanufacturing, the design of ad-hoc programs such as trade-ins and leasing, the role of take-back legislation, networking and incentives. Tactical decisions have focused on used-product acquisition strategies and product disposal decisions. Aravendan and Panneerselvam (2014) and Sundari and Vijayalakshmi (2016) survey the models proposed in CLSC that use optimization tools like mixed-integer linear programming, genetic algorithms and tabu searches. Govindan et al. (2015) provide a descriptive survey, identifying the major areas of research and publication. Guo et al. (2017) describe CLSC papers based on contracts.

In Table 2 in the "Appendix", we characterize all reviewed papers in terms of the following: (a) the type of game (e.g., deterministic, two stages, etc.); (b) the CLSC structure; (c) the player in charge of collection; (d) the decision/control variables; (e) the coordination mechanism; (f) the main focus point of the paper; (g) the presence or absence of competition at any tier of the CLSC; and finally (h) the equilibrium concept. This table allows the reader to quickly scan the main features of a paper and to contrast the various contributions. We display all CLSC configurations explored in the literature in Fig. 2 and link each configuration to the papers surveyed in Table 2 in the colon "CLSC structures (figures)".

The rest of the paper is organized as follows. Section 2 surveys the return functions, and Sect. 3 reviews the coordination mechanisms. Section 4 concludes with some suggestions for future investigation in strategic CLSCs.

2 Return functions

The return function is a key ingredient of the CLSC model. It specifies the backward flow of end-of-use/life products, and is at the heart of the coordination mechanism used by firms to align their objectives. Before proceeding further, we make the following:

Remark 1 Some consumers are not sure of the value of some products at the time of purchase, and will return them later if they do not fulfill their expectations. The literature and practice refer to these returns as false failure returns (FFR). These returns are defined as products with no functional or cosmetic defect but that are nonetheless returned by consumers (Xu et al. 2015). Consumer returns amount to more than \$100 billion each year in the USA (Shear et al. 2002), and FFRs account for 80% of these (Lawton (2008). Typically, the retailer accepts these returns and resells them at a discount. The literature has often treated these returns as stochastic, which typically follows from the fact that consumers are not initially sure about the product value, and it has proposed mechanisms to handle them, e.g., set a return deadline. Also, FFRs give rise to interesting coordination problems in supply chains; see, e.g., Xu et al. (2015), Chen (2011), and Yang et al. (2017). We do not cover this literature per se because of the absence of the remanufacturing/recycling aspect.

The game-theoretic CLSC literature has modeled the return function either as an exogenous parameter, a decision variable, or a function of some decision variable(s).

2.1 Exogenous returns

Some papers assume a given return rate to measure the product's backward flow. In this approach, mainly selected for analytical tractability, the CLSC chain is passive, that is, it does not incentivize consumers to bring back their used products. Note that some contributions start by analyzing, as a benchmark, the case of passive returns, and then consider active (or incentivized) returns. The simplest version of an exogenous return function is provided in Xiong et al. (2013), where the backward flow is measured by $rq_{\mathcal{N}}$, where $q_{\mathcal{N}}$ is the quantity of new product sold previously, and r is the given return rate. Ma et al. (2013) differentiate between two types of consumers: those who keep the products and those who replace them when they become obsolete. A given proportion of replaced units make their way to the retailer or e-retailer from whom consumers purchase their new products. Although these two sellers are structurally different, the authors assume an identical return rate. Ramani and De Giovanni (2017) and De Giovanni and Ramani (2018) distinguish between returns that can be refurbished and resold and those that are sent to the manufacturer for recycling opportunities.

Chuang et al. (2014) look at the collection structure that a manufacturer should adopt, i.e., collecting by itself, or let the retailer or a third party do the job. Their results show that the manufacturer's choice will depend on the degree of economies/diseconomies of scale in the collection operations. Mitra and Webster (2008) consider a two-period game. In the first period, a manufacturer sells the product, and in the second period it competes against a collector in the product returns market. Yoo and Kim (2016) propose a return function of the form $r = r_0 + r_1 I$, where r_0, r_1, and I are parameters referred to as the passive return rate, the active return rate, and the incentive, respectively. Here, the final outcome depends on the incentive, which, however, is not a decision variable. Similarly, Sheu (2011) considers a return rate and a related percentage of recyclable returns as parameters, whose values can be determined by a regulator. In such a case, these parameters can be seen as mandatory targets.

2.2 Returns as a decision variable

Most of the literature determined the returns (or the return rate) endogenously. In a seminal paper, Savaskan et al. (2004) assumes that the return rate is a function of collection efforts E, which takes the form $r = \sqrt{\frac{E}{\eta}}$, where η is a scaling parameter. Equivalently, we have $E = \eta r^2$. The centralized profit function is given by

$$\Pi = (\alpha - p)(p - c + r\Delta) - E,$$

where p is the product's price, Δ the return residual value, c the unit cost, and α a positive parameter. Substituting for E, we get the following optimization problem[2]:

$$\max_{p,r} \Pi = (\alpha - p)(p - c + r\Delta) - \eta r^2.$$

Different options for collecting the used products are contemplated by a manufacturer, namely, collecting itself, or subcontracting this operation to the retailer or to a third party. Three leader-follower games are analyzed, with the manufacturer always acting as leader, and one centralized CLSC. Comparing the equilibrium outcomes, the authors conclude that the best option is to let the retailer, who is the CLSC agent closest to the consumer, be in charge of collecting used products. We shall refer to the model in Savaskan et al. (2004), which has been adopted/adapted in several studies, as the SBW model.

Savaskan and Van Wassenhove (2006) extend the SBW model by including competition at the retail level. When the manufacturer collects, the chain profits are driven by the impact of scale of returns on the collection efforts. When an indirect reverse channel is adopted, that is, when the manufacturer subcontracts collection to the retailers, then the supply chain profits are driven by the competitive interaction between retailers. Hong et al. (2015) extend the SBW's framework by letting the demand, which is the basis for future returns, depend not only on price but also on advertising. Wu and Zhou (2017) extend the SBW model to examine the impact of supply chain competition on the strategic choice of the collection system. The main takeaway is the following: even if the supply chains are *ex-ante* symmetric, an asymmetric equilibrium can emerge, in which one chain adopts a retailer-managed collection, while the other opts for manufacturer-managed collection. Further, Huang et al. (2013) extend the SBW model by letting a retailer R and a collector C compete for the returns, given by $r_R = \sqrt{\frac{E_R - \varphi E_C}{\eta}}$ and $r_C = \sqrt{\frac{E_C - \varphi E_R}{\eta}}$, where φ denotes the intensity of the efforts to attract returns. These return functional forms have also been used in Liu et al. (2017). Zhao et al. (2017a, b) consider a CLSC in which both a manufacturer and a retailer collect returns from the market, with their efforts given by $E_M = \frac{\eta(\varphi r_R^2 + r_M)}{1-\varphi^2}$ and $E_R = \frac{\eta(\varphi r_M^2 + r_R)}{1-\varphi^2}$. Then, each firm determines its own optimal

[2] Most of the papers reported in this section draw on Savaskan et al. (2004) and typically maximize one or more objective(s) with respect to the return rate. Needless to say that, throughout our paper, some contributions could have been classified otherwise, but any choice can be questioned and ultimately a decision must be made.

return, when a third-party logistics (3PL) can also alternatively collect for the retailer. Jena and Sarmah (2014) use the SBW's model to investigate competition at the manufacturer level. In this tier, the manufacturers decide their own return rate $r_j = \sqrt{\frac{E_j}{\eta}}$, $j = 1, 2$ but without considering the direct influence of competition as in Huang et al. (2013). Zu-Jun et al. (2016) retain a three-echelon CLSC (one manufacturer, one retailer, and two recyclers), study different configurations, and discuss how cooperative strategies can lead to win–win outcomes for all parties involved.

Choi et al. (2013) use the return function in SBW to investigate who among a manufacturer M, a retailer R, and a collector C should be the CLSC leader. They show that the best option is to give the leadership to the retailer. The return rates are then ordered as follows: $r_R > r > r_M > r_C$. Panda et al. (2017) extend the return function proposed in SBW by accounting for corporate social responsibility (CSR). One result is that when the manufacturer is socially responsible, the return rate is higher. Wang et al. (2015) adopt the return function in SBW, with the government implementing a reward-incentive mechanism. They obtain that the collector sets the return rate at the desired target $\widetilde{r}$.

Wei et al. (2015) allow a retailer to determine the return rate in a model à la SBW. The equilibrium return rates are characterized in terms of power (leader or follower) and information (symmetric or asymmetric). Ma et al. (2018) follow the same structure, that is, the retailer optimally determines the return rate (namely, the recycling rate) in relation to the competitive environment and the coordination mechanism adopted by the CLSC. Instead, Li et al. (2014) allow a collector to determine the optimal return rate using the SBW model. The returns are influenced by the collector's performance, which can be either high or low, as well as by the presence of an extended producer responsibility. Similarly, Ma et al. (2017) add retailer's advertising to the SBW model and obtain that this change does not affect the return preferences. Modak et al. (2018) add product quality to the SBW analysis, and find that a third party's involvement in the used product collection is always disadvantageous. In a two-period model with the collection taking place in the second period, Wei et al. (2018) show that a higher collection rate is obtained when both the manufacturer and the retailer collect. More precisely, we have $r_{M\&R} > r_M > r_R$.

In Wu and Kao (2018), there are two players, namely, an original equipment manufacturer (OEM) and an independent remanufacturer (IR). The OEM's product quality affects not only this player's cost, but also the IR's cost. The IR believes that the returns' quality λ is uniformly distributed between 0 and Q, where Q is the quality of a new product. Then, the IR decides on the quantity to collect according to λ and the marginal remanufacturing cost $c_{\mathcal{R}}(Q - \lambda)$. In Hong et al. (2017), a licensor (a manufacturer who can produce new and remanufactured products) and a licensee (who can only remanufacture the licensor's products) compete through their collection efforts. Their respective return rates are given by $r_i = \sqrt{\frac{E_i - \varphi E_{3-i}}{\eta}}$, $i = 1, 2$ where φ is the competition intensity and η a scaling parameter. Xie et al. (2017) adopts a return rate à la SBW, that is, $r = \sqrt{\frac{E}{\eta}}$, while however letting $E = \eta e^{\phi_R}$, where η is a scaling parameter and ϕ_R is the revenue-sharing contract parameter for reverse logistics.

Taleizadeh and Moshtagh (2018) propose a return function for both new ($\mathcal{N}$) and remanufactured ($\mathcal{R}$) products that depends on the acceptance quality level q_k with $k = \mathcal{N}, \mathcal{R}$, and takes the form $r_k = D_k g_k k e^{-f q_k}$, where D_k is the exogenous demand and f_k, g_k are scaling parameters. Accordingly, higher quality levels indicate a lower consumer willingness to return the product and, thus, lower returns. Hu et al. (2016) look at the impact of different contractual arrangements on the return rate, but with a major difference from previous contributions, in that consumers exhibit strategic recycling behaviors. Hong and Yeh (2012) use the same return function as in SBW and compare the results of two scenarios. In the first scenario, the retailer collects and the manufacturer cooperates with a third-party firm to handle used products. In the second, a third-party firm is subcontracted by the manufacturer for the collection work.

In Maiti and Giri (2017), the retailer collects the used products from consumers and through an exchange offer, and replaces a fraction of the collected used products by new ones. Essentially, the retailer decides how many units of used products should be returned by consumers to obtain one new good in exchange. Wang et al. (2017, 2018a, b) and Zhao et al. (2017a, b) use the same two-way approach to collecting as in Maiti and Giri (2017), with the return rate being a control associated to the manufacturer, the retailer, and the collector, respectively.

2.3 Returns as a function of decision variables

Another stream of research modeled the return flow as a function of the CLSC's control variables. In the next subsection, we distinguish between linear and nonlinear return functions.

2.3.1 Linear return function

A linear return function that encompasses all models proposed in the literature can be expressed as follows:

$$r = r_0 + r_1 I - r_2 I_C + r_3 E + r_4 \omega + r_5 V + r_6 S + r_7 A - r_8 L \qquad (1)$$

where I is the incentive given by the collector to the consumer, that is, a rebate on the price of the new product in case of repurchasing, or on the acquisition price; I_C is the competitor's incentive; E the collector's acquisition efforts; ω the warranty period; V the purchased volume; S the backward service efforts; A the advertising efforts; and L the lean program efforts. The parameter r_0 is the passive return rate, while parameter $r_z, z = 1, \ldots, 8$ is the returns' sensitivity to the corresponding variable.

A few papers considered the acquisition price I in (1) to be the unique endogenous driver of the returns, i.e., $r = r_0 + r_1 I$; see, e.g., Kaya (2010), Yoo and Kim (2016), Huang and Wang (2017a, b, c). These papers differ in the value given to the non-incentivized returns r_0 (zero or strictly positive, with some considering both cases in turn), and in terms of who is making the decision (manufacturer, remanufacturer, or collector). Govindan and Popiuc (2014) retain a returns rate of the form $r = r_1 \frac{I}{I_{\max}}$, where $I_{\max}$ is an exogenous incentive that consumers seek to receive.

Typically, $I < I_{\max}$ and, consequently, $r \in (0, 1)$. Heydari et al. (2017, 2018) use the Govindan and Popiuc (2014) return function in a CLSC in which the retailer decides on I. A similar return function is used by He (2015) where I is the acquisition price (incentive) to be determined either by a manufacturer or a collector (supplier).[3] In Zhao and Zhu (2017), the manufacturer offers an acquisition price to the retailer for each collected unit, and accordingly, the retailer sets the acquisition price to the consumer. To account for the fact that not all returned products are remanufacturable, the model is stochastic. Additionally to the incentive, Xie et al. (2018) include the production volumes and the backward flow service as determinants of the returns, that is, $r = r_1 I + r_5 V + r_6 S$.

A series of contributions allow for competition in acquisition prices. In Wang et al. (2017), the returns acquired by the manufacturer take the form $r = r_0 + r_1 I_M - r_2 I_C$, where I_M is the incentive (acquisition price) offered by the manufacturer to the consumers, and I_C is the incentive (acquisition price) offered by the collector. (When the manufacturer outsources the collection to a retailer, I_M is replaced by I_R.) Taleizadeh et al. (2018) propose a return function that depends on the acquisition price and the collection efforts. A retailer and a 3PL compete in the same collection market, with their return functions being specified as follows:

$$r_R = (1 - \varphi) r_0 + r_1 I_R - r_2 I_{3PL} + r_3 E_R,$$
$$r_{3PL} = \varphi r_0 - r_2 I_R + r_1 I_{3PL} + r_3 E_{3PL},$$

that is, own returns are increasing (decreasing) in own (competitor's) incentive, and increasing in own effort to attract returns. A similar approach is taken by Taleizadeh and Sadeghi (2018), where two competing CLSCs compete to acquire end-of-use products.

Other papers have assumed that the CLSC members do not provide any incentive to consumers to return their products, but let the returns depend on another variable. De Giovanni and Zaccour (2014) retained a return function given by $r = r_3 E$, where E is the collection efforts, that is, a green activity program to induce consumers to return their end-of-life products. Similarly, in a two-period model, Ramani and De Giovanni (2017) specify the return function as $r = r_0 + r_7 A$. In Giri et al. (2018), the return function depends is given by $r = r_0 + r_4 \omega$, where the returns can be either refurbished or remanufactured. Finally, Genc and De Giovanni (2018a, b) adopt the form $r = r_0 - r_8 L$, where L are the investments in lean-led programs. As such programs increase the product quality, the returns are decreasing in L.

2.3.2 Non-linear return function

Another (rather tiny) stream of research has assumed a nonlinear return function. In a two-period game, Genc and De Giovanni (2017) let the returns be given by $r = \frac{\eta p}{Q}$. The first-period purchasers' decision to return the good in the second period depends

[3] He (2015) also suggested an alternative return function taking the form $\widetilde{r} = \widetilde{r}_0 I^{\widetilde{r}_1}$ and show that their overall findings hold.

on the price, p, and the product quality, Q. Price is a proxy of the return residual value: the higher the price, the higher the refund the consumer gets and the higher the return rate. Conversely, the higher the residual quality that the goods have in the second period, the lower the return rate will be. Zhou et al. (2017) consider a return flow that depends on the prices set by a qualified recycler and an unqualified recycler. They identify seven possible price-competition regions in which the return flows take different shapes.

In Gan et al. (2017), the return function is given by $r = \eta I^g$, where $\eta > 0$ is a scaling parameter and $g \in [0, 1]$ measures the return curve steepness. Saha et al. (2016) adopt the functional form $r = 1 - \frac{\eta I_0}{I}$, where I_0 is the minimum acquisition price at which consumers start returning products.

Following Kaya (2010), Chen et al. (2018) model the returns as a function of the acquisition price and the retailer's markup, $r = \frac{1}{1-t} d I_R^\sigma$, where d is the rate of conversion of recycled products into new products, σ is the price elasticity for recyclables, t is the consumers' environmental awareness, and I_R is the acquisition price that retailers pay to consumers. The latter takes the form $I_R = (1 - \beta) I_M$, where β is the retailer's markup and I_M is the acquisition price that the manufacturer pays to the retailer, where both β and I_M are decision variables. In a two-period model, Miao et al. (2017) assume that consumers are heterogenous in their product's valuation, with their willingness-to-pay θ being uniformly distributed between zero and one. Denoting by s the trade-in subsidy given by the government, by p_t the trade-in price given by the manufacturer, and by $p_{\mathcal{N}}$ the price of the new product, the utility in the second period is given by $U = \theta - p_{\mathcal{N}} + I + s$. The returns are then computed as $r = 1 - \kappa$, where $\kappa = \max\left\{\frac{p_{\mathcal{N}} - I - s}{1-\delta}, p_{\mathcal{N}}\right\}$ and δ is depreciation rate.

2.4 Dynamic returns

In the above literature, an implicit (sometimes explicit) assumption is that a static or two-period model can well approximate returns flows. In a static model, the assumption is that the market is at its steady-state value and that returns can be computed concomitantly with demand. In a two-period game, the returns in the second period are a fraction of the quantities sold in the first period, and this simple over-the-two-period link is supposed to be a good representation of the dynamics of returns.

Few authors have modeled the returns as a state variable in an infinite-horizon dynamic game. In De Giovanni and Zaccour (2013), the returns are given by the following linear-differential equation:

$$\frac{dr(t)}{dt} = \dot{r}(t) = \eta E(t) - \zeta r(t), \quad r(0) = r_0,$$

where $E(t)$ is the collection effort (green activity program) made by the manufacturer, ζ is a decay parameter (consumers' forgetting rate), and r_0 is the initial returns. In De Giovanni et al. (2016) and De Giovanni (2016), both the retailer and the manufacturer invest in the collection effort, leading to

$$\frac{dr(t)}{dt} = \dot{r}(t) = \eta_M E_M(t) + \eta_R E_R(t) - \zeta r(t), \quad r(0) = r_0.$$

In this model, the returns are a sort of a public good, and the question is how to prevent free-riding. De Giovanni (2014)—see also De Giovanni (2017)—models a dynamic return function that depends on the green goodwill $G(t)$, which evolves à la Nerlove and Arrow (1962), that is,

$$\dot{G}(t) = \eta_i A_i(t) - \zeta G(t), \quad G(0) = G^0,$$

where $A(t)$ is the advertising effort at time $t \in [0, \infty)$. The returns are a concave increasing function in the goodwill and specifies as $r(G(t)) = \eta\sqrt{G(t)}$.

De Giovanni (2018) adopts a nonlinear state equation à la Sethi (1983). More specifically, the return rate takes the form $\dot{r}(t) = \eta E(t)\sqrt{1 - r(t)} - \zeta r(t)$. Here, the collection effort targets, with marginal decreasing effect, non-environmentally concerned customers $(1 - r(t))$, who dispose the end-of-use/life goods in the landfill.

3 Coordination mechanisms

The coordination mechanisms that CLSC members adopt to align their objectives represent the second main concern in the CLSC literature. Coordination consists in implementing certain practices that improve, in a Pareto sense, the payoff of all parties involved in the CLSC. We review different mechanisms that have been used in the literature, i.e., per-return incentive, contracts, and incentives, as well as of government interventions and chain structure changes.

3.1 Exogenous per-return incentive

In this subsection, the per-return incentive given by one player to another to collect the used products and/or to consumers to bring back these products is assumed to be exogenously defined. We shall refer to this mechanism as ExPuI (for exogenous per-unit incentive). In a typical CSLC game involving one manufacturer and one retailer, the players' optimization problems are as follows:

$$\Pi_M = \max_{w} D(\cdot)(w + (\Delta - I^{ex})r(E))$$
$$\Pi_R = \max_{p,E} (D(\cdot)(p - w + I^{ex} r(E)) - E)$$

where Π_M and Π_R are the manufacturer's and the retailer's profits, respectively; $D(\cdot)$ is the demand function depending on the retail price p and possibly on other other decision variables; E is the effort to attract returns; w is the wholesale price; $r \in (0, 1)$ is the return rate, Δ is the returns' residual value and I^{ex} is the exogenous per-return incentive. The manufacturer, who is typically the chain leader, seeks to close the loop as far as $\Delta > I^{ex}$, while the retailer is willing to manage the returns when $I^{ex} r(E)D(.) > E$. If a 3PL collects, then it will be rewarded with the same per-unit payment I^{ex}.

In SBW, it is shown that such an exogenous incentive mechanism coordinates a CLSC when the retailer makes the collection, but is inefficient when the 3PL collects. A series of papers have proposed some modifications and extensions to this model. Ma et al. (2017) add the retailer's advertising to the SBW model and obtain the same results. Hong et al. (2015) extend the SBW model by accounting for the advertising effect on the demand function while using an ExPuI. They obtain identical results to SBW, that is, that CLSC members always prefer that the retailer collects. Wei et al. (2018) allow for green efforts to also influence the demand. The collection can be done by the manufacturer, the retailer, or both firms. When the ExPuI is given to the retailer, who exclusively manages the returns, then coordination is not possible. When both firms collect, the ExPuI raises the prospect of reaching coordination. Han et al. (2017) consider a model à la SBW with disruption in the returns. Their result is the same as in SBW, namely, that coordination is better achieved when the retailer does the collection.

De Giovanni and Zaccour (2014) extend the SBW models to a two-period setting, with the manufacturer offering an ExPuI to a retailer or a 3PL to collect. One takeaway from this paper is that, except for a small region in the parameter space, the manufacturer is better off collecting for itself, rather than giving an incentive to either of the other parties to do it. Saha et al. (2016) extend the SBW model to also consider the effects of a direct channel. The collector sets the acquisition price and receives an ExPuI from the manufacturer. Coordination turns out to be difficult to achieve as each firm (manufacturer, retailer, and 3PL) has an incentive to collect. In a CLSC formed by one manufacturer and one retailer, Genc and De Giovanni (2017) obtain a similar result, albeit with a different model, namely, that an ExPuI does not deliver coordination. Adding competition at retail layer does not change the result.

Ramani and De Giovanni (2017) model the case of the DellReconnect CLSC, in which Dell partners with a Goodwill agency to collect end-of-use/life electronics. The Goodwill agency collects the electronics and sells them on the market, which cannibalizes Dell's sales and hurts its profits. The authors obtain that Dell cannot coordinate the CLSC when it only offers an ExPuI for all products that cannot be resold in the secondary market after being refurbished and recycled. De Giovanni and Ramani (2018) explore a similar setting while distinguishing between resalable and recyclable returns. The manufacturer seeks to incentivize the collector to reduce the cannibalization effect by providing some services to consumers that lead to a higher demand and higher returns. Again, the result is that an ExPuI alone never coordinates a CLSC.

Yoo and Kim (2016) model a game between a manufacturer, a seller, and a collector as processes (or functions). The manufacturer offers an ExPuI, and the authors investigate several integration options (full and partial integration). They show that coordination cannot be achieved by an ExPuI, because the manufacturer prefers the integration with the seller, the seller prefers the integration of the manufacturer and the collector, while the collector prefers a fully decentralized CLSC. Maiti and Giri (2017) complement an ExPuI with an exchange program. The retailer collects from a different channel than the manufacturer's by offering an exchange program to consumers. The authors consider four modes of play, namely, Nash, manufacturer Stackelberg leader, retailer Stackelberg leader, and centralized CLSC. None of the decentralized cases leads to coordination, but a bargaining model does.

In Modak et al. (2018), the demand depends on price and quality, while the collection of used product for recycling can be done by either the retailer, or the manufacturer, or a third party. The authors show that involving a third party is never beneficial to the CLSC. They compute a threshold for the collection effort that determines which—the manufacturer or the retailer—can provide the best-quality product at lowest price. As the results point towards a channel conflict, they define a subgame-perfect equilibrium and alternatively offer a bargaining strategy to solve the conflict and distribute the profit surplus.

Taleizadeh et al. (2018) consider a CLSC in which a manufacturer gives an ExPuI to a retailer and a 3PL to collect products from the same market. The manufacturer decides whether to compete with the retailer in the new product market. This competition is profit-improving for the manufacturer, while the retailer benefits from it only when the manufacturer attracts a small number of consumers. By contrast, the 3PL is indifferent between the two scenarios. The manufacturer proposes a two-part contract complemented with a cooperative program to coordinate the CLSC. When each of these programs is used alone, coordination is never achieved. Another setup is considered, where the manufacturer supports the retailer's and the 3PL's collection efforts by lowering the wholesale price, and the two other firms give a fixed transfer to the manufacturer. Taleizadeh et al. (2018) show that this combination gives better coordination opportunities.

The two remaining papers look at coordination from a different perspective while maintaining an ExPuI. Zhao et al. (2017a, b) investigate coordination issues in a two-echelon fuzzy closed-loop supply chain. They use mechanisms based on information sharing to achieve coordination, while the incentive given to collectors is always fixed. Genc and De Giovanni (2018a, b) model a cost-advantage coordination mechanism based on lean programs. When a manufacturer invests in lean programs, the supplier's marginal production cost decreases accordingly, which affects pricing and sales. They show that a package composed of both operational and strategic lean investments always coordinates the CLSC.

The main conclusion of this subsection is that an ExPuI coordinates a CLSC only under some circumstances. In fact, there is valid conceptual reason for arguing that the incentive must be exogenously given. The use of an ExPuI has often been dictated by analytical tractability.

3.2 Endogenous per-return incentive

In the class of incentive mechanisms that aim to coordinate the CLSC, the endogenous per-return incentive (EnPuI) is probably the most popular scheme used in the literature. Basically, the collector receives a payment I^{en} for each unit collected back from consumers. In a typical CSLC game involving one manufacturer and one retailer, the players' optimization problems are as follows:

$$\Pi_M = \max_{w,I^{en}} D(\cdot)(w + (\Delta - I^{en})r(E)),$$
$$\Pi_R = \max_{p,E} (D(\cdot)(p - w + I^{en} r(E)) - E),$$

where I^{en} is a decision variable of the manufacturer. If a 3PL is involved, then it receives I^{en} per collected unit.

Assuming that the manufacturer is the agent most interested (or constrained by law) in collecting the used products, then the natural question is as follows: under what conditions is it in the best interest of the manufacturer to outsource the collection task to retailers and/or 3PLs? Put differently, what type of reverse channel is the best option for the manufacturer and the other CLSC's members? Intuitively, one expects the answer to depend on the cost structures of the different parties, the competitive environment, and on the interplay between the EnPuI and other decision variables, e.g., wholesale and retail prices, efforts to collect, etc.

Savaskan and Van Wassenhove (2006) is one of the first formal studies to investigate the interaction between decisions in the forward- and reverse-logistics channels and the implications on the CLSC's profits. They extend the SBW's model by still assuming that the decentralized collector (competing retailers only, no 3PL) receive a per-return incentive I, which is now endogenously determined. By choosing I, the CLSC can in principle eliminate double marginalization. One result in Savaskan and Van Wassenhove (2006) is that the EnPuI coordinates the chain when competition between retailers is pronounced, while it is inefficient in the opposite case: then, the CLSC prefers a direct collection system implemented by a manufacturer.

Wu and Zhou (2017) further extend the SBW model to a supply chain competition game in which each manufacturer supplies a per-return incentive, I, to its collector. If the competing CLSC adopts the efficient mode of retailer-managed collection, the manufacturer in the other CLSC also prefers retailer-managed collection if the downstream competition is not drastically intensified. This is always the case when the efficiency gain from remanufacturing is not significant. Otherwise, the manufacturer in the focal CLSC prefers to conduct the collection activity itself and the per-return incentive does not allow a CLSC to coordinate. Huang et al. (2013) propose a modified version of the SBW model, in which the manufacturer never collects, while the retailer and the 3PL compete on the returns. The manufacturer proposes a per-return incentive that depends on the returns' residual value and the average recycling price of returns. In this game, the manufacturer has two additional control variables given by the per-return incentive proposed to each collector. Huang et al. (2013) show that the existence of competing collectors and a dual per-return incentive make the manufacturer economically better off when the competition intensity is low. Instead, in all other cases, the manufacturer finds it convenient to coordinate with a retailer only.

Zhao et al. (2017b) consider a game in which the manufacturer and a collector (either a retailer or a 3PL) optimally sets the same control variables as in the SBW model. However, here, both firms collect products from the market. Coordination seems to be a difficult target when firms compete on returns. The configuration in which the incentive is offered to the retailer works better than the setting with a 3PL collecting. This is due to the direct effect that collection has on pricing strategies. Li et al. (2014) obtain an equivalent result: when competition for collection exists in different tiers, the collection carried out by a manufacturer–retailer configuration is always preferable to the manufacturer–3PL and retailer–3PL collection options.

Choi et al. (2013) use an EnPuI to induce both a retailer and a collector to invest more in the returns policy. They investigate who should be the leader in a CLSC when such an incentive is in place, demonstrating that coordination is very difficult:

the manufacturer and the retailer wish to be the leaders, while the collector prefers the retailer to be the leader. Therefore, they propose a two-part tariff and a revenue-sharing contract as mechanisms to coordinate the chain. They theoretically explain that these two contracts can coordinate the CLSC but without providing a formal proof.

Chuang et al. (2014) extend the SBW model by letting the demand be random. The collector can be either the manufacturer, the retailer, or a third party. In the two last cases, the collector receives an EnPuI. They show that if there are economies of scale in the collection cost, then the manufacturer manages the returns through a retailer; when there are diseconomies of scale, the manufacturer should collect for itself. This result also holds true when the return rate is endogenous. Panda et al. (2017) add a corporate social responsibility to the SBW model, that is, the manufacturer maximizes the profits, plus a social outcome deriving from the demand. Giving an EnPuI to a retailer can only partially coordinate the chain, with the degree of coordination being dependent on the convenience of being socially responsible. Complementing an EnPuI with a revenue-sharing contract allows the CLSC members to coordinate the chain while being CSR.

He (2015) explore two contracts to achieve coordination: a complete compensation contract, in which the manufacturer compensates the supplier for every unit recycled, and a partial compensation contract, in which the manufacturer only compensates for every unit over supplied. Both contracts are suitable to reduce the double marginalization effect and to coordinate the chain when the supplier faces considerable losses in the non-coordinated CLSC. In the latter case, these two contracts can be complemented by a two-part tariff composed of a wholesale price and a per-return payment. Through this integration, coordination is always reached, independent of the compensation scheme used by the CLSC.

Wang et al. (2017) investigate coordination in which a manufacturer outsources the collection through a retailer and competes against a collector to acquire the returns. Overall, this coordination mechanism helps the manufacturer to increase the returns and get better profits, as recycling is always better than not recycling. Nevertheless, the choice between collecting for itself or coordinating with a retailer depends on the industrial settings. The implementation of an EnPuI allows the retailer to charge lower prices, but coordination is only achieved under specific conditions.

In Huang and Wang (2017b), the return function depends on the acquisition price. Various CLSC settings are proposed, in which the collection can be managed by a manufacturer, a distributor, or a 3PL. Their findings show that the manufacturer always prefers a CLSC in which it collects and remanufactures, while the distributor prefers a setting in which it remanufactures. Consequently, this mechanism does not coordinate the CLSC. Gan et al. (2017) consider a game between one manufacturer, one retailer, and one collector acting in different time periods. When the product reaches the end-of-use stage, the collector collects and transfers the returns to the manufacturer according to an acquisition price. This mechanism allows firms to achieve coordination when the consumers show a high willingness to shift from a new to a remanufactured good. Otherwise, this EnPuI fails and should be complemented by other mechanisms.

In Chen et al. (2018), the manufacturer decides the acquisition price to be offered to a retailer. They show that a manufacturer acting as a Stackelberg leader and implementing an EnPuI yields higher outcomes than in a Nash game. This finding is reinforced when the worth-of-mouth effect and price sensitivity take on high values. In Li et al. (2014), the manufacturer gives an EnPuI to a collector, while the acquisition price depends on the optimal return rate chosen by the collector. The collector's operational performance can be either high or low, while the manufacturer can be subject to an extended producer responsibility law that limits its operations. The amplitude of these two elements determines the configuration that leads to coordination. In principle, the presence of a law makes the collector's type more visible, thus pushing the manufacturer to invest more, adopt new technologies, and expand the market.

Miao et al. (2017) also considers an EnPuI flowing from the manufacturer to the retailer. The retailer finds this incentive appealing and always opts for a chain configuration in which it exclusively manages the collection process by fixing the acquisition price and appropriating the EnPuI. By contrast, the manufacturer finds that such an EnPuI causes a loss of control in managing the returns process and a loss in profit. Consequently, coordination cannot be achieved here with an EnPuI.

Hong and Yeh (2012) consider two collection models. In the first, the retailer collects and the manufacturer cooperates with a third-party firm to handle used products. In the second model, a third-party firm is subcontracted by the manufacturer for the collection work. They found that the first model is not always superior to the second in terms of the return rate, manufacturer's profits, and channel members' total profits. However, when the third-party firm is a non-profit organization for recycling and disposal, the benefits are higher when the retailer collects than when a third party does it. Heydari et al. (2017) propose an endogenous incentive mechanism in which the manufacturer offers a certain recycling fee to the retailer to incentivize returns. Alternatively, the manufacturer can try to stimulate the returns by also offering a share of its present and future sales to the retailer. The findings show that when a retailer sets the incentive for consumers without the manufacturer's intervention, the CLSC underperforms. When the manufacturer incentivizes the retailer through a recycling fee, the CLSC always achieves coordination. When, instead, a share on present and future sales is offered, the retailer is not always better off and coordination can only be achieved under some conditions.

3.3 Contracts

Several types of contracts, e.g., buyback, revenue-sharing, cooperative advertising, and two-part tariff contracts, have been proposed in the CLSC literature. All these contracts were initially proposed in the context of supply chains. A buy-back contract allows a downstream firm to return unsold units to the manufacturer at the end of the selling season. A general CLSC game formulation is given below:

$$\Pi_M = \max_{w,u,I}\left\{u(w + (\Delta - I)r(E)) - C_M(u) - w[u - D(\cdot)]^+\right\},$$

$$\Pi_R = \max_{p,E}\left\{D(\cdot)(p + Ir(E)) - wu - C_R(E)\right\},$$

where u is the manufacturer's production quantity, $(u - D(.))^+$ is the unsold quantity that the retailer returns to the manufacturer, $C_M(u)$ the manufacturer's production cost, and $C_R(E)$ is the retailer's cost of the effort to collect end-of-life/use products.

Revenue-sharing contracts were initially introduced in the context of supply chain coordination. They aim at mitigating the double marginalization effect by removing the marginalization at the wholesale price level. In a CLSC, a generic formulation of the two players' optimization problems is as follows:

$$\Pi_M = \max_I \{D(\cdot)(p\phi + (\Delta - I)r(E))\},$$
$$\Pi_R = \max_{p,E} \left\{D(\cdot)(p(1-\phi) + Ir(E)) - C_R(E)\right\},$$

where $\phi \in (0, 1)$ is the revenue sharing parameter.

A stream of the literature deals with cooperative advertising (or green-effort) programs in which a manufacturer supports the efforts of a collector. (For comprehensive reviews of the literature on cooperative advertising programs in marketing channels and supply chains, see Aust and Buscher (2014) and Jørgensen and Zaccour (2014)). Typically, the players' optimization problems are defined as follows:

$$\Pi_M = \max_{w,I,B} \left\{D(\cdot)[w + (\Delta - I)r] - BC_R(E)\right\},$$
$$\Pi_R = \max_{p,E} \left\{D(\cdot)(p + Ir(E)) - wu - (1-B)C_R(E)\right\},$$

where $B \in (0, 1)$ is the support rate, that is, the percentage of the retailer's green efforts paid by the manufacturer.

Remark 2 In many of the papers reviewed in this section, the authors use more than one of the items highlighted above, or complement one with another coordinating scheme, e.g., quantity discount, two-part tariff. Consequently, our classification is far from being unique.

3.3.1 Buy-back contracts

Xu et al. (2015) propose three variants of a buy-back contract to coordinate the CLSC. They first analyze a classical case with a constant salvage value, showing that it fails to achieve coordination. Similarly, a differentiated buy-back contract that distinguishes between unsold and returned products does not coordinate the chain. Instead, a buy-back contract depending on the return deadline, τ, guarantees coordination, as it encourages the retailer to procure the optimal quantity and to offer a τ -dependent refund. Chen (2011) also uses a buy-back contract to coordinate a CLSC managing stochastic returns. The manufacturer decides the wholesale price under an uncertain consumer willingness to return. The uncertainty can be resolved by the retailer sharing some consumers return information with the manufacturer. In principle, the manufacturer is always better off when the uncertainty is resolved, while the retailer's profits turn out to be higher only when the manufacturer under-estimates the probability of consumers' returns. When the manufacturer offers a buy-back contract, the results are fully reversed. The manufacturer's profits decrease when the probability of getting returns is under estimated, while the retailer's profits turn out to be higher only when the manufacturer over-estimates the probability of consumer returns.

Taleizadeh and Moshtagh (2018) propose a buy-back program embedded in a vendor management inventory (VMI) contract in a four-echelon CLSC model. The manufacturer decides on the inventory levels to be kept at the retailer's location, implementing a full consignment contract for both new and remanufactured goods. They show that the manufacturer and the retailer are always economically better off with the consignment. The retailer benefits from the absence of ordering costs, while the manufacturer takes advantages of a larger lot sizing policy and lower replenishment cycles. By contrast, the supplier and the collector would prefer an integrated CLSC, as the acceptance quality level and the number of shipments could have a lower negative effect on the objective function. Yang et al. (2017) propose a refund incentive mechanism that a retailer can offer to two competing manufacturers based on a money-back guarantee mechanism. The retailer's convenience of providing an incentive fully depends on the returns' residual value and, in turns, is independent of the manufacturers' efficiency and performance. When the incentive is given to one manufacturer only, the competitor's profits and returns decrease. Finally, providing an incentive to both manufacturers is the best policy a retailer can implement, even if one manufacturer does not make any returns.

Yoo and Kim (2016) adopt a CLSC model à la SBW, with the difference that the return rate depends on the acquisition price. Later they investigate two coordination mechanisms. First, the CLSC can adopt a buy-back contract to seek coordination. Accordingly, the supplier can purchase the returns at a certain price. Second, the supplier can apply a quantity discount contract, which has an impact on the overall outcome of the supply chain. One result is that firms never achieve coordination, because in each framework only one firm sees its profits improved with respect to the decentralized non-coordinated scenario.

3.3.2 Revenue-sharing contracts

Govindan and Popiuc (2014) propose a revenue-sharing contract (RSC) mechanism in which a manufacturer shares the revenues either with a retailer in a two-echelon CLSC, or with both a retailer and a distributor in a three-echelon CLSC. In both instances, coordination is achieved through an RSC with exogenous sharing parameters. Similarly, Xie et al. (2018) use a combination of revenue sharing and support programs to coordinate the CLSC. Under a revenue-sharing contract, the retailer shares the revenues with the manufacturer, while in the support program, the manufacturer pays part of the retailer's service efforts. Both firms prefer the simultaneous adoption of both mechanisms, which makes it possible to reach coordination when both the sharing and support parameters are exogenous. Heydari et al. (2018) model an CLSC in which a retailer collects obsolete products from the market and sells them to a manufacturer, who remanufactures these items after inspection. The use of a per-return incentive creates some externalities that can be overcome by implementing an RSC. The firms share the revenues from reselling products to the market.

The RSC allows the retailer to mimic the rebate offered by a centralized CLSC. The findings suggest that complementing a per-return incentive with an RSC allows firms to coordinate the CLSC.

De Giovanni (2014) models coordination through a reverse RSC in which the manufacturer transfers an exogenous share obtained from collection to a retailer. Coordination highly depends on the administrative costs linked to the sharing contract. When administrative costs exist, coordination is difficult and reachable only when the share is low and the returns' residual value is high. Should the administrative cost be null, coordination opportunities substantially increase. Xie et al. (2017) model a coordination mechanism based on two sharing mechanisms: one based on forward flows, and one based on reverse flows. Both sharing parameters are determined by the manufacturer and, simultaneously, this configuration is complemented by an exogenous cooperative advertising program. Xie et al. (2017) show that the presence of a dual sharing contract mechanism does not necessarily lead to coordination, because increasing one of the sharing parameters reduces the manufacturer's profits while it increases the retailer's profits. At the same time, the double marginalization effect still persists.

Zhao and Zhu (2017) analyze a benchmark model with an exogenous per-return incentive that a remanufacturer supplies to a retailer. The retailer sets the acquisition price, while the manufacturer determines the wholesale price. Later, they propose a complex RSC. Zhao and Zhu (2017) demonstrate that there exists a pair of parameter values linked to the RSC through which coordination is possible, while they also highlight the effectiveness of government's subsidies in increasing the space for reaching coordination. Similarly, Han et al. (2017) complement a per-return incentive with an RSC, showing that the RSC always allows the firms to coordinate a CLSC when the retailer collects. Later, they extend the model to a returns-disruption scenario, showing that the manufacturer's preferences change. Coordination becomes more challenging due to the penalty associated to return disruption. Consequently, Han et al. (2017) show the conditions according to which the manufacturer prefers to collect itself, independent of using an RSC.

3.3.3 Cooperative green-effort programs

In De Giovanni and Zaccour (2013), the dynamic game involves one manufacturer and one retailer. The aim is to achieve coordination by implementing a cost-revenue-sharing contract. Differently from the literature, here, the retailer supports the manufacturer's green efforts by paying at time t a share $B(t) \in (0, 1)$ of the cost. The rationale for this support is that the manufacturer shares part of the remanufacturing advantages with the retailer, according to the exogenous sharing parameter, $\phi \in (0, 1)$. With a contract of the type $(B(t), \phi)$, the authors characterize the conditions under which coordination is achieved. De Giovanni (2017) models a CLSC setting in which a manufacturer incentivizes a retailer to advertise more to increase the stock of green goodwill by sharing a part of its revenues. The transfer occurs through the implementation of an RSC, where the sharing rule can be either exogenous or endogenous. When sharing is endogenous, coordination is never achieved, because the manufacturer sets a low share and the retailer would then prefer a non-coordinated setting. Adopting an exogenous sharing parameter increases the chances of coordinating the chain. Coordination takes place when the sharing parameter is fixed within a specific range of values.

Hong et al. (2015) propose a cooperative advertising program as well as a two-part tariff mechanism as coordination mechanisms to be compared to a classical per-return incentive. The cooperative advertising never allows firms to achieve coordination because a manufacturer prefers to collect the end-of-use product by itself, rather than paying a fraction of the retailer's advertising expenses. Instead, a two-part tariff mechanism coordinates an CLSC because it brings the retail price and the return rate to the same levels as a centralized chain.

3.3.4 Licensing contracts

Few papers dealt with coordination issues in the presence of licensing contracts, which typically involve a fixed fee and royalties to be paid by the licensee to the licensor.

The choice of a quality level by an OEM does not only affect its own production cost, but also the recovery cost of the IR. Technology licensing or R&D cooperation can help reduce the costs of both parties. Among other things, Wu and Kao (2018) investigate and compare the equilibrium outcomes of technology licensing with a licensing royalty and an R&D joint venture for technology codevelopment. Interestingly, they also extend their models to a dynamic setting, a move not often made in the CLSC literature. A comprehensive numerical analysis shows that the joint venture allows the CLSC to coordinate in the short run, while technology licensing improves the outcomes in the long run.

Hong et al. (2017) consider a two-period game involving a manufacturer (license holder) and a remanufacturer (licensee). The manufacturer produces new as well as remanufactured products. The remanufacturer collects used products from the same market as the manufacturer, but can only produce remanufactured goods. The authors look at the Cournot equilibrium outcomes of two licensing contracts (fixed fee and royalty). They obtain that the fixed fee contract dominates royalty licensing from the viewpoints of both the consumer surplus and environmental protection. The manufacturer's optimal licensing strategy is determined by a threshold of the fixed fee, below (above) which the manufacturer is better off using royalty (fixed fee) licensing.

3.3.5 Other contracts

De Giovanni et al. (2016) apply the concept of incentive strategy in a CLSC dynamic game. Incentive strategies are such that, at equilibrium, each firm is better off implementing its part of the vertically integrated solution (it could be any other solution agreed upon in a preplay arrangement), then switching to a noncooperative mode of play. In this context, incentive strategies are of the form "I behave cooperatively if the other firm also does so." De Giovanni (2018) applies the same concept to a spent-battery-recycling CLSC. When CLSC members face the constraints imposed by the battery sector, the incentive strategy mechanism allow firms to reach coordination when collecting and recycling is marginally convenient. Further, the implementation of incentive strategies in the context of competing retailers enhances the chance of achieving coordination. Therefore, the presence of competition is beneficial for CLSC coordination.

De Giovanni (2016) evaluates the benefits of coordination by comparing two coordination mechanisms: a state-dependent and a control-dependent incentive. While the state-dependent incentive links to the performance that the CLSC achieves on the return rate, the control-dependent incentive is proportional to the retailer's green activity efforts. In both cases, the manufacturer grants the incentive to the retailer. The findings demonstrate that firms have divergent preferences in most of the case, making coordination a very difficult target when the returns depend on both firms' green efforts. A state-dependent incentive coordinates the chain only for high retailer's environmental effectiveness. Instead, a control-dependent incentive is profit-Pareto-improving for low incentive values, high retailer's environmental effectiveness, and customers' repurchasing intention. In all other cases, firms should search for other coordination mechanisms to reach coordination.

Hu et al. (2016) consider several coordination mechanisms in a CLSC with strategic recycling behavior by consumers. The manufacturer can propose a two-stage price contract, which includes a direct incentive depending on the difference between the collected units and the targets imposed by the take-back legislation. In this case, it plays an active role in the collection process, while the chance of reaching coordination is lower than in a classical wholesale price contract case. The manufacturer can also propose two types of support: one consisting of a pure subsidy and one being a support program linked to the collection cost. The former favors the manufacturer's profits while the latter encourages the collector's profits, which complicates coordination. Finally, the CLSC can use an indemnity contract to seek coordination. The collector indemnifies the manufacturer directly for each uncollected unit, while the manufacturer pays the collector a transfer price for each collected unit. This contract can better coordinate the CLSC.

Ma et al. (2018) consider two closed-loop supply chain models with alliance recycling under the pay-as-you-throw (PAYT) and recycling fund (RF) mechanisms, to investigate whether coordination can be achieved when moving from one setting to the other. Also, the models consider the effect of the target recycling rate and the competition between recycling alliances. In a scenario without competition, both customers and the retailer benefit when implementing a PAYT, while the social welfare is larger under an RF mechanism. If there is competition between recycling alliances, the PAYT system continues to be beneficial for customers and the retailer, while the RF system benefits the recycling alliance. Therefore, in presence of competition, coordination turns out to be even more difficult to achieve.

Giri et al. (2018) start by analyzing a benchmark CLSC model in which a manufacturer determines the wholesale price and the warranty period and a retailer determines the selling price. Then, they give to the manufacturer the opportunity to coordinate the chain by doing some additional green program efforts, with the purpose of increasing sales. This mechanism works overall, although it leads to higher prices. Alternatively, firms can reach coordination by implementing an RSC. The latter always coordinates the CLSC by making all firms economically better off.

3.4 Subsidies

A number of contributions consider the case where the manufacturer (most often the government) gives a subsidy S to the collector, with S being either a fixed amount or dependant on E. The players' optimization problems are as follows:

$$\Pi_M = \max_{w}\{D(.)(w + \Delta r) - rS(E)\},$$
$$\Pi_R = \max_{p,E}\left\{D(.)(p - w) - C_R(E) + rS(E)\right\}.$$

Zhou et al. (2017) introduce a subsidy mechanism that a manufacturer provides to a qualified recycler but not to an unqualified recycler. Through the subsidy, the qualified recycler adopts value-based pricing, which is exemplified by the maximum consumers value. In such a way, it avoids a price war with the unqualified recycler. The authors also check the social welfare created through the CLSC when the government grants the subsidy.

The other contributions covered below consider a government subsidy.

In Xiong et al. (2013), the supplier determines the wholesale price while the manufacturer sets the quantity of new products to sell, and collects the returns for remanufacturing and selling. The government gives a subsidy when remanufacturing is marginally convenient, with the aim of making the CLSC perform at the centralized-chain level. The coordination mechanism's efficiency depends on the relationship between new and remanufactured products. When the two product types are substitute, the subsidy is efficient from the economic and environmental perspectives. When the two goods are complements, the subsidy can deteriorate the environmental performance. Note that the subsidy is fully exogenous, so firms adjust their strategy accordingly, while never being able to influence it. Similar to Xiong et al. (2013), Ma et al. (2013) model a coordination mechanism based on a government subsidy. The government does not play a role in the game. The subsidy influences all firms' decisions while no firm can influence the subsidy in any way. When this type of subsidy is implemented in a CLSC composed of one manufacturer and two competing retailers (one retailer and one e-retailer), the overall environmental performance increases. From a profit perspective, the subsidy has a positive influence on the manufacturer's and retailer's outcomes, with an ambiguous impact on the e-retailer's profits. Consequently, coordination is not always Pareto-improving.

Mitra and Webster (2008) model the case of competition for the returns between one manufacturer and one collector. The government pays a subsidy according to the returns volume collected. Three scenarios are modeled: (i) the subsidy is given only to the manufacturer; (ii) the subsidy is granted only to the collector; and (iii) the subsidy is granted to both. Granting the subsidy only to the manufacturer yields a better environmental, social (sales), and economic performance. Wang et al. (2015)

characterize a CLSC game in which a government provides a reward–penalty mechanism according to a return rate target, where the collection can be managed either by a manufacturer or a collector. When such a mechanism exists, more responsibility should be assigned to the firm leading the collection. Coordination can be achieved depending to the responsibility ratio, which represents the fraction of goods that the government assigns each firm to collect. Sheu (2011) considers a game in which manufacturers and collectors are involved in a CLSC network, with the decisions being the reservation prices for acquiring and selling recycled goods. Government's subsidies are shown to benefit the entire CLSC.

Heydari et al. (2017) retain tax exemptions and subsidies (among other mechanisms considered in the paper). Both these mechanisms can be proposed either to the manufacturer or the retailer. The results show that offering these mechanisms to a manufacturer improves the collection process and makes the government's decisions more efficient, especially when the CLSC also implements additional discounts for consumers. Overall, the mechanisms proposed by the government harm coordination, because each firm is better off when directly dealing with the government rather than when the government deals with the other CLSC member.

Wang et al. (2018a, b) model a CLSC game in a two-period setting in which a manufacturer decides on the price, and a collector sets the collection efforts. The collector receives a simple exogenous per-return incentive whose amplitude can vary according to the government's reward–penalty mechanism based on two parameters: reward–penalty intensity and target collection. This mechanism makes it possible to reach coordination only partially. While the collector is always economically better off, the manufacturer is not: its profits decrease in the first period, while they change non linearly in the reward–penalty intensity and the collection target. Therefore, the government's reward–penalty mechanism can be detrimental to the manufacturer's profits due to remanufacturing efficiency. Wang et al. (2017) look at a government's reward–penalty mechanism (RPM) for a CLSC with two sequential competing manufacturers. Comparing the results to the case without an RPM, the authors conclude that the RPM lowers the wholesale price and the retail price, while it boosts the sales quantity, the profits of the manufacturer, retailer, and the CLSC overall, as well as the collection rate.

3.5 Chain structure

Questions related to chain configuration and power structure are present, at least implicitly, in many, if not most of the contributions reviewed in this paper. Indeed, many papers compare the strategies and outcomes under a centralized CLSC and a decentralized CLSC. In the decentralized scenario, results with a leader, be it the manufacturer or the retailer, and without a leader are compared, with the aim of seeing whether leadership can lead to CLSC coordination. The different power structures are also combined with different options regarding who is in charge of collecting past-sold products, that is, the manufacturer, the retailer or a third party. Here we give a few examples that illustrate the approaches used and some results.

Wei et al. (2015) investigate whether adopting manufacturer or retailer leadership allows firms to coordinate the CLSC. They show that coordination cannot be reached because each firm wishes to be the leader. (Before tackling the question of leadership in a CLSC, the literature has addressed the issue in a supply chain context. For an example in a dynamic context, see Jørgensen et al. 2001 and the references therein.) Gao et al. (2016) are also interested in assessing the impact of different channel power structures on equilibrium decisions and outcomes in a CLSC with price- and effort-dependent demand. Their main results are as follows: (i) shifting leadership from the manufacturer to the retailer benefits both players when the collection effort's effectiveness at expanding demand is large enough; (ii) a symmetric channel power structure is the most favorable for both the CLSC and consumers when the collection effort's effectiveness at expanding demand is relatively low; and (iii) CLSCs with a dominant retailer are the most profitable.

Zu-Jun et al. (2016) characterize a CLSC game with one manufacturer, one retailer, and two collectors, and search for the most efficient chain structure that allows all firms to be economically better off. The manufacturer, being the chain leader, can integrate with one or more firms within the CLSC while offering a per-return incentive. As expected, the centralized chain is always the best collective configuration. Nevertheless, the retailer always prefers a structure in which the manufacturer integrates with both collectors; by doing so, the manufacturer charges a lower wholesale price due to the absence of collectors' incentivizes. By contrast, the manufacturer does not necessarily opt for the same integration structure, as both the demand and the return rate would be higher when integrating with one retailer and one collector. Therefore, some additional coordination mechanisms should complement the per-return incentive to increase the chances of coordinating the chain.

Huang and Wang (2017a) look at the impact of information sharing on the outcomes of a CLSC formed of one manufacturer, one distributor, and one 3PL. The distributor has private information, and the question is whether it is beneficial to share it with the two other members. The authors analyze three scenarios: the manufacturer collects and remanufactures, partially collects and lets the distributor also collect (scenario 2), or the 3PL (scenario 3) also be involved in collecting used products. One main result is that introducing information sharing is welcomed by the manufacturer and the 3PL, but is detrimental to the distributor. Introducing licensing fees mitigates the distributor's loss.

4 Conclusions

In this paper, we surveyed two major ingredients in the CLSC literature, namely, the return rate functions and the coordination mechanisms. We restricted our survey to games involving at least two tiers of the CLSC, in which firms create incentivizes, put in place ad-hoc strategies, get subsidies from governments, and also change their chain structure to pursue Pareto-improving payoffs. Our investigation highlights the results obtained with the different return functions and coordination mechanisms that have been used so far.

We end this paper by pointing out some research avenues that we feel are relevant to pursue to gain additional insights into the coordination of CLSCs.

Exogenous returns The advantage behind the assumption that returns are exogenous is analytical tractability, which could be fine as a first approximation of the return rate. A next step would be to link this rate to the costs that consumers incur when voluntarily returning their used products. These costs include, e.g., waste collection, creation of ad-hoc batches, car loading, and transportation. A good understanding of the relationship between the voluntary behavior and these costs would help firms and governments design effective communication and policies to mitigate, at least at a perceptual level, these externalities.

Returns as a control variable A long series of contributions have adopted the framework developed in Savaskan et al. (2004), treating returns as a decision variable. Different scenarios have been studied to answer the question of who should be in charge of collecting, keeping in mind that manufacturers are the most interested in closing the loop. In most of the literature, outsourcing means giving up the decision of how much to collect, and the physical collection process, to another party. When manufacturers face an extended producer responsibility policy (which implies penalties if they do not reach a target), outsourcing may become riskier and requires that a sophisticated contract is offered by the manufacturer. This invites more work on how to share the financial and physical responsibilities in the case of outsourcing.

Strategy-dependent returns Returns have been assumed in some papers to depend on the refund (or acquisition price) and/or on some green efforts. In De Giovanni and Zaccour (2019), the return flow depends on the technology upgrades and the price difference between product versions. Also, returns can be related to services, information systems, government actions, supply chain network, product design, customization, production process selection, and customer satisfaction. CLSC coordination needs to integrate at least some of these items in future investigations.

Static versus dynamic returns Most of the literature computed the returns in static or two-stage game frameworks. When lags in returns or the number of times a product can be remanufactured are an issue, a full dynamic model would become a necessity. Of course solving for the equilibrium values of the resulting model would not be easy, but this is not a valid reason to avoid adopting the right model.

Focus of dynamic models The dynamic games literature mainly focuses on returns that are motivated by production cost savings. The nature of the game changes completely when returns can be incentivized to sell new products. Indeed, pricing, strategic consumers, product quality over time, and cannibalization issues would become prominent, and not much has been done in this context. Also, the dynamic games literature has been silent so far on the best inventory policy to adopt when managing both virgin materials, finished products and returns at the same time. Clearly, more work is needed in this area.

Stochastic returns Only a few game theory models have dealt with CLSC coordination when the return function is stochastic. Future research can extend the SBW model to stochastic returns and assess how they impact the CLSC structure and the coordination targets. The literature (e.g., Guide and Van Wassenhove 2009) mentions uncertainty in timing, quality, and quantity of returns. We know little about how to account for these three elements simultaneously while designing coordination targets or mechanisms.

Contracts The literature has focused mainly on cost- and revenue-based subsidies, revenue-sharing contracts, and two-part tariffs. In his review of contract-based mechanisms in supply chains, Cachon (2003) proposes other options, e.g., sale- and return-rebate contracts, price- and quantity-discount mechanisms, buy-back, and quantity-flexible contracts. The role of these mechanisms, as well as others, e.g., vendor-management inventory, incentive strategies, manufacturer suggested retail price, and minimum advertised price, in coordinating a CLSC is surely of intellectual and practical interest.

Other research avenues A few other directions in CLSC coordination are worth taking. Among them corporate social responsibility, competition at different tiers of the CLSC, competition between CLSCs, and returns of complementary products.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

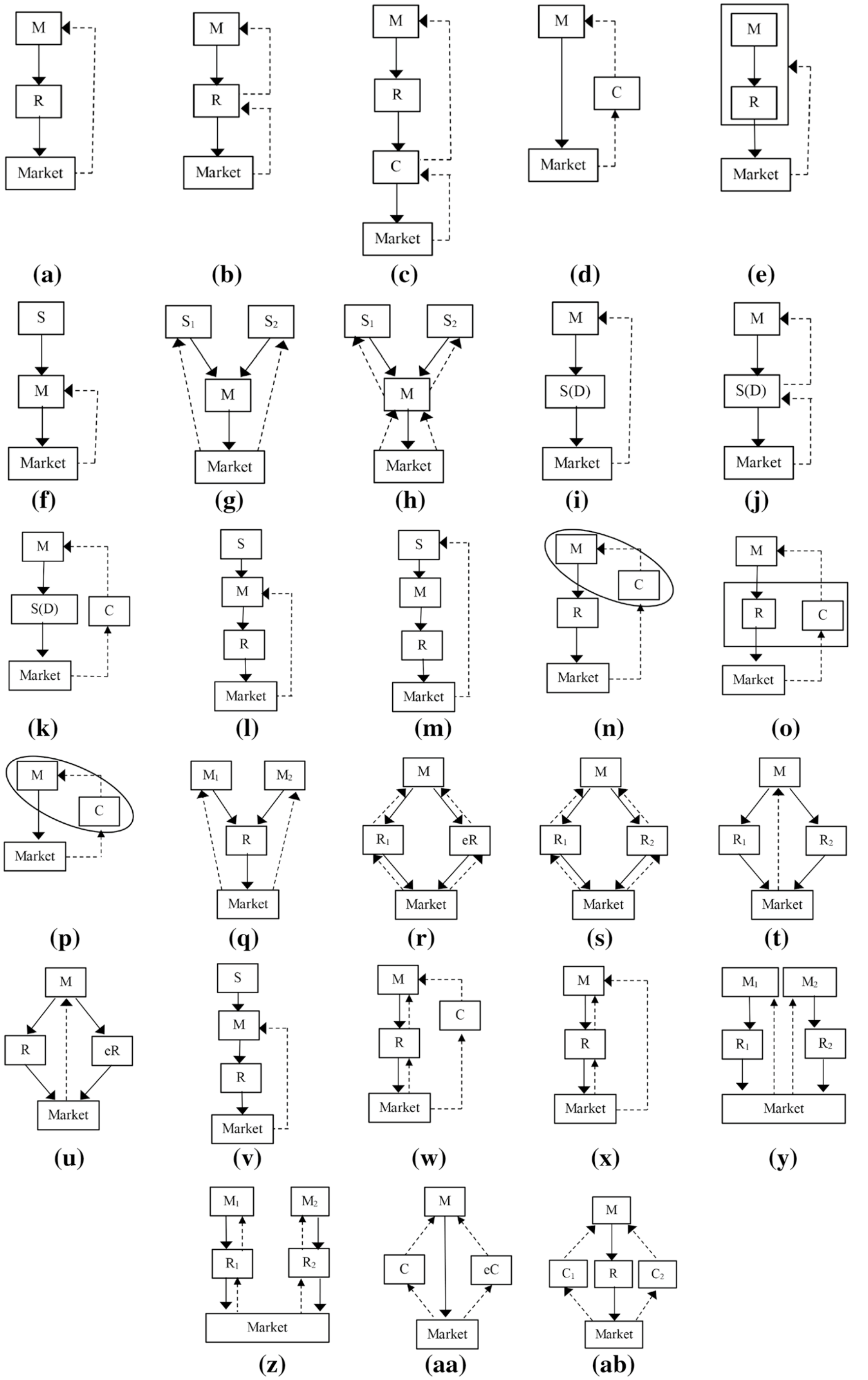

Fig. 2 Closed-loop supply chain structures (M—manufacturer, R—retailer, eR—eRetailer, C—collector, eC—eCollector, D—distribution center, S—supplier)

Appendix

See Table 2.

Table 2 Details of the surveyed papers

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Chen (2011)	Static, stochastic	M–R (Figure a)	M	Buyback incentive, quantity, wholesale price	Buyback incentive	Collect, share information and inventory management	No	Manufacturer Stackelberg leader
Chen et al. (2018)	Static, deterministic	M–R (Figure b)	R	Acquisition price, retailer's markup	Per-unit incentive	Collect	No	Nash and Manufacturer Stackelberg leader
Choi et al. (2013)	Static, deterministic	M–R–C (Figure c)	C	Per-return incentive, price, return rate, wholesale price	Per-return incentive	Collect and select the leader	No	Stackelberg with various propositions on the leader
Chuang et al. (2014)	Static, stochastic	M–R–C (Figures a, b and c)	M–R–C	Price, production quantity, return rate, wholesale price	Per-return incentive	Collect	No	Manufacturer Stackelberg leader
De Giovanni (2016)	Dynamic, deterministic	M–R (Figure a)	M	Wholesale price, price, green activity programs efforts	Per-unit incentive linked to the state (returns), per-return incentive linked to the retailer's green efforts	Collect and remanufacture	No	
De Giovanni (2014)	Dynamic, deterministic	M–R (Figure a)	M	Green efforts, price	Sharing-based incentive	Collect	No	Nash

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
De Giovanni (2017)	Dynamic, deterministic	M–R (Figure a)	M	Green efforts, price, sharing parameter, wholesale price	Endogenous and exogenous sharing parameter	Collect and share the collection benefits	No	Manufacturer Stackelberg leader
De Giovanni and Ramani (2018)	Static, deterministic	M–C (Figure d)	M–C	Price, service strategy	Return incentives	Collect	No	Nash
De Giovanni (2018)	Dynamic, deterministic	M–R (Figure a)	M	Collection efforts, price, wholesale price	Incentive strategies	Collect, remanufacture and resell	Retailers	Manufacturer Stackelberg leader
Genc and De Giovanni (2017)	Two-period, deterministic	M–R Centralized chain (Figures a, band e)	M, R, Centralized chain	Price, quality, wholesale price	Per-return payment	Collect	Retailers	Manufacturer Stackelberg leader
Genc and De Giovanni (2018a, b)	Static, deterministic	S–M (Figure f)	M	Lean investments, price, wholesale price	Strategic lean investments	Collect	No	Supplier Stackelberg leader
De Giovanni and Zaccour (2013)	Dynamic, deterministic	M–R (Figure a)	M	Green efforts, price, support program	Revenue sharing contract and support program	Collect and remanufacture	No	Manufacturer Stackelberg leader
De Giovanni and Zaccour (2014)	Two-period, deterministic	M–R (Figures a and b)	M–R	Collection efforts, price, wholesale price	Per-return payment	Collect and remanufacture	No	Manufacturer Stackelberg leader

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Gao et al. (2016)	Static, deterministic	M–R (Figure a)	M	Advertising efforts, collection efforts, price, wholesale price	Two-part tariff	Collect and remanufacture	No	Manufacturer and Retailer Stackelberg leaders, Nash game
Gan et al. (2017)	Multi-period, deterministic	M–R–C (Figure c)	C	Acquisition price, price, wholesale price	Per-return incentive	Collect, remanufacture and sell	No	Manufacturer Stackelberg leader
Giri et al. (2018)	Static, deterministic	M–R (Figure a)	M	Green programs efforts, price, warranty period, wholesale price	Revenue sharing contract	Collect and remanufacture	No	Manufacturer Stackelberg leader
Han et al. (2017)	Static, deterministic	M–R (Figures a and b)	M–R	Price, return rate, revenue sharing, wholesale price	Revenue sharing	Collect	No	Manufacturer Stackelberg leader
He (2015)	Static, stochastic	S–M (Figure g)	S–M	Acquisition price and quantity	Complete and partial compensation contracts complemented with a two-part tariff	Collect	Suppliers	Nash

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Heydari et al. (2017)	Static, deterministic	M–R (Figure b)	R	Discount factor, discount offered to consumers, fee factor, optimal consumer's willingness to return	Recycling fee, discount on present and future sales, government's tax exemptions, government's subsidies	Collect and resell	Retailers	Nash
Heydari et al. (2018)	Static, stochastic	M–R (Figure b)	R	Acquisition price, per-recycled unit fee, sharing parameter	Per-return incentive and revenue sharing contract	Collect and resell	No	Nash
Hong and Yeh (2012)	Static, deterministic	M–R–C (Figures b and c)	R–C	Acquisition price, price, return rate, wholesale price	Per-return incentive	Collect	No	Manufacturer Stakelberg leader
Hong et al. (2015)	Static, deterministic	M–R–C (Figures a, b and c)	M–R–C	Price, return rate, support rate, wholesale price	Per-return incentive, cooperative advertising and two-part tariff	Collect	No	Manufacturer Stackelberg leader
Hong et al. (2017)	Two-period, deterministic	M–C (Figures a and d)	M–C	Quantity of new and remanufactured products, return rates	Fix payment, royalty	Compete on collection and remanufacture		Manufacturer Stackelberg leader

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Hu et al. (2016)	Static, stochastic	M–C (Figure d)	C	Collection efforts, return quantity, subsidy, wholesale price	Wholesale price, per-unit incentive, two-stage contract, support programs, indemnity contract	Collect	No	Nash
Huang et al. (2013)	Static, deterministic	M–R–C (Figures b and c)	R–C	Per-return incentive, price, return rate, wholesale price	Per-return incentive	Collect and compete on returns	No	Manufacturer Stackelberg leader
Huang and Wang (2017a)	Static, deterministic	M–D–C Figures (i, j and k)	M–D–C	Acquisition price, price, wholesale price	Per-return incentive, licensing fee	Collect	No	Manufacturer Stackelberg leader
Huang and Wang (2017b)	Static, stochastic	M–D–C Figures (i, j and k)	M–D–C	Acquisition price, licensing fee, price, wholesale price	Per-unit incentive	Collect	No	Distributor Stackelberg leader
Huang and Wang (2017c)	Static, deterministic	S–M–R (Figures l and m)	M–S	Acquisition price, price, wholesale price	M gives more power to S but without any formal incentive	Collection and resell	No	Supplier Stackelberg leader

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Li et al. (2014)	Static, stochastic	M–C (Figure d)	C	Acquisition price, return rate	Per-unit incentive	Collect	No	Nash
Liu et al. (2017)	Static, deterministic	M–C-R Figures (e, n and o)	M–C, M–R, R–C	Acquisition price, price, wholesale price	Per-unit incentive	Collect	No	Manufacturer Stackelberg leader
Jena and Sarmah (2014)	Static, deterministic	M–R (Figure q)	M	Price, return rates, wholesale price	Per-unit incentive	Collect	Manufacturers	Manufacturers Stackelberg leaders
Kaya (2010)	Static, stochastic	M–Collecting agency (Figures d and p)	Centralized chain, Collecting agency	Incentive, quantity to remanufacture, transfer price of returns	Per-return payment, fix transfer price	Collect and remanufacture	No	Nash
Ma et al. (2013)	Static, deterministic	M–R-eR (Figure r)	R, eR	New product price, remanufactured product price, wholesale price	Governmental subsidy	Collect and resell	Retailer vs eRetailer	Manufacturer Stackelberg leader
Ma et al. (2017)	Static, deterministic	M–R–C (Figures a, b and c)	M–R–C	Advertising efforts, collection efforts, price, wholesale price	Per-return incentive	Collect	No	Manufacturer Stackelberg leader

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Ma et al. (2018)	Static, deterministic	M–R (Figure q)	R	Return rate, price, recycling fee, unit recycling fee paid by manufacturers to recycling fundmanagement board, unit subsidy fee, wholesale price			Manufacturers	Manufacturer Stackelberg leader
Maiti and Giri (2017)	Static, deterministic	M–R (Figure b)	R	Exchange rate used/new goods, markup, quality, returns	Bargaining model	Collect and resell	No	Nash, manufacturer stackelber leader, retailer stackelberg leader
Miao et al. (2017)	Two-period, stochastic	M–R (Figures a and b)	M–R	Acquisition price, incentive, price, wholesale price	Per-return incentive	Collect	No	Manufacturer Stackelberg leader
Mitra and Webster (2008)	Static, deterministic	M–C (Figure d)	M–C	Price of new and remanufactured products	Governmental subsidy	Collect	No	Nash
Modak et al. (2018)	Static, deterministic	M–R–C (Figures a, b and c)	M–R–C	Price, quality, return, wholesale price	Per-return incentive, subgame perfectness rule	Collect	No	Manufacturer Stackelberg leader

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Panda et al. (2017)	Static, stochastic	M–R Centralized (Figures b and d)	R Centralized	Price, return rate, wholesale price	Per-return incentive, revenue sharing contract	Collect	No	Manufacturers Stackelberg leaders
Ramani and De Giovanni (2017)	Two-period, deterministic	M–C (Figure d)	C	Advertising efforts, price for new and remanufactured goods	Per-return payment	Collect, resell and recycle	No	Nash
Savaskan et al. (2004)	Static, deterministic	M–R M–R-3PL Centralized chain (Figures a, b, c and e)	M, R, 3PL, Centralized chain	Collection efforts, price, wholesale price	Per-return payment	Collect and remanufacture	No	Manufacturers Stackelberg leaders
Savaskan and Van Wassenhove (2006)	Static, deterministic	M–Competing R Centralized chain (Figures e, s and t)	M, R, Centralized chain	Collection efforts, per-return payment, price, wholesale price	Per-return payment	Collect and remanufacture	Retailers	Manufacturer Stackelberg leader
Saha et al. (2016)	Static, deterministic	M–R–C (Figures a, b and c)	M–R–C	Acquisition price, price, returns, wholesale price	Per-return incentive	Collect	No	Manufacturer Stackelberg leader
Sheu (2011)	Three-stage, stochastic	M–C (Figure d)	C	Collection quantity, price, subsidy	Nash-bargaining and government subsidy	Collect	Manufacturers and collectors	Nash

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Sheu and Chen (2012)	Static, deterministic	Ss–M-government (Figure g)	Suppliers	Quantity to produce, subsidies and fees, wholesale price	Subsidies and green fees	Collect	No	Nash
Taleizadeh and Sadeghi (2018)	Static, deterministic	M–R–eChannel (Figure u)	M	Acquisition price, price, wholesale price	Per-return incentive	Collect and compete	Supply chain level	Nash, and various forms of Nash-Stackelberg
Taleizadeh et al. (2018)	Static, deterministic	S–M–R–C (Figure v)	M	Acceptance quality level, number of shipments, quantity order, replenish cycle time	VMI	Collect, inspect, and remanufacture	No	Nash
Taleizadeh et al. (2018)JCP	Static, deterministic	M–R–C (Figure w)	R & C	Advertising efforts, collection efforts, price, quality efforts, wholesale price	Per-return incentive, two-part tariff and cooperative programs	Collect and remanufacture	No	Manufacturer Stackelberg leader
Wang et al. (2015)	Static, deterministic	M–C (Figure d)	C	Price, return rate, wholesale price	Government reward–penalty mechanism	Collect	No	Manufacturer Stackelberg leader

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Wang et al. (2017)	Static, deterministic	M–R–C (Figures a, b and c)	M–R–C	Acquisition price, price of new and remanufactured goods, wholesale price	Per-return incentive	Collect	No	Manufacturers Stackelberg leader
Wang et al. (2017b) JCP	Static, deterministic	Ms–R (Figure q)	Ms	Collection efforts, price, wholesale price	Government's reward–penalty mechanism	Collect	Manufacturers	Manufacturers Stackelberg leaders
Wang et al. (2018a, b)	Two-period game, deterministic	M–C (Figure d)	C	Collection efforts, price	Per-return incentive, government's reward–penalty mechanism	Collect and remanufacture	No	Manufacturer Stacklberg leader
Wei et al. (2015)	Static, deterministic and stochastic	M–R (Figure b)	R	Price, return rate, wholesale price	Per-return incentive	Collect	No	Manufacturer and Retailer Stackelberg leader
Wei et al. (2018)	Static, deterministic	M–R (Figure a, b and x)	M–R-M&R	Price, return rate, wholesale price	Per-return incentive	Collect	No	Manufacturer Stackelberg leader

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Wu and Kao (2018)	Static, stochastic	OEM-IR (Figure b)	IR	Collection quantity, quantity of new goods, quantity of remanufactured goods, quality	Technology licensing and joint venture	Collect and remanufacture as new	No	Manufacturer Stackelberg leader
Wu and Zhou (2017)	Static, deterministic	M–R with competing CLSC (Figures y and z)	M–R	Price, returns, wholesale price	Per-return payment	Collect, remanufacture and compete	Supply chain competition	Manufacturers Stackelberg leaders
Xie et al. (2017)	Static, deterministic	M–R Centralized (Figures b and d)	R	Advertising sharing parameters, price, wholesale price	Reverse and forward revenue sharing contracts	Collect	No	Manufacturer Stackelberg leader
Xie et al. (2018)	Static, deterministic	M–R (Figure b)	R	Forward and backward channel efforts, price, quantity	Revenue sharing contract and support program	Collect	No	Manufacturer Stackelberg leader
Xiong et al. (2013)	Static, deterministic	S–M (Figure m)	M	Quantity of new goods, quantity of remanufactured goods, wholesale price	Governmental subsidy	Collect and remanufacture as new	No	Nash
Xu et al. (2015)	Static, stochastic	M–R (Figure b)	R	Price, refund, wholesale price	Buy-back contract	Collect	No	Nash

Table 2 (continued)

References	Game type	CLSC structures (Figures)	Collector	Controls	Coordination mechanism	Focal point	Competition in a tier	Equilibrium
Yang et al. (2017)	Static, stochastic	Competing M–R (Figure q)	R	Price, wholesale price	Money-back guarantee	Collect	Manufacturers	Manufacturers Stackelberg leaders
Yoo and Kim (2016)	Static, deterministic	M–S–C (Figures i, j and k)	M–S–C with several integration options	Price, wholesale price	Per-return incentive	Collect	No	Supplier Stackelberg leader
Yoo et al. (2015)	Static, deterministic	S–M (Figure i)	M	Acquisition price, price, price discount, returns, wholesale price	Per-return incentive	Collect	No	Manufacturer Stackelberg leader
Zhao et al. (2017a, b)	Static, stochastic with fuzzy demand	M–R (Figure b)	R	Price, return rate, wholesale price	Per-return incentive	Collect	No	Manufacturer Stackelberg leader
Zhao et al. (2017b)	Static, deterministic	M–R–C (Figures b and c)	R–C	Acquisition price, price, return rate, wholesale price	Per-return incentive	Collect	No	Manufacturer Stackelberg leader
Zhao and Zhu (2017)	Static, stochastic	M–R (Figure b)	R	Acquisition price, wholesale price	Per-return incentive	Collect	No	Manufacturer Stackelberg leader
Zhou et al. (2017)	Two-period, deterministic	M-Recyclers G-Recyclers (Figure aa)	Recyclers	Price, recycling price	Subsidy	Collect	Recyclers	Manufacturer Stackelberg leader
Zu-Jun et al. (2016)	Static, deterministic	M–R–C (Figure ab)	C	Price, return rate, wholesale price	Per-return incentive	Collect and integrate with partners	Collectors	Manufacturer Stackelberg leader

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