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Impacts Of Asymmetric Decision Policies And Consumer Behavior On Supply Chain Coordination Under Consumer Returns

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IMPACTS OF ASYMMETRIC DECISION POLICIES AND CONSUMER BEHAVIOR ON SUPPLY CHAIN COORDINATION UNDER CONSUMER RETURNS

A Thesis Presented

by

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ABSTRACT

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FEBRUARY 2008

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Within this thesis we investigate the effect of asymmetric agent decision making on the coordination of a two echelon supply chain facing consumer returns. On the basis of the classical newsvendor setup, supply chain players may face stochastic, or stochastic and price-dependent demand. We consider consumer returns to be either (1) a specific percentage of sold products, or (2) dependent on the retail price. Given the lack of coordination of the decentralized supply chain, we not only consider wholesale price-only contracts but also examine a buy-back option, where the manufacturer offers to buy back unsold items from the retailer at the end of the selling period. In all cases, we perform comprehensive computational studies to examine how decision variables and profits are affected by asymmetric versus symmetric decision making. In the asymmetric cases only one supply chain player includes consumer returns in his optimization process. Furthermore, as asymmetric behavior indicates the existence of a prisoner's dilemma, we conduct a game theoretic analysis which delivers interesting insights on the value of information sharing.

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CHAPTER 1

INTRODUCTION AND MOTIVATION

In order to acquire new customers and to satisfy old ones, consumer return policies have been significantly relaxed over the last few years. Most mass merchandisers offer full refunds for returned products if the item is returned within $30 - 90$ days of purchase. Gentry (1999) [20] states that customer returns are estimated to be around 6% and mass merchandisers may have returns as high as 15% of the goods sold. Catalogue or e-commerce retailers even can face returns up to 75% (Mostard and Teunter (2006) [39]), whereas this figure varies greatly by product and time of the year. In the year 2006 reports showed that the value of returned goods accounted for almost 1% of the total U.S. gross domestic product (Aberdeen Group [19]). Due to increasing global competition, shorter product lifecycles and a still growing lenient attitude towards consumer returns, this amount is likely to rise even higher in the future. Consequently, the management of customer returns requires more and more attention by companies. The so-called process of reverse logistics, i.e. the return and exchange, repair, refurbishment, remarketing, and disposition of products, is today an integral component of competitive retail companies. Improving the reverse logistics process helps with recapturing lost revenues, reducing operating costs, and by offering the customer reduced risk when purchasing a product, customer loyalty and satisfaction are increased as well. In order to manage the reverse logistic process mutual understanding between retailer and manufacturer of the process itself and of the applied return policy is crucial. Of course, the process of reverse logistics adds more complexity to the relationship between manufacturer and retailer.

The aim of this thesis is to study the effects that asymmetric agent decision making have on the coordination of a supply chain facing consumer returns, whereas we extend the work that was done by Ruiz Benítez and Muriel (2007) [42]. The latter investigated supply chain coordination in the symmetric cases, where both members either consider or ignore consumer product returns. Demand in this thesis is assumed as either stochastic or stochastic and price-dependent. For both types of demand we further assume returns to be a constant fraction of sold goods, whereas for the latter we also consider a price-dependent return function. Since the case of a price-sensitive return function is not studied by Ruiz Benítez and Muriel (2007) [42], the impacts on supply chain behavior and coordination under both symmetric and asymmetric decision making are investigated.

This thesis focusses on a two echelon supply chain with a single retailer and single manufacturer which are coordinated by a wholesale price-only contract. Consequently asymmetric behavior is if one part of the supply chain considers consumer returns for its decision making and the other one not. As a second step we are taking buy-back contracts into account in order to determine positive or negative impacts on supply chain coordination. For each of the above mentioned models a computational study and a sensitivity analysis is conducted in order widen initial findings. As we have asymmetric information among the players a game theoretic analysis, which delivers interesting insights on the value of information sharing, is conducted. Furthermore asymmetric information can cause strategic opportunities for one player to exploit the other, what is studied as well.

The remainder of this thesis is organized as follows. The following chapter 2 gives a review on literature about consumer returns and supply chains. Coordination issues and considered contracts are presented. Additionally, literature dealing with asymmetric settings and decision making under such is outlined. Chapter 3 describes the model and framework under consideration in the thesis. Moreover, we introduce the asymmetric decision processes and the profit functions according to which the members of the supply chain optimize their decisions. The benchmark cases, i.e. the case where both players either consider or ignore returns in their decision process, are also presented. Chapters 4, 5 and 6 deal with the computational studies about the mentioned symmetric and asymmetric settings and respective contracts. Retrieved results are compared to the benchmark cases which are investigated by Ruiz Benítez and Muriel (2007) [42]. The basic assumption in chapter 4 is that demand is stochastic and the return rate is a constant fraction of sales. The computational work in chapter 5 focusses on stochastic and price-dependent demand, whereas returns are still a constant rate. Chapter 6 finally introduces the price-dependent return rate with a underlying stochastic and price-dependent demand model. As in the asymmetric settings the players lack information about the optimization process of the other player, a game theoretic analysis in conducted in chapter 7. Furthermore, strategic options which the players could follow in order to raise their profits are studied as well. Lastly Chapter 8 summarizes and points out the main findings of this thesis and outlines further directions of research and possible extensions that can be made to this work.

CHAPTER 2

LITERATURE REVIEW

In the following paragraphs, literature is reviewed in order to put this work into perspective. We start out by presenting papers dealing with consumer returns. Secondly, research pertaining to supply chain coordination under respective contracts is presented. Special attention within this part is paid to the dissertation of Ruiz Benítez (2007) [42]. The third and last part of this chapter refers to literature about asymmetric information settings and supply chain coordination under such.

2.1 Consumer Returns

Consumer product returns are driven by the "consumer is king" attitude prevalent in the United States. Therefore, consumer returns are an integral part of today's business policies, whereas the most relaxed return policies can be found in the United States. Because customer rights have been strengthened by recently introduced laws and companies, headquartered in the US, are entering the foreign markets, other parts of the world are catching up fast (Guide et al. (2006) [23]). Product returns occur because the product is faulty, it does not meet the customer's expectation or the consumer has no further use of it. However, most returns are considered false failure returns, where the product is indeed working but mistakenly or deliberately considered as damaged or the consumer simply changed his mind. As an example, Hewlett Packard faces up to 80% false failure (i.e. type-2) returns of their total customer returns (Ferguson et al. (2005) [17]). The latter develop a target rebate contract which helps to decline the type-2 returns by increasing the retailer's sales effort. In particular, the retailer receives a specific dollar amount per each unit of false failure returns below a target rate. This provides an incentive to increase sales efforts, and thus decreases the number of false failures. Returns are typically assumed to be a constant proportion of sales, so that if a retailer sells more items the number of returned items increases (Kiesmueller and van der Laan (2001) [31]). The relationship between retail prices and returns is studied by Anderson et al. (2006) [1], whereas they find empirical evidence for a positive relationship between the price paid and the number and rate of returns. Guide and Van Wassenhove (2001) [24] study customer returns and the respective layout of closed-loop supply chains for different products and industries and point out management and key research issues. The classical newsvendor problem with resalable returns is studied by Mostard and Teunter (2006) [39]. Under the assumption that returned items can be resold unlimited times in one selling season unless they are broken, the authors derive a simple closed-form equation that determines the optimal order quantity and all relevant revenues and costs in the supply chain.

DeCroix (2006) [14] analyzes a multi-echelon inventory system where the inventory stages are arranged in series. Returned products are shipped to a recover facility, where further processing of the item takes place. Considered actions are storing, disposing, or remanufacturing and re-entering the forward flow of material. Guide et al (2001) [24] and Fleischmann (2001) [18] focus on returns that occur due to the end of the life of the product or because of overstocking. When dealing with consumer returns, not all products are handled the same way. Sometimes the manufacturer does not give retailers the possibility to return items. Instead of, the item could be disposed right away by the retailer, whereas either the retailer or the manufacturer bears the costs, or the retailer handles the returned items independently. The latter is the case at Walmart (Corbett and Savaskan (1999) [12]). Also lump sum transfers between retailers and manufacturers are common in order not to loose goodwill of the other player, whereas those transfers are especially important for returned products in slotting allowance contracts (Lariviere and Padmanabhan (1997) [40]). Another important aspect of returns is the risk associated with them. Tsay (2002) [48] addresses how the uncertainty about returns affects both sides of a manufacturer-retailer relationship, and how these dynamics are altered by the introduction of a manufacturer return policy.

2.2 Supply Chain Coordination and Considered Contracts

Supply chain coordination and its improvement through different contracts between manufacturer and retailer are studied widely in diverse literature. In general there are various types of contracts, whereas the simplest one is the price-only contract. In this case, the wholesale price set by the manufacturer is the only required parameter. In a two-echelon supply chain under a price-only contract, coordination issues are studied by Lariviere and Porteus (2001) [33], whereas they find the relative variability to play a key role. As the variability declines the manufacturer charges higher wholesale prices and takes a larger share of profits. Despite an increased efficiency of the decentralized system, i.e. total supply chain profits are greater, the retailer's profits are lower. Sulaiman and Wooseung (2006) [46] find that the optimal selling price between the manufacturer and the distributor is decreasing as the customer demand increases, what complies with Lariviere and Porteus.

In a decentralized network, supply chain players generally try to maximize own profits what consequently leads to the occurrence of the "double marginalization effect" introduced by Spengler (1950) [44]. Instead of the manufacturing cost, the retailer faces the wholesale price transmitted by the vendor and therefore has lower profits than in the centralized case. This leads to the necessity of incentive schemes. Extensive literature on supply chain contracts and coordination issues can be found in Lariviere [32], Tsay et al. (1999) [47] and especially in Cachon (2003) [5].

Buy-back contracts represent a widely used instrument to improve the performance of decentralized supply chains. In particular, the vendor agrees to buy back unsold items partly or to the full extent of left over items at the end of the period . Consequently, the retailer gets an incentive to order more than without a contract since a buy-back contract raises the retailers marginal revenue. Note, that the phenomenon of "double marginalization" leads to lower orders of the retailer than in a centralized system. However, a policy that does not allow returns at all or one where unlimited returns are allowed for partial credit is not optimal (Pasternack (1985) [41]). Moreover, Pasternack proves that in case of stochastic demand, buy-back contracts can indeed be used to coordinate supply chains. The null returns policy, where the manufacturer does not offer the option to buy back unsold items and the unlimited returns policy (the manufacturer gives full refund for every unsold item) are compared in Padmanabhan and Png (1997) [40]. As observed by Chan et al. (2007) [9] buy-back contracts can also be misused by a selfish manufacturer to raise his profits and lock most of the supply chain profits, whereas the retailer may have no profit at all.

An interesting aspect of buy-back contracts is that they are independent of the demand distribution. Donohue (2000) [15] studies a two-stage production environment with two distinct production modes and an offered buy-back contract. By determining the optimal buy-back price and the wholesale prices corresponding to both production modes, such a contract can coordinate the decentralized supply chain. In case that the retailer can set the retail price and therefore demand is a function of this price, Kandel (1996) [29] finds that coordination can not be reached by a buy-back contract. Buy-back contracts for a decentralized supply chain with price-sensitive and stochastic demand is studied by Yuyue et al. [51]. Their results show that the profit functions for both channel partners are unimodal for a large family of demand functions and randomness distributions, what allows them to determine the unique optimal retail decisions and also closed-form expressions for the optimal contract parameters. A pricing and return-credit strategy for a monopolistic manufacturer of single-period commodities is also extensively studied by Lau and Lau (1999) [34]. By setting respective wholesale and repurchase prices, a return-credits agreement can often be manipulated by a shrewd manufacturer to increase his profit egoistically. In other words he has the lion share of profits, unless the retailer is supported by an external force. More literature containing buy-back contracts under random and price dependent demand can be found in Granot and Yin (2005) [22] and in Emmons and Gilbert (1998) [16]. The latter shows that buy-back contracts increase the coordination of supply chains, since the offer to buy back items at the end of the selling season tends to increase total profits of the retailer and manufacturer. The former develop closed-form expressions for the optimal wholesale and repurchase price under linearly growing expected demand. Bernstein and Federgruen (2005) [3] find that, if demand is stochastic and price-dependent, buy-back contracts can not be used to coordinate supply chains. Ruiz Benítez and Muriel (2007) [42] consider a two echelon supply chain under the presence of consumer returns with a single manufacturer and a single retailer that faces only stochastic or stochastic and price dependent demand. They extensively study the effects of wholesale and buy-back contracts on the coordination of a decentralized supply chain that faces consumer returns, when either none or both of the players consider returns in their optimization process. Generally, supply chain coordination is enhanced when ignoring returns, due to higher order amounts by the retailer. Also, the player that faces the higher share of logistic costs benefits from considering returns in the optimization process. Further results are that buy-back contracts can help to ensure coordination when considering returns in the optimizations. Beyond buy-back contracts Ruiz Benitez and Muriel (2007) [42] also consider return allowance contracts, revenue and price sharing contracts and also price postponement strategies in their work. In extension to the latter, Lenk (2007)

[36] studies the effects that price postponement has on the performance and coordination of a decentralized organized two-echelon supply chain facing product returns. In contrast to the results of Ruiz Benitez and Muriel (2007) [42] considering returns leads to higher supply chain profits than ignoring returns. Under price-postponement a buy-back option improves the supply coordination, regardless if the players consider returns or not. However, the last-mentioned contracts are only of minor importance for this work. For the sake of completeness, we briefly present other types of contracts and incentive schemes that can help to improve or ensure coordination. In order to realize coordination Jeuland and Shugan (1983) [28], for example, proposed a quantity discount schedule. Profit maximization of the total supply chain is then achieved by fixing the retailer's and manufacturer's profits to a linear function of total channel profits. Moorthy (1987) [38] states that quantity discount schemes are not necessary for channel coordination. Pricing schemes with quantity surcharges are sufficient instead. More literature pertaining to different kinds of contracts and coordination strategies can be found in Lee and Tang [35] and in Van Mieghem and Dada [49]

Primarily, this work understands itself as an extension to the work of Ruiz Benitez and Muriel (2007) [42] with particular attention to the aspect when asymmetric settings are present, where only one player considers returns and the other one not. Also, the game theoretic aspect of having two players equipped with different information and thus arising strategic options is considered.

2.3 Asymmetric Information and Coordination

Research involving supply chain contracts under asymmetric information in a newsvendor setting is rare in the literature. Kandel (2006) [29] for example finds that asymmetric information leads to the phenomenon of more optimistic sales forecasts by the manufacturer compared to the retailer. Usually different parties make commitments under different states of information. Decision making based on a local rather than global perspective is also a natural consequence of decentralized control, whereas double marginalization is one salient issue likely to arise. Tsay (1999) [47] shows that these problems can be partially remedied by a quantity flexibility contract, in which the retailer commits to a minimum purchase and the manufacturer guarantees a maximum coverage. However, other contracts are not able to coordinate the supply chain effectively. Interesting literature for this thesis is found in Gong (2000) [21]. He studies the optimal contract for a supplier selling to a retailer when demand is uncertain and when the retailer can take a costly hidden action to forecast demand. In other words, he analyzes an asymmetric setting of information. He finds as a result that the best optimal solution for the supply chain can not always be implemented when asymmetric information is given.

Information asymmetry in the demand and its distribution in a single retailer and manufacturer supply chain is studied by Chambers and Snir [8]. Given a critical property of the demand, namely Separability under Individual Optimization, the supply chain can be coordinated by using buy-back contracts. As a further result, offering the retailer multiple contracts is not necessary. Moreover, it is optimal to offer the retailer only a single contract to reach the best coordination. Corbett (2001) [10] analyzes the buyer's optimal menu of contracts when the supplier has private information about setup costs and shows how consignment stock can help to reduce the impact of this information asymmetry. Moreover, he studies consignment and assumes that the supplier cannot observe the buyer's backorder cost. Other literature pertaining to asymmetry in supply chain deals with available information of the cost structures of the players (Corbett and de Groote [11]), whereas Corbett, Zhou and Tang [13] studies the value to a supplier of obtaining better information about a buyer's cost structure, and of being able to offer more general contracts.

Asymmetric information is also an important part within the subject of game theory. The general ideas of game theoretic concepts that we are going to use are summarized in Varian (1982) [50]. As shown later in this thesis, depending on available information, the players can raise their profits or at least foresee the possible outcome of a deal given that both do act rationally. If decisions are made multiple times, results might also change. Samuelson (1984) [43] studies a bargaining model under asymmetric information in which an uninformed buyer faces an informed seller. He concludes, that the uninformed buyer achieves his best possible outcome when he has the opportunity to make a first-and-final offer which the seller can reject or accept. Further, he finds that asymmetric information may preclude a mutually beneficial sale. A two player game with bayesian information (i.e. incomplete information about the other player) is studied by Harsanyi (1968) [26], whereas he shows how erroneous beliefs of one agent can be exploited by the other. However, the setting in this thesis is to have complete information about costs but asymmetric information about the decision making process. Optimal retail contracts under conditions of asymmetric information and moral hazard are examined by Blair and Lewis (1994) [4]. The dealer is privately informed about demand and can increase it through promotion, which is not observable by the manufacturer before contracting with the latter. They conclude that optimal coordinating contracts exhibit some form of resale price maintenance and quantity fixing.

Asymmetric information and the respective efficiency in such environments is also considered in Holmstroem and Myerson (1983) [27] and Harris and Townsend (1981) [25]. Speaking of lower efficiency and a worse coordination under asymmetric information, Sulaiman (2006) [46] presents supply chain models for developing optimal pricing strategies to achieve partial and maximal joint coordination in centralized systems. Another main conclusion is that strategic partnerships and/or strong trust among participating companies is critical in the success of the coordinated operation of supply chain. Strategic options that arise due to information asymmetries are considered in the work of Cachon and Lariviere (1999) [6]. In a two-stage supply chain the retailer's and manufacturer's situation regarding orders and capacity is studied. The retailer has the option to either order more than needed to gain a more favorable allocation or show his real needs by ordering the needed amount exactly. The manufacturer, in turn, has to deal with the capacity allocation problem. However, Cachon and Lariviere find that truth-indicating mechanisms do not coordinate the supply chain, and finally resulting profits might even be worse. Studies about pure strategies and Nash-equilibriums in supply chains are conducted by Anupindi (2001) [2] and Cachon and Zipkin (1999) [7]. The latter studies a two-stage serial supply chain with stationary stochastic demand and fixed transportation systems. They find that the players (almost) always end up in a Nash-equilibrium which differs from the optimal solution. Thus, competition reduces efficiency. The former studies a general framework for the analysis of inventory decisions in a multi retailer distribution system. For the inventory decision they develop conditions for the existence of a pure strategy Nash-equilibrium.

Observe that in most cases the asymmetry arises from the lack of information on the demand or cost parameters in the respective model. In our case, however, asymmetry arises due to retailer and manufacturer following different decision making policies. To the best of our knowledge, there is no literature that is dealing with decision making or supply chain coordination under the presence of consumer returns with the given situation of asymmetric information about the optimization policy followed by the respective players.

CHAPTER 3
FRAMEWORK AND MODEL

Within this work we mainly study the case where retailer and manufacturer are not following the same policy regarding consumer returns. In other words, the decision process is asymmetric, where only one player includes consumer returns in his optimization process and the other one ignores them. The idea is to extent findings of the symmetric optimization processes from Ruiz Benítez and Muriel (2007) [42] under both, stochastic, and stochastic and price-dependent demand, to the asymmetric settings. For the first part of the thesis we consider consumer returns to be a constant proportion of sales, whereas we later also focus on price-dependent returns. As literature hasn't dealt with supply chain performance under the premise of price-dependent consumer returns yet, the symmetric cases are studied as well and retrieved results are compared to the performance of the asymmetric settings.

This chapter first outlines the respective formulas for the expected profits and order quantities of the manufacturer and retailer under both, stochastic, and stochastic and price-dependent demand. Importantly, these formulas are taken to set up the two asymmetric optimization processes, which are described thereafter. Since the respective optimization formulas are different for different forms of demand, we present the two models in this chapter separately, starting out with the simpler case of stochastic demand and thereupon showing the more complicated stochastic and price-dependent case. Note, that the latter model is also used when returns are price-dependent.

Next, chapter 4 focusses on the computational study under stochastic demand, where the results for the asymmetric settings are compared to the findings that have been gained by Ruiz Benítez and Muriel (2007) [42], who studied the symmetric decision making processes. When needed, we simply borrow their results. Chapter 5 deals with supply chain performance under stochastic and price-dependent demand when consumer returns are a constant proportion of sales. Again we extent findings to the cases of asymmetric decision making. In chapter 6 consumer returns are considered to be dependent on the retail price. Starting out by presenting respective return functions, an analysis of the symmetric and asymmetric cases follows.

3.1 General Framework

As stated in the introduction, we study a two echelon supply chain including a single manufacturer and a single retailer. The model that we are using throughout the thesis was introduced by Ruiz Benitez and Muriel (2007) [42]. Since we are considering one product and a single period with only one replenishment opportunity by the retailer, the classic newsvendor problem setup is given. The selling season, as mentioned, is one period, whereas the selling price remains constant over that period. Furthermore, we are not including customer goodwill in our model and as a consequence, unmet demand is lost without incurring costs. Total sales S equal the minimum of ordered goods Q by the retailer or the total amount of demand at the end of the period, that is $S = \min(Q, y)$. Accordingly, the retailer has a single-replenishment possibility. Goods that are left over at the end of the selling period have a salvage value of v. In the case of an existing buy-back contract, the manufacturer agrees to buy back all unsold items from the retailer for a fixed price s after the selling season. If there is no such contract, the salvage value is kept by the retailer. The manufacturer has production costs of c and unlimited production capacities. We assume that the manufacturer can not utilize economies of scale, that is the production costs per item are constant. For the basic framework we assume that a certain (constant) percentage α of the periods' sold goods is returned to the retailer, who gives the customers a full refund. The manufacturer then gives the retailer a refund to the amount of w. As mentioned, we also study price-dependent returns what, however, does not alter the presented framework. The vendor is in charge of handling the returned product, i.e. shipping, inspection, possible refurbishment or scrapping of the items. The salvage value of a returned item is represented by v_r. Incurred logistic costs on average per returned good are l_1 for the manufacturer and the retailer faces l_2 in costs. Total reverse logistic costs are $l = l_1 + l_2$. The letter β is used to express the fraction of the total logistic costs l faced by the retailer, i.e. $\beta = \frac{l_1}{l_1+l_2} \times 100$. Of course β varies greatly from industry to industry, depending on how much work product returns cause for the retailer and the manufacturer, respectively. Finally, R represents the total amount of consumer returns. Consequently, R can be expressed as $R = \alpha \times S$.

As in relevant literature, assumptions are made to have a meaningful problem. We require $r > w > c$ and $w > s > v \geq v_r$. Additionally, $r > w - (\frac{\alpha}{1-\alpha})l_2$ and $w > (\frac{c}{1-\alpha}) + (\frac{\alpha}{1-\alpha})(l_1 - v_r)$ ensures that both players face positive profits when considering returns. More restrictions are mentioned in the respective chapters when needed.

Figure 3.1 illustrates the selling and return process and shows monetary flows in the supply chain.

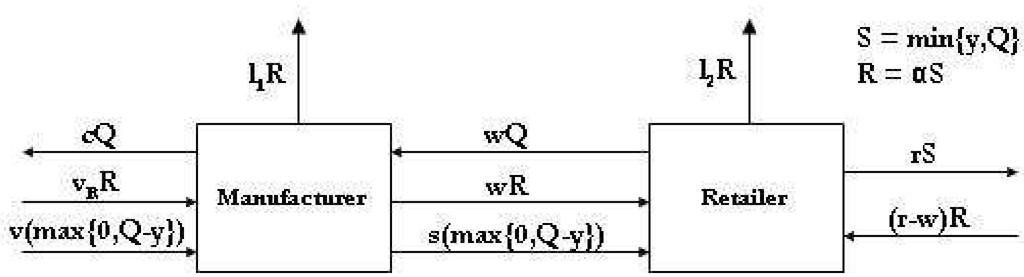

Figure 3.1. Setup and Monetary Flows within the Supply Chain (Ruiz Benitez and Muriel (2007) [42])

We are also assuming a certain sequence of actions or events that occur within the considered period.

1. Ahead of the selling period the wholesale price w is assessed by the vendor. In case of an existing buy-back contract the resale price s is also set.

2. The order quantity Q and, in case of stochastic and price-dependent demand, also the retail price r, at which the goods are sold, are determined by the retailer.

3. As a last step, demand uncertainty is observed and total sales S and the amount of product returns R as well as profits or losses in the supply chain are found.

Since the model was first formulated in Ruiz Benítez and Muriel (2007) [42], we mainly stick to the notation given in their work. The manufacturer is considered as female and the retailer as male. The use of the superscripts ^{CR} and ^{IR} is different. In this work, ^{CR} and ^{IR} refer to the optimization strategies after which *the players* act in the symmetric or asymmetric settings. If surrounded by brackets, however, the symmetric optimization policies are referred to. Since we are looking at the supply chain setting of two asymmetrically acting players, i.e. only one player considers returns, we introduce the superscripts ^{MC,RI} and ^{MI,RC} to describe these additional cases. ^{MC,RI} expresses that the manufacturer is considering returns, whereas the retailer's optimization is without taking them into account. Thus, ^{MI,RC} describes the respective converse setting of the optimization process. Subscripts $_M$, $_R$ and $_T$ indicate whether the manufacturer, the retailer or the total supply chain is considered. As examples, total profits $\Pi_T^{MI,RC}$ in the asymmetric setting (MI, RC) consist of the profits of the manufacturer (Π_M^{IR}) and the retailer (Π_R^{CR}), whereas the retailer's profits in policy (IR) are expressed with $\Pi_R^{(CR)}$.

3.2 Model for Stochastic Demand

We further present the formulas we are going to use in the thesis, whereas we firstly introduce the model for stochastic demand. The retailer faces stochastic demand y, with density and cumulative functions $f(\cdot)$ and $F(\cdot)$, respectively. The retail price of the good is exogenously given. This assumption, which is a basic microeconomic concept in fully competitive markets, can be made since we are considering an industry where no player has enough market share to dictate the retail price. Note, that the formulas presented in this section include the buy-back option. The case without a buy-back contract (i.e. a wholesale contract) can be covered by simply setting s equal to v. This gives no incentive to the retailer selling back left over inventory to the manufacturer. The salvage value then remains at the retailer. In the asymmetric settings, we are looking at a decentralized supply chain where each player tries to maximize its own profits independently. In order to describe the asymmetric optimization process, we first present the formulas that are used by the players when optimizing their respective profits in a decentralized supply chain in sections 3.2.2 and 3.2.2. The description of the respective asymmetric policies according to the optimization processes is done in section 3.4, whereas we also extent analytical findings from the symmetric policies (IR) and (CR). However, the symmetric cases where both supply chain members either consider or ignore returns in the optimization procedure are well-described in Ruiz Benítez and Muriel (2007) [42].

3.2.1 Centralized System

In the centralized system the whole system behaves as if operated by a central planner who is maximizing the system-wide profits. The centralized systems have been studied by Ruiz Benítez and Muriel (2007) [42] (considering returns) and Pasternack (1985) [41] (ignoring returns). As we are focussing on decentralized decision making, the centralized systems are of minor importance for our work. However, since we are using them for matters of comparison as benchmark cases, we briefly present the respective formulas here. Total expected profits - including consumer returns - for the supply chain are:

$$\Pi_{C,T}^{CR}(Q) = (r(1-\alpha) - \alpha(l - v_r) - v)[\int_0^Q xf(x)dx + \int_Q^\infty Qf(x)dx] - Q(c - v) \quad (3.1)$$

Differentiating expression 3.1 with respect to Q results in:

$$Q_C^{CR*} = F^{-1}(\frac{r(1-\alpha) - \alpha(l - v_r) - c}{r(1-\alpha) - \alpha(l - v_r) - v}) \quad (3.2)$$

In Ruiz Benítez and Muriel (2007) [42] it is shown that this solution is unique and therefore a global maximum. The corresponding expected profits in a centralized system where no consumer returns are considered equals the following expression:

$$\Pi_{C,T}^{IR}(Q) = -cQ + \int_0^Q [xr + (Q - x)v]f(x)dx + r\int_Q^\infty Qf(x)dx] \quad (3.3)$$

The optimal order quantity is:

$$Q_C^{IR*} = F^{-1}(\frac{r - c}{r - v}) \quad (3.4)$$

3.2.2 Decentralized System

In the decentralized system manufacturer and retailer try to maximize profits on their own. The supply chain members are rational decision makers which use existing information about prices and/or quantities to reach the best expected profits. In other words, each supply chain member is acting in his own best interest and is not concerned about system-wide profits. Below are the formulas that are applied in the decentralized optimization processes.

Players Considering Returns

Firstly, we present the formulas for the retailer and manufacturer when considering consumer returns in their optimization process. According to Ruiz Benítez and Muriel (2007) [42] the retailers expected profit in one selling season is:

$$\Pi_R^{CR}(Q) = -wQ + (r(1-\alpha) - \alpha(l_2 - w))[Q - \int_0^Q (Q-x)f(x)dx] + s\int_0^Q (Q-x)f(x)dx \tag{3.5}$$

The wholesale price w is given by the manufacturer. In order to find the optimal order amount Q^*, we differentiate $\Pi_R^{CR}(Q)$ with respect to Q and set this amount equal to 0. This gives us the following result:

$$Q^{CR*} = F^{-1}\left(\frac{(1-\alpha)r - \alpha(l_2 - w) - w}{(1-\alpha)r - \alpha(l_2 - w) - s}\right) \tag{3.6}$$

Note that the second derivative with respect to Q is non-negative, thus the gained Q is optimal.

$$\frac{\partial^2 \Pi^{CR}(Q)}{\partial Q^2} = -f[(1-\alpha)r - \alpha(l_2 - w)] \leq 0 \tag{3.7}$$

In case of considering the returns, the manufacturer faces profits according to the following formula:

$$\Pi_M^{CR}(w, s|Q) = Q(w - c - s + v) - [\alpha(w + l_1 - v_r) - s + v](Q - \int_0^Q (Q-x)f(x)dx) \tag{3.8}$$

where Q is as written in formula 3.6.

Players Ignoring Returns

The optimization formulas according to which manufacturer and retailer find their optimal respective wholesale price or order amount by not taking consumer returns into account are presented in this section. The expected profits for the retailer in case of a decentralized two echelon supply chain have been studied by Pasternack (1985)

[41]. However, we are not including goodwill in our model and the retailer can sell back all items that are left over at the end of the selling period.

$$\Pi_R^{IR}(Q) = Q(r-w) - (r-s)\int_0^Q (Q-x)f(x)dx \tag{3.9}$$

Again, we differentiate $\Pi_R^{IR}(Q)$ with respect to Q to find the optimal value of Q. This gives:

$$Q^{IR*} = F^{-1}(\frac{r-w}{r-s}) \tag{3.10}$$

The second derivative is non-positive:

$$\frac{\partial^2 \Pi^{IR}(Q)}{\partial Q^2} = (s-r)f(Q) \leq 0 \tag{3.11}$$

Thus, formula 3.10 describes again a global maximum.

By setting α to zero in formula 3.8 we can derive the manufacturer's profit when ignoring returns.

$$\begin{aligned}
\Pi_M^{CR}(\alpha = 0) &= Q(w-c-s+v) + (s-v)(\int_0^Q xf(x)dx + \int_Q^\infty Qf(x)dx) \\
&= Q(w-c-s+v) + (s-v)[\int_0^Q xf(x)dx + \int_0^\infty Qf(x)dx - \int_0^Q Qf(x)dx] \\
&= Q(w-c) - (s-v)(\int_0^Q (Q-x)f(x)dx)
\end{aligned} \tag{3.12}$$

$$\Pi_M^{IR}(w, s|Q) = Q(w-c) - (s-v)(\int_0^Q (Q-x)f(x)dx) \tag{3.13}$$

Q is according to formula 3.10.

3.3 Model for Stochastic and Price-dependent Demand

Within the following sections we present the formulas for stochastic and price-dependent demand. Demand at the retail level is now affected by the retail price r as well. In other words, an altered retail price leads to a change in demand for the products. We therefore modify our initial model by a distribution of the demand parameterized by the retail price r. Two groups of stochastic and price-dependent models can be found in literature: the additive demand model, $D(r, x) = y(r) + x$ (Mills (1959) [37]), and the multiplicative demand model, $D(r, x) = y(r)x$ (Karlin and Carr (1962) [30]) where $y(r)$ is decreasing in the retail price r and x is the random component with mean 1. In what follows, we utilize the multiplicative model that is formulated in Emmons and Gilbert (1998) [16] and make necessary extensions in order to include customer returns. Following its wide use throughout the literature, expected demand is assumed to be of the form $D(r) = b \times (r - k)$ with $b < 0$ and $k > 0$. Because demand can't be negative, we require $k \geq r$. Since $D(r)$ is only defined on $[c, r_{up}]$, $D(r) = 0 \; \forall \; r \geq r_{up}$. The expected demand quantity $D(r)$ is assumed to be decreasing in the retail price, to be continuous, nonnegative and also twice differentiable. Consequently, the actual demand, y, can be modeled as a product of the expected demand $D(r)$ and the positive random variable x. Hence, the density function for demand can be expressed as follows:

$$g(x, r) = D(r)^{-1} f(\frac{x}{D(r)}) \text{ with } y \geq 0, \tag{3.14}$$

where $f(\cdot)$ is the density distribution function of x and $F(\cdot)$ is the corresponding cumulative distribution function. $F(\cdot)$ is assumed to be invertible and $f(\cdot)$ shall have a continuous derivative $f'(\cdot)$. Both players, manufacturer and retailer, have knowledge of the respective demand distribution and the retailer can, up to a certain extent, control demand with the setting of the retail price r. As a consequence the retailer finds his optimal order quantity now to be dependent of D(r) and profits of the players are dependent of D(r) as well.

In the next sections we present the formulas for the profits of both, manufacturer and retailer as well as the optimal order quantities. We start out with the centralized supply chain and then go over to the decentralized case. The model that we are considering in the following is an extension of the classical newsvendor problem (see Emmons and Gilbert (1998) [16]). Additions to include consumer returns occurring at the retail level are studied by Ruiz Benitez and Muriel (2007) [42]. For the decentralized systems the terms include the buy-back option. Again, by simply setting s to v the wholesale contract can be modeled.

3.3.1 Centralized System

Ignoring Returns

Total profit for the supply chain is:

$$\Pi^{IR}(Q,r) = (r-v)(D(r) - \int_{Q/D(r)}^{\infty} (D(r)x - Q)f(x)dx) - Q(c-v) \tag{3.15}$$

By differentiating the latter expression with respect to Q we find the optimal order quantity:

$$Q^{IR*}(r) = D(r)F^{-1}\Big(\frac{r-c}{r-v}\Big) \tag{3.16}$$

For a fixed retail price r, the expected optimal profits are:

$$\Pi^{IR}(r) = (r-v)D(r)\int_{0}^{F^{-1}(\xi_1)} xf(x)dx \tag{3.17}$$

where $\xi_1 = (r-c)/(r-v)$.

However, the inverse cumulative distribution function makes it difficult to analyze and obtain a closed form expression for the optimal retail price. For the purpose of gaining more insight into the problem, we can simplify the expression by assuming f(x) to be a uniform distribution on the interval [0,2]. With this assumption the retailer's profit reduces to:

$$\Pi^{IR}(r) = \frac{(r-c)^2}{r-v} D(r)$$

As we assume a linear demand model with the form $D(r) = b \times (r-k)$, where $b < 0$ and $k > 0$, D(r) is strictly decreasing in r. Thus, an explicit expression for the retail price r can be easily obtained by solving the equation resulting when taking the derivative of (3.18) with respect to r and equal it to zero. The retailer's profit maximizing price is

$$r^{IR*} = \frac{3v + k + \sqrt{(k+8c-9v)(k-v)}}{4}$$

Having r^{IR*} the optimal order amount Q^{IR*} is easy to obtain:

$$Q^{IR*} = \frac{2D(r)(r^* - c)}{r^* - v}$$

Considering Returns

The supply chain expected profit is:

$$\Pi^{CR}(Q,r) = ((1-\alpha)r - \alpha(l - v_r) - v)(D(r) - \int_{Q/D(r)}^{\infty} (D(r)x - Q) f(x) dx) - Q(c - v) \tag{3.18}$$

The optimal order quantity Q^* is found by differentiating $\Pi^{CR}(Q,r)$ with respect to Q and simplifying:

$$Q^{CR*}(r) = D(r) F^{-1}\Big(\frac{(1-\alpha)r - \alpha(l - v_r) - c}{(1-\alpha)r - \alpha(l - v_r) - v}\Big) \tag{3.19}$$

Then, for a fixed retail price r, the expected optimal profits follow

$$\Pi^{CR}(r) = ((1-\alpha)r - \alpha(l - v_r) - v) D(r) \int_0^{F^{-1}(\xi_2)} x f(x) dx \tag{3.20}$$

where $\xi_2 = ((1-\alpha)r - \alpha(l-v_r) - c)/((1-\alpha)r - \alpha(l-v_r) - v)$.

As shown by Ruiz Benitez and Muriel (2007) [42] under deterministic and price dependent demand the optimal retail price increases and thus the optimal ordering quantity decreases when consumer returns are considered. This is valid if $D(r)\times(r-c)$ is unimodal.

By making the assumption that $f(x)$ is a uniform distribution defined on the interval [0,2] it is possible to find an explicit expression for r. Taking the specified uniform distribution, the expected optimal profit for the centralized supply chain becomes:

$$\Pi^{CR}(r) = \frac{((1-\alpha)r - \alpha(l-v_r) - c)^2}{(1-\alpha)r - \alpha(l-v_r) - v} D(r)$$

Taking derivative of the latter expression with respect to r, equal it to zero and simplifying gives:

And thus, the optimal order quantity is:

$$Q^{CR*} = \Big(\frac{(1-\alpha)r^* - \alpha(l-v_r) - c}{(1-\alpha)r^* - \alpha(l-v_r) - v}\Big) 2D(r)$$

$$\begin{aligned} r^{CR*} &= \frac{3\alpha(l-v_r) + 3v + (1-\alpha)k}{4(1-\alpha)} \\ &+ \frac{\sqrt{((1-\alpha)k + 8c - 9v - \alpha(l-v_r))((1-\alpha)k - v - \alpha(l-v_r))}}{4(1-\alpha)} \end{aligned}$$

3.3.2 Decentralized System

In the decentralized system players act rational. In other words, they act individually and seek to maximize their own profits instead of the total supply chain profits. This section presents the respective formulas for the expected profits and order quantities of the manufacturer and retailer in a decentralizes setting. We first present the expressions in case of consumer returns are ignored in the player's individual optimization process. Secondly, we consider the setting when consumer returns are included in the decision process. The latter formulas are presented in Ruiz Benitez and Muriel (2007) [42], whereas Emmons and Gilbert (1998) [16] consider the former case.

Players Ignoring Returns

Depending on the values w and s, which are set by the manufacturer, the retailer faces profits according to

$$\Pi_R^{IR}(Q,r) = (r-s)\left(\int_0^{Q/D(r)} D(r)xf(x)dx + \int_{Q/D(r)}^{\infty} Qf(x)dx\right) - Q(w-s) \quad (3.21)$$

For a specific r, the problem can be reduced to the traditional newsboy problem. Thus, the optimal order quantity in dependency of r is:

$$Q^{IR*}(r) = D(r)F^{-1}\left(\frac{r-w}{r-s}\right) \quad (3.22)$$

Hence, the retailer's profit function for the optimal order quantity and with given r is:

$$\Pi_R^{IR}(r) = (r-s)D(r)\int_0^{F^{-1}(\eta_1)} xf(x)dx \quad (3.23)$$

where $\eta_1 = (r-w)/(r-s)$.

As under stochastic demand, the manufacturer finds her profits, given that the retailer acts optimally by choosing (Q^*, r^*), according to the following formula:

$$\Pi_M^{IR}(w,s;r^*,Q^*) = (w-c)Q^* - (s-v)\int_0^{Q^*/D(r^*)} (Q^* - xD(r^*))f(x)dx \quad (3.24)$$

Identical to the centralized case, the inverse cumulative distribution function makes it difficult to analyze the formulas. Again, the assumption of a uniform distribution on the interval $[0,2]$ and $D(r) = b(r-k)$, the optimal order quantity and the retailer's profit function, given a retail price r when ignoring returns, are, respectively:

$$Q^{IR*}(r) = \Big(\frac{r-w}{r-s}\Big)2D(r)$$

$$\Pi_R^{IR*}(r) = \frac{(r-w)^2}{r-s}D(r)$$

Note that we require $k > w \geq s$. If $w \geq k$ the retailer would not be able to sell the item at a profit, since $D(r)$ is negative for any $r > w \geq k$. Taking the derivative of 3.23 and simplifying results in the retailer's optimal resale price:

$$r_R^{IR*} = \frac{3s + k + \sqrt{(k+8w-9s)(k-s)}}{4}$$

Consequently, the manufacturer's optimal profits are

$$\Pi_M^{IR}(w,s;r_R^*,Q_R^*) = (w - c(1-\eta_2))Q_R^* - \frac{(s-v)(Q_R^*)^2}{4D(r_R^*)}$$

where $\eta_2 = (r_R^* - w)/(r_R^* - s)$.

Players Considering Returns

When considering returns in the optimization process, the retailer expects profits, depending on w and s, to be as follows:

$$\begin{aligned}\Pi_R^{CR}(Q,r) &= ((1-\alpha)r - \alpha(l_2 - w) - s)\Big(\int_0^{Q/D(r)} D(r)xf(x)dx + \int_{Q/D(r)}^{\infty} Qf(x)dx\Big) \\ &- Q(w-s) \qquad (3.25)\end{aligned}$$

For a given retail price r the latter expression can be reduced and the optimal order quantity is:

$$Q^{CR*}(r) = D(r)F^{-1}\Big(\frac{(1-\alpha)r - \alpha(l_2-w) - w}{(1-\alpha)r - \alpha(l_2-w) - s}\Big) \qquad (3.26)$$

The retailer's profit function for the optimal order quantity and with given r is then

$$\Pi_R^{CR}(r) = ((1-\alpha)r - \alpha(l_2 - w) - s)D(r)\int_0^{F^{-1}(\eta)} xf(x)dx \tag{3.27}$$

where $\eta = ((1-\alpha)r - \alpha(l_2 - w) - w)/((1-\alpha)r - \alpha(l_2 - w) - s)$.

The manufacturer finds her profits including the costs of returns according to the following formula. The retailer is expected to act rational again.

$$\begin{aligned}\Pi_M^{CR}(w, s; r^*, Q^*) &= (w-c)Q^* - (s-v)\int_0^{Q^*/D(r^*)} (Q^* - xD(r^*)f(x)dx \\ &-(\alpha(w + l_1 - v_r))[\int_0^{Q^*/D(r^*)} D(r^*)xf(x)dx + \int_{Q^*/D(r^*)}^{\infty} Q^* f(x)dx]\end{aligned} \tag{3.28}$$

Again, assuming f(x) to be a uniform distribution defined on $[0, 2]$ and Demand to be of the type $D(r) = b(r-k)$, we find the optimal order quantity and the profit function of the retailer:

$$Q^{CR*}(r) = \Big(\frac{(1-\alpha)r - \alpha(l_2 - w) - w}{(1-\alpha)r - \alpha(l_2 - w) - s}\Big)2D(r)$$

$$\Pi_R^{CR}(r) = \Big(\frac{((1-\alpha)r - \alpha(l_2 - w) - w)^2}{((1-\alpha)r - \alpha(l_2 - w) - s)}\Big)D(r)$$

Of course, the optimization formulae include the costs of returns. The manufacturer's share $w + l_1 - v_r$, whereas the retailer faces $r - w + l_2$ of the total return costs $r + l - v_r$. The following expressions for the manufacturer's profit function and the retailer's optimal price are obtained by Ruiz Benitez and Muriel (2007) [42]:

$$\begin{aligned} r_R^{CR*} &= \frac{3\alpha(l_2 - w) + 3s + (1-\alpha)k}{4(1-\alpha)} \\ &+ \frac{\sqrt{((1-\alpha)k + 8w - 9s - \alpha(l_2 - w))((1-\alpha)k - s - \alpha(l_2 - w))}}{4(1-\alpha)}\end{aligned}$$

and

$$\begin{aligned}\Pi_M^{CR}(w,s;r_R^{CR*},Q_R^{CR*}) &= (w-c-\alpha((w+l_1-v_r)+v)(1-\eta_2))Q_R^{CR*} \\ &- \frac{(s+(\alpha(w+l_1-v_r)-v))(Q_R^{CR*})^2}{4D(r_R^{CR*})}\end{aligned}$$

where $\eta_2 = ((1-\alpha)r_R^{CR*} - \alpha(l_2-w) - w)/((1-\alpha)r_R^{CR*} - \alpha(l_2-w) - s)$.

3.4 Asymmetric Optimization Procedures

An asymmetric optimization process is given if manufacturer and retailer do not optimize for w or Q, respectively, with regards to consumer returns similarly. Since the manufacturer has to find the optimal wholesale price initially, she first has to make an assumption on whether the retailer considers returns or not. In the asymmetric cases, the wrong assumption is made. Clearly, the type of the considered demand distribution changes only the formulae for profits and order quantities but has no effect on the asymmetric optimization process. For purposes of convenience we describe the asymmetric setup by means of the hitherto presented stochastic demand formulas.

We now consider the two policies (MC, RI) and (MI, RC).

Policy (MC, RI)

In this case, the manufacturer is considering consumer returns in his optimization process for the wholesale price w. In turn, the retailer does not consider them. This means that the manufacturer erroneously makes the assumption that the retailer finds his optimal order quantity under the premise of consumer returns. The optimization process is as follows:

1. The manufacturer optimizes for w.

   In order to do this, an exhaustive search for the best wholesale price is conducted. For any w the respective optimal order amount for the retailer is determined (see formula 3.6). After this step the manufacturer's total profits can be calculated. Observe that Q is found by the manufacturer by assuming consumer returns and she therefore uses formula 3.8.

2. The retailer calculates his optimal order amount Q.

   Formula 3.10 is applied by taking the given wholesale price w, which was found through optimization by the manufacturer in the previous step. Note that this means he finds the optimal Q without considering returns. The retailer's profit is calculated according to 3.9.

3. Profits of the manufacturer are updated and total supply chain profits for the case (MC, RI) are calculated.

Comparing the order amounts of the retailer under the two policies (IR) and (CR), which are studied by Ruiz Benitez and Muriel (2007) [42], we find that the amount of ordered items is higher in the case without consumer returns.

$$Q^{IR} = F^{-1}(\frac{r-w}{r-s}) \geq F^{-1}(\frac{r-\alpha(r-w-l_2)-w}{r-\alpha(r-w-l_2)-s}) = Q^{CR} \tag{3.29}$$

This is true because $w \leq s$. As a consequence, the manufacturer receives more orders from the retailer than she had assumed in her optimization, what entails a higher total profit as well. We evaluate the effects of this false assumption on the profits and order quantities of the retailer, the manufacturer, and on the total supply chain in the computational study part.

Policy (MI, RC)

Now the manufacturer does not take returns into account, but the retailer does. The sequence of actions is according to the one stated for the first asymmetric case:

1. The manufacturer optimizes for w.

   Since she assumes returns are ignored in the whole optimization process, formulas 3.13 and 3.10 are used to find the optimal w or the assumed order amount, respectively.

2. The retailer calculates his optimal order amount Q.

   Since the retailer considers returns, he finds his profits according to the wholesale price w of the manufacturer and formula 3.5. The optimal order quantity Q according to 3.6.

3. Total profits of the manufacturer and supply chain for the case (MI, RC) are calculated.

Since demand faced by the manufacturer is lower when considering returns in the optimization process, the retailer now makes a smaller order than assumed by the manufacturer. Hence, profits are lower for the manufacturer. Again, the effects are studied in the following chapters.

CHAPTER 4

STOCHASTIC DEMAND

This chapter extends the stochastic demand model presented earlier with computational studies. The goal of the computational work is to find and compare the optimal order quantities, the respective wholesale prices, and the profits for the retailer and manufacturer as well as for the whole supply chain in the asymmetric settings. In order to compare retrieved results, both symmetric decentralized and centralized policies are considered, whereas the centralized system - when considering returns - realizes the best performance the supply chain can achieve (Ruiz Benítez and Muriel (2007) [42]). The policies under consideration in the computational study are those, which are described in section 3.4, namely (MC, RI) and (MI, RC).

Throughout this chapter demand is assumed to be stochastic and therefore represented by a normal distribution $y \sim N(\mu, \sigma)$. For the base case we choose $\mu = 3$ and $\sigma = 0.75$. The retail price r is 4 per unit and the salvage values v and v_r are set to zero. As stated in the introduction, return rates reach from 6% to 75% in extreme cases. For now, we set $\alpha = 0.2$. The manufacturer bears most of the reverse logistic costs incurred by consumer returns. Corresponding to the handling of returned products, we consider that the retailer faces only 5% of total logistic costs $l = 2$. Accordingly, $l_1 = 1.9$ and $l_2 = 0.1$. In order to calculate final profits when a player ignores returns in its optimization process, the cost of returns have to be subtracted a posteriori. The share of reverse logistic costs carried by the retailer and manufacturer is $r - w + l_2$ and $r + l_1 - v_r$, respectively. This combines to total logistic costs per unit that are incurred by consumer returns of $r - v_r + l$. For the first part, a buy-back option is not considered, that is, the value s is set to v.

4.1 Wholesale Price-Only Contract

Using Maple interesting results are retrieved for the cases of asymmetric optimization process especially when comparing order quantities and profits with the decentralized symmetric optimization processes. Figure 4.1 shows the assumed order quantities Q_M^{CR} and Q_M^{IR} of the manufacturer and the order quantities Q_R^{CR} and Q_R^{CR} that are in fact realized by the retailer. The curves subtend the x-axis at the value of the retail price. Clearly, the assumed order amount by the vendor ignoring returns is the same as the indeed realized order size by the retailer if he ignores consumer returns as well and vice versa. However, the graphs reflect that the order amounts in case of ignored returns are higher than if included as we showed earlier. Consequently, in the asymmetric setting, the manufacturer faces lower profits than she assumed when including returns or higher profits when not taking account of them in her optimization process.

In general, results for the asymmetric case reflect the findings in the symmetric settings. Accordingly, in the asymmetric supply chain setting the profits for the manufacturer are negative for low values of w. The retailer, in turn, faces his highest profits at low wholesale prices. As in the symmetric cases, the vendor is significantly better off after a threshold w_t following the asymmetric setting (MC, RI). This describes the same situation as found in the work by Ruiz Benítez and Muriel (2007) [42], where the manufacturer makes more profit if the retailer ignores consumer returns in his optimization process. On the other hand, after a certain w profits for the retailer are higher when he includes consumer returns in his decision making. Note, that the profit functions for the retailer are the same for the policies (MC, RI) and

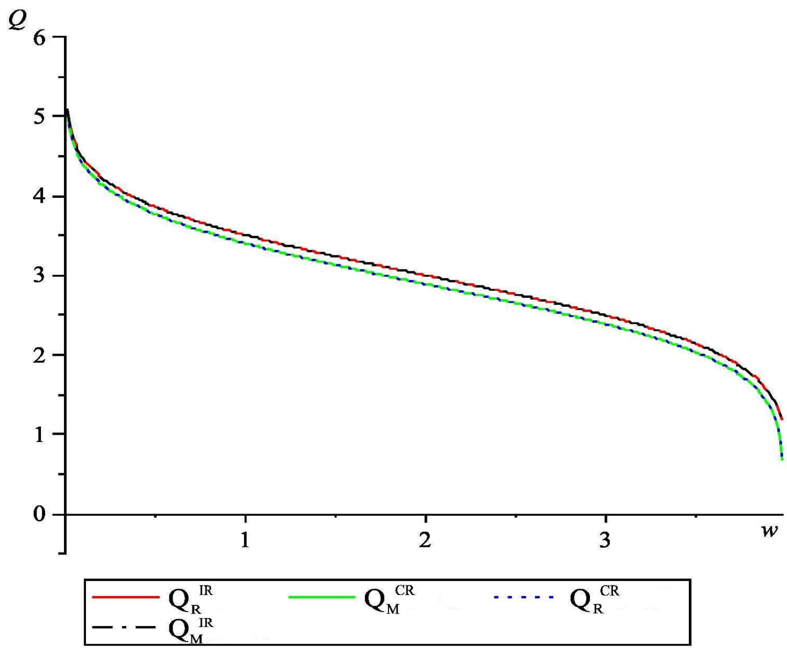

Figure 4.1. Order Quantity of the Retailer over w under Stochastic Demand

(IR) or (MI, RC) and (CR), respectively. Thus, the difference in the retailers profits for the two asymmetric cases is very small.

Regarding coordination, the total supply chain profits obtained in the asymmetric cases (MC, RI) and (MI, RC) are in between the range of the symmetric policies (CR) and (IR). However, profits of the manufacturer and retailer can be higher (or lower) than the best (or worst) performance reached in the decentralized cases. For the manufacturer this is the case because she expects to have profits according to the symmetric cases' results, whereas the in fact realized order amount is different, what as a consequence lowers or increases her final profits. The retailer in turn can realize higher profits than in (CR) because a lower wholesale price w of 3.47 instead of 3.56 is given by the vendor, what allows him to move to the left on his profit function and is consequently raising his profits (see figure 4.2). Under the policy (MC, RI) the observation is the opposite. Due to a higher transferred wholesale price of 3.56

		Symmetric		Asymmetric	
		(CR)	(IR)	(MC,RI)	(MI,RC)
Cent.	Q^*	3.27	3.50	-	-
	Π	4.61	4.58	-	-
Decent.	Q^*	1.97	2.16	2.08	2.06
	w^*	3.56	3.47	3.56	3.47
	Π_R	0.5405	0.6805	0.5355	0.6862
	Π_M	2.9273	3.0746	3.0970	2.9112
	Π_T	3.4678	3.7551	3.6325	3.5974

Table 4.1. Equilibrium Values for Centralized and Decentralized Policies including the Asymmetric Settings in the Base Case with a Normally Distributed Demand

instead of 3.47 resulting profits are worse than in (IR). Looking at the relative values though, both, the retailer and the vendor can be only about 1% better or worse off in the asymmetric cases compared to the initial symmetric ones.

As a result, supply chain coordination is not reached and the centralized policy (IR) still performs best. Table 4.1 comprehends for each policy the optimized order quantities and wholesale prices as well as profits for each player and the total supply chain. Note that optimal wholesale prices are the same because of the incorrect assumption about the optimization process which the manufacturer makes initially. Figure 4.2 visualizes profits of the players and of the total supply chain for the two considered asymmetric policies as a function of the wholesale price w.

Our computational study also shows that the profit-curves in the asymmetric cases, which the manufacturer indeed realizes after receiving the order amount from the retailer, are the same than respective curves of the symmetric policies. Assumed profits $\Pi_{M,ass}^{MI,RC}$ and $\Pi_{M,ass}^{MC,RI}$ are found by taking $\Pi_M^{IR}(w, s|Q^{IR*})$ or $\Pi_M^{CR}(w, s|Q^{CR*})$, what equals the symmetric optimization cases (IR) and (CR). Now, observe in figure 4.3 that the assumed profit functions are identical to the indeed realized profit functions of the vendor in (MC, RI) and (MI, RC), i.e. $\Pi_M^{MC,RI}(w)$ and $\Pi_M^{MI,RC}(w)$. Different profits to the symmetric cases are realized because the order quantity has

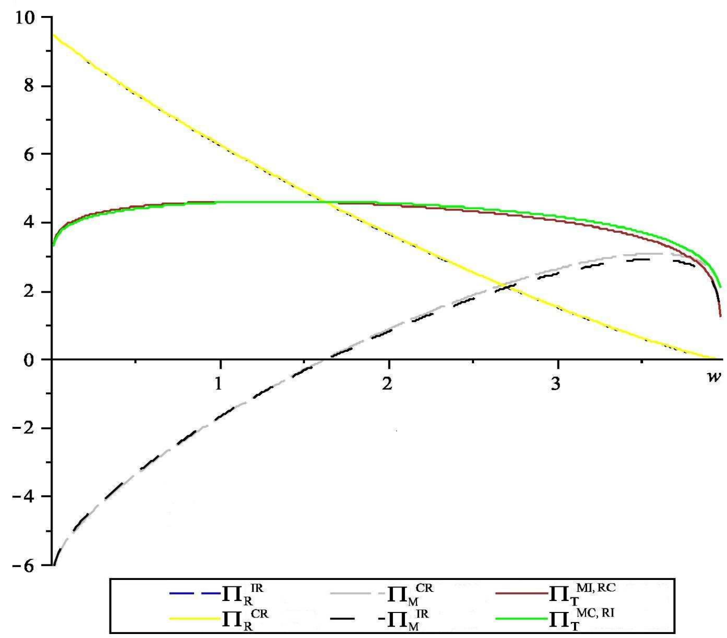

Figure 4.2. Base Case Profits of Manufacturer, Retailer, and the Total Supply Chain in the Asymmetric Settings under Stochastic Demand

changed. However, this is only valid under a price-only contract, that is if s is set to v. We will see changes that occur when considering buy-back rebates.

4.1.1 Sensitivity Analysis

In order to find the impacts of consumer returns on supply chain coordination in the case of asymmetric settings and to show the robustness of our initial findings, a sensitivity analysis is conducted. Different values for c, r and v, as well as changes in l, α, β, and the coefficient of variation $\frac{\sigma}{\mu}$ are considered. Additionally, the option of a buy-back contract (i.e. $s > 0$) is studied extensively. Note that for high values of σ a truncated normal distribution is used to avoid negative demand. Unless otherwise noted, the settings of the base case are used, that is $\alpha = 0.2$, $\beta = 0.05$, $l = 2$ and the salvage values v and vr are set to zero. Furthermore, no repurchase option is yet offered by the retailer.

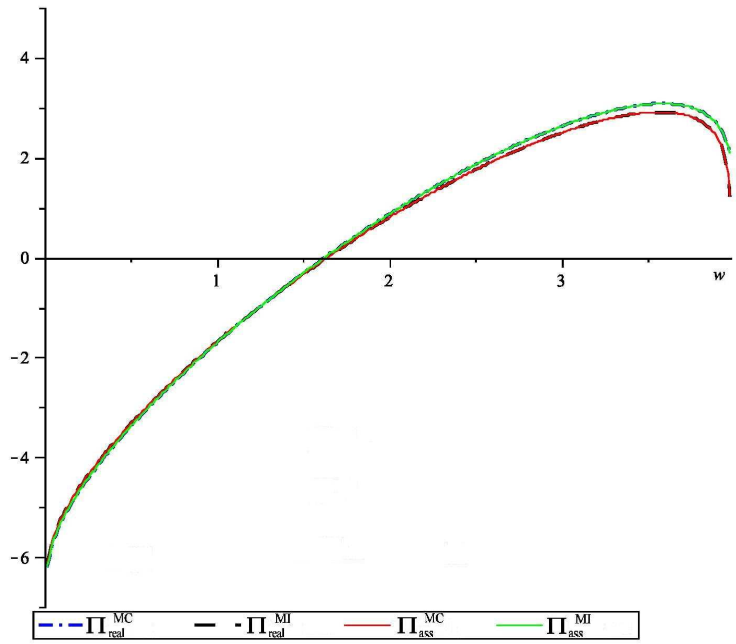

Figure 4.3. Assumed and indeed Realized Profits of the Manufacturer under Stochastic Demand in the Asymmetric Settings

Changes in Beta and Different Return Rates

It is intuitive that profits of the supply chain members are affected by the share of logistic costs they have to bear, i.e. l_1 and l_2, and by the overall product return rate α. In the following, we evaluate the robustness of our findings in the base case and therefore vary the percent share of logistic costs faced by the manufacturer and retailer, β, and the percent volume of returns, α.

Figure 4.4 shows the optimal order quantities and profit functions for both asymmetric cases for different magnitudes of β. Identical to the results of Ruiz Benítez and Muriel (2007) [42], the optimal wholesale price decreases when the manufacturer considers returns and remains constant when ignoring them. Consequently, for the asymmetric cases the optimal order quantity of the retailer decreases in policy (MI, RC) and increases in policy (MC, RI). In the latter case, the reason is that on one hand the retailer ignores returns, i.e. the factor β, but on the other hand

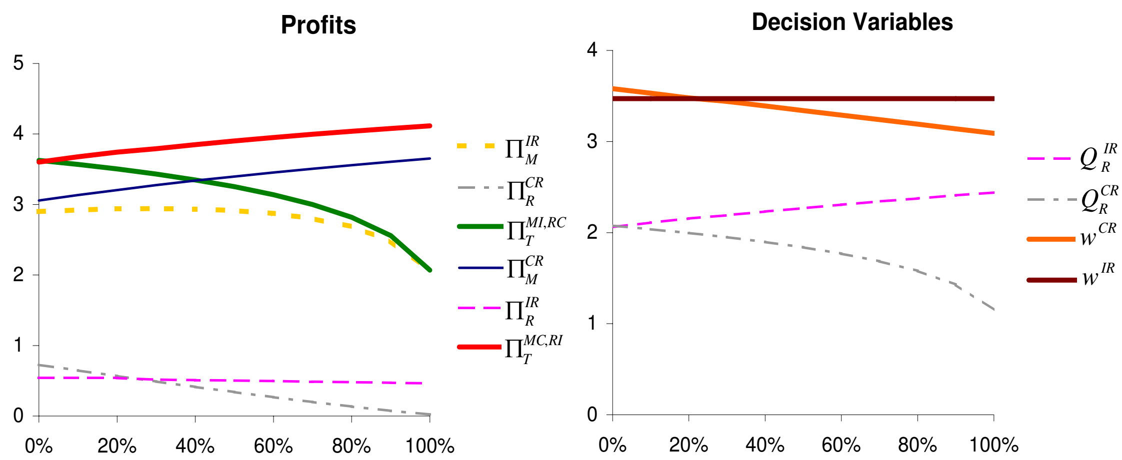

Figure 4.4. Profits, Order Quantities and Optimal Wholesale Prices for Different Shares of Logistic Costs β in the Asymmetric Settings

lower wholesale prices are submitted by the vendor. However, his profits only decline marginally, what is due to the fact that the higher logistic costs are almost fully compensated by higher sales. The total profit of the supply chain $\Pi_T^{MC,RI}$ raises with β, since the lower wholesale price w coordinates the system better. For the policy (MI, RC) total supply chain profits decline with a rising β. The more logistic costs the retailer has to bear, the lower his order quantity is, what can be seen as a reaction on high return costs. *In other words, the effect of "double marginalization" in setting* (MI, RC) *increases for higher magnitudes of* β. Consequently, the retailer's profit $\Pi_R^{MI,RC}$ decreases steadily to zero. Since the manufacturer's profits are also decreasing, $\Pi_T^{MI,RC}$ is a falling function in β. Therefore the supply chain faces better coordination for higher values of β in the asymmetric case (MC, RI) than in the asymmetric base cases, whereas of the two supply chain members only the manufacturer can raise her profits significantly.

Figure 4.5 shows received profits, optimal and assumed order quantities as well as optimal wholesale prices in the asymmetric cases for different α-values with an equal share of logistic costs between the players. For both cases we find - as expected -

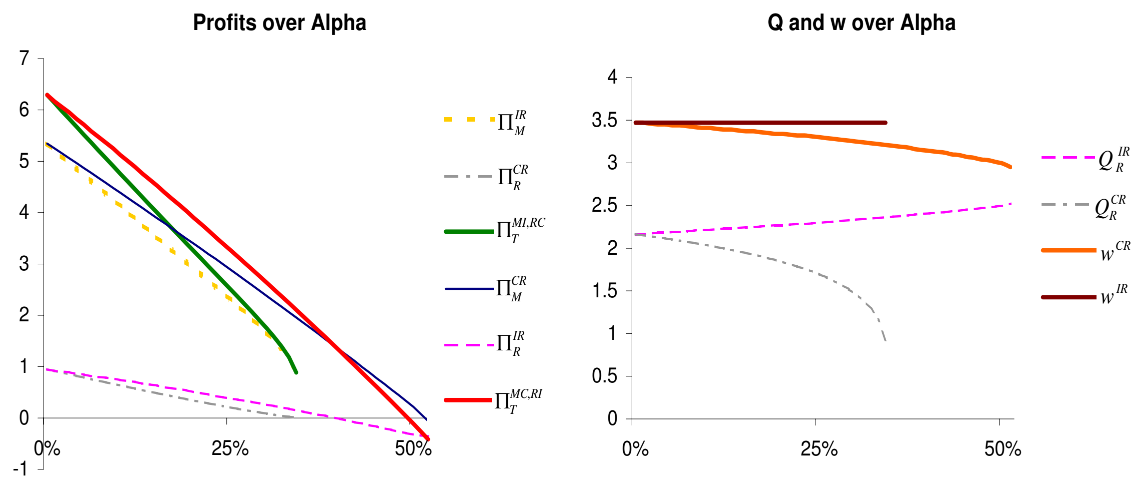

Figure 4.5. Profits, Order Quantities and Optimal Wholesale Prices for Different Return Rates for an Equal Share of Logistic Costs (β=0.5)

falling functions of profits. Considering $\Pi_T^{MC,RI}$ the total supply chain is facing a loss if more than 50% of all sold goods are returned. Excluding returns in his calculations, the retailer's profit is already negative before this threshold. He still expects to have positive profits, whereas, unnoticed beforehand, the costs of returns puts him in the red. At about 52% the manufacturer realizes a loss, and consequently a deal is not made for higher return rates. However, for the second asymmetric setting (MI, RC) the behavior is different.

Firstly, when including returns in the retailer's optimization process order quantities are lower, resulting in a worse performance of both players and the total supply chain than compared to (MC, RI). The wholesale price remains constant, since it is found according to formula 3.10 on page 20. At about 35% of returns the retailer's profit is getting negative. Solely provided with a wholesale contract he does not order anymore after this threshold. Consequently, policy (MI, RC) is not existing for $\alpha > 35\%$.

With lower or higher values of β, the curves for profits, Q^*, and w^* are dropping slower or faster, respectively. Consequently, the range over which policy (MI, RC)

$\beta = 0.05$

	α	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.51**	**0.84**
(MI,RC)	w^*	3.47	3.47	3.47	3.47	3.47	3.47	3.47
	Π_M^{IR}	4.11	2.91	1.76	0.67	-0.34	-0.44	-0.76
	Π_R^{CR}	0.82	0.69	0.56	0.44	0.32	0.31	0.00
	$\Pi^{MI,RC}$	4.92	3.60	2.32	1.11	-0.02	-0.13	-0.76
	Q_{CR}^*	2.11	2.06	1.99	1.92	1.82	1.81	0.37
(MC,RI)	w^*	3.50	3.56	3.63	3.74	3.89	3.88	-
	Π_M^{CR}	4.21	3.10	2.00	0.95	0.01	-0.08	-
	Π_R^{IR}	0.76	0.54	0.33	0.13	-0.02	-0.02	-
	$\Pi^{MC,RI}$	4.97	3.63	2.34	1.08	-0.01	-0.10	-
	Q_{IR}^*	2.14	2.08	2.01	1.86	1.56	1.59	-

$\beta = 0.5$

	α	**0.1**	**0.2**	**0.3**	**0.36**	**0.4**	**0.50**	**0.52**
(MI,RC)	w^*	3.47	3.47	3.47	3.42	-	-	-
	Π_M^{IR}	4.12	2.91	1.66	0.80	-	-	-
	Π_R^{CR}	0.63	0.34	0.08	0.01	-	-	-
	$\Pi^{MI,RC}$	4.75	3.25	1.74	0.80	-	-	-
	Q_{CR}^*	2.03	1.84	1.46	0.96	-	-	-
(MC,RI)	w^*	3.41	3.34	3.25	3.19	3.14	2.99	2.91
	Π_M^{CR}	4.39	3.40	2.37	1.75	1.32	0.21	-0.06
	Π_R^{IR}	0.74	0.50	0.26	0.09	-0.02	-0.33	-0.36
	$\Pi^{MC,RI}$	5.12	3.90	2.63	1.84	1.30	-0.11	-0.42
	Q_{IR}^*	2.21	2.27	2.33	2.38	2.41	2.50	2.55

$\beta = 0.95$

	α	**0.1**	**0.2**	**0.25**	**0.3**	**0.4**	**0.50**	**0.52**
(MI,RC)	w^*	3.47	3.47	3.39	-	-	-	-
	Π_M^{IR}	4.08	2.32	1.35	-	-	-	-
	Π_R^{CR}	0.46	0.05	0.00	-	-	-	-
	$\Pi^{MI,RC}$	4.54	2.37	1.35	-	-	-	-
	Q_{CR}^*	1.93	1.32	0.87	-	-	-	-
(MC,RI)	w^*	3.31	3.12	3.00	2.87	2.54	2.09	1.94
	Π_M^{CR}	4.54	3.63	3.14	2.63	1.52	0.29	-0.03
	Π_R^{IR}	0.73	0.46	0.32	0.16	-0.18	-0.57	-0.61
	$\Pi^{MC,RI}$	5.26	4.09	3.46	2.79	1.34	-0.28	-0.64
	Q_{IR}^*	2.29	2.42	2.49	2.57	2.74	2.96	3.03

Table 4.2. Profits, Order Quantities and Optimal Wholesale Prices for Different Return Rates and Shares of Logistic Costs (β=0.05, 0.5 and 0.95) under Stochastic Demand

	(MI,RC)					(MC,RI)				
CV	w^*	Q^*	Π_M^{IR}	Π_R^{CR}	$\Pi^{MI,RC}$	w^*	Q^*	Π_M^{CR}	Π_R^{IR}	$\Pi^{MC,RI}$
0.10	3.84	2.42	4.10	0.25	4.35	3.86	2.46	4.20	0.21	4.41
0.25	3.47	2.06	2.91	0.69	3.60	3.56	2.08	3.10	0.54	3.63
0.35	3.22	1.95	2.41	0.86	3.27	3.33	1.99	2.65	0.68	3.33
0.55	2.80	1.89	1.81	1.07	2.88	2.93	1.98	2.11	0.87	2.97
1.00	2.29	2.01	1.35	0.77	2.13	2.44	2.16	1.73	0.56	2.29

Table 4.3. Performance of the Asymmetric Settings for Different Coefficients of Variation

exists is wider or smaller. Table 4.2 lists the results for β-values of 0.05, 0.5 and 0.95. Under the setting (MC, RI), for smaller magnitudes of β, Π^{MC} drops below zero before Π^{RI} does, what means that the deal is not made. Moreover, the manufacturer's profits are calculated with the order quantity $Q^{IR*} > Q^{CR*}$. It follows, that the manufacturer finds his assumed profits to be negative before the respective α-values presented in table 4.2.

Different Mean and Variance of the Expected Demand

After studying different magnitudes of consumer returns and share of logistic costs, we perform a sensitivity analysis regarding the impacts of changes in the coefficient of variation ($CV = \frac{\sqrt{\sigma^2}}{\mu}$), which expresses the variation of the demand distribution relative to its mean. It directly affects all decision variables and profits. In order to prevent possible negative demand at a normal distribution for higher values of σ, a truncated normal distribution is being used. Table 4.3 shows the equilibrium values of the asymmetric policies for different coefficients of variation. The CV of 0.25 is highlighted in bold as it represents the base case.

For the symmetric policies Lariviere (1999) [32] proves that the optimal wholesale price is determined by the coefficient of variation and increases the smaller the CV is. This finding holds true for the asymmetric cases under stochastic demand as well. Interestingly, the order quantity which is finally realized by the retailer is convex, i.e.

it has its minimum for medium values of the CV. Total supply chain profits are always better in (MC, RI) - just as in the base case. The overall finding, which is declining profits in a rising CV, holds for the asymmetric cases as well as for the symmetric cases that are studied by Ruiz Benitez (2007) [42].

Different Production Costs and Retail Prices

Production costs and retail prices affect the marginal revenues of the players directly. Therefore, a sensitivity analysis concerning values of r under different logistic costs $l = \{0.5, 1, 2\}$ is performed. However, in the centralized cases the condition $r > \frac{c+\alpha(l-vr)}{1-\alpha}$, derived from the optimal order quantity (see condition (SC) in Ruiz Benitez and Muriel (2007) [42]), has to be observed. In the following, we show the effects of higher resale prices on the supply chain if the players decide asymmetrically when optimizing their profits. As both, production costs c and retail price r, have an identical impact on the profit margins of the players, we can simply focus on r. Table 4.4 shows absolute values for the two asymmetric cases compared to the best achievable results under the centralized policy (CR). The percent differences in profits to the respective decentralized cases (IR) or (CR) are presented in table 4.5. Omitted values are due to negative profits that cause percent values over 100%.

Conducting the according computational studies the following results are gained:

- Except for very small marginal revenues the total supply chain is for the given values of l better off in the case (MC, RI). Coordination is worse than in the symmetric centralized and decentralized policies, though.

- Regarding the retailer's profits we find him except for some high values of r better off under the setting (MI, RC), as opposed to the manufacturer, who makes higher profits if setting (MC, RI) applies. Note, that the manufacturer does not know he is better off when considering returns, since he expects the

	Asymmetric (MC, RI)					Asymmetric (MI, RC)					Central (CR)	
r	w^*	Q^{IR}	Π_M^{CR}	Π_R^{IR}	Π_T	w^*	Q^{CR}	Π_M^{IR}	Π_R^{CR}	Π_T	Q^*_{CR}	Π_T^{CR}
						$l = 0.5$						
1.38	1.37	1.28	0.00	0.01	0.01	1.32	1.64	-0.06	0.06	0.00	1.19	0.01
2	1.88	1.83	0.76	0.13	0.89	1.83	1.88	0.70	0.20	0.90	2.68	1.09
4	3.52	2.12	3.68	0.63	4.31	3.47	2.07	3.51	0.72	4.23	3.35	5.47
8	6.74	2.25	9.74	1.77	11.52	6.72	2.16	9.32	1.82	11.14	3.75	14.76
10	8.35	2.27	12.79	2.35	15.14	8.36	2.17	12.25	2.35	14.59	3.86	19.47
20	16.47	2.30	28.07	5.12	33.19	16.53	2.20	26.89	5.04	31.93	4.15	43.23
						$l = 1$						
1.51	1.49	1.34	0.00	0.00	0.01	1.42	1.70	-0.09	0.09	0.00	1.19	0.01
2	1.90	1.77	0.59	0.09	0.68	1.83	1.86	0.52	0.19	0.71	2.58	0.84
4	3.53	2.11	3.49	0.60	4.09	3.47	2.07	3.31	0.71	4.02	3.32	5.18
8	6.80	2.22	9.54	1.66	11.20	6.72	2.16	9.11	1.81	10.92	3.74	14.46
10	8.39	2.26	12.58	2.27	14.85	8.36	2.17	12.04	2.34	14.37	3.85	19.18
20	16.53	2.29	27.86	5.00	32.86	16.53	2.20	26.68	5.02	31.70	4.15	42.93
						$l = 2$						
1.76	1.73	1.41	0.01	0.00	0.01	1.63	1.76	-0.12	0.12	0.00	1.19	0.01
2	1.93	1.64	0.28	0.04	0.32	1.83	1.83	0.17	0.18	0.34	2.27	0.38
4	3.56	2.08	3.10	0.54	3.63	3.47	2.06	2.91	0.69	3.60	3.27	4.62
8	6.79	2.23	9.13	1.66	10.78	6.72	2.16	8.70	1.79	10.48	3.73	13.88
10	8.43	2.24	12.17	2.18	14.35	8.36	2.17	11.62	2.31	13.93	3.84	18.58
20	16.49	2.30	27.43	5.05	32.48	16.53	2.20	26.25	5.00	31.26	4.14	42.33

Table 4.4. Asymmetric Settings under a Wholesale Contract: Profits, Order Quantities and Optimal Wholesale Prices for Varying Retail Prices at Different Logistic Costs $l = 0.5$, 1 and 2 with $c = 1$, $\beta = 0.05$ and $\alpha = 0.2$

	%Δ (MC, RI) vs. (CR)			%Δ (MI, RC) vs. (IR)		
r	Π_M^{CR}	Π_R^{IR}	$\Pi^{MC,RI}$	Π_M^{IR}	Π_R^{CR}	$\Pi^{MI,RC}$
			$l = 0.5$			
1.385	51.97	-12.07	1.23	-4.19	1.55	-
2	5.81	-0.79	4.80	-5.23	0.81	-3.94
4	4.73	-0.60	3.92	-4.49	0.57	-3.67
8	4.48	-0.64	3.66	-4.31	3.56	-3.11
10	4.43	-0.52	3.63	-4.27	2.06	-3.30
20	4.38	-0.51	3.59	-4.19	1.61	-3.32
			$l = 1$			
1.51	72.51	-35.96	2.33	-4.29	2.05	-
2	7.75	-1.72	6.37	-6.23	1.07	-4.36
4	5.05	-0.75	4.15	-4.76	0.71	-3.84
8	4.62	-0.60	3.81	-4.42	3.58	-3.18
10	4.54	-0.57	3.74	-4.35	2.11	-3.36
20	4.42	-0.53	3.64	-4.23	1.59	-3.35
			$l = 2$			
1.76	-	-	-	-4.00	2.71	-86.49
2	16.13	-8.43	12.45	-10.28	1.96	-4.43
4	5.80	-0.95	4.75	-5.31	0.81	-4.20
8	4.86	-0.66	3.97	-4.66	3.67	-3.34
10	4.74	-0.69	3.88	-4.52	2.17	-3.47
20	4.50	-0.53	3.68	-4.31	1.62	-3.41

Table 4.5. Percent Differences of Equilibrium Values between Asymmetric and respective Decentralized Policies under a Wholesale Contract for Different Retail Prices and Logistic Costs

retailer to consider returns as well. We focus on this subject matter in chapter 7 again.

- The percent differences shown in table 4.5 confirm our initial findings that the results of both asymmetric cases are in between those of the decentralized cases. The manufacturer has higher profits when (MC, RI) applies and lower ones in case of (MI, RC) compared to the respective benchmark cases. For the retailer it is vice versa.

- As the profit margin of both players increases, the percent difference of the asymmetric settings compared to the respective decentralized policies decreases. Higher logistic costs lead to slower declining differences.

Positive Salvage Values

Salvage values represent the estimated value of an asset, in this case the product, at the end of the selling period. Salvage values can be realized in various ways, including mark-downs on the product, alternative use of the total or parts of the good or sale of the product for scrap or recycling. In this section we vary the unsold item salvage value v with according values of $v_r = \{0, \frac{v}{2}, v\}$. Note that if the manufacturer is not offering a buy-back option, the salvage value is kept by the retailer. Therefore, within the manufacturer's and retailer's profit functions as well as in the formulae for the optimal order amounts which are presented in chapter 4, s has to be substituted by v.

First of all, positive salvage values improve the performance of each of the players and of the total supply chain. Furthermore, as positive salvage valuea v_r decrease the costs of returns, the effect on channel profits is reverse to those of α and l. The results in table 4.6 represent the fact that higher unsold item values v are an incentive for the retailer to order more, as well as higher salvage values v_r of the returned items allow the manufacturer to set lower wholesale prices, which leads to a higher optimal order amount in the case (MC, RI). Both players and the total supply chain are better off for higher values of v and v_r, what is intuitive. For values of v close to w^*, the retailer faces almost no loss for an unsold item, what allows him to order significantly more and finally boost his profits. In other words, he finds himself almost completely hedged against low demand. For higher salvage values a decentralized supply should, if trying to maximize total profits, therefore set the wholesale price close to the respective v-value. Individually, the manufacturer herself has, however, no incentive do to so, since this would lessen her profits.

As mentioned in chapter 3, the cost of a returned unit for the manufacturer is $w + l_1 - v_r > 0$. Obviously higher salvage values for returned items are equivalent to having a lower value for the parameter of l_1, that is the logistic costs incurred at the manufacturer. This finding is verified by tables 4.4 and 4.6, where the results are altered in the same way for declining logistic costs and rising salvage values. A shift in the share of logistic costs, resulting from different β-values, has the same effects as well, since $l_1 = l \times (1 - \beta)$. Under a wholesale contract the same holds true for the retailer and v.

4.2 Buy-Back Contract

As shown by Pasternack (1985) [41], a pricing and return policy, in which the manufacturer agrees to buy back unsold items for partial credit from the retailer at the end of the selling season, can achieve channel coordination. In exchange for the partial credit s, the manufacturer receives the unsold item with a salvage value of $v \geq 0$. Note that for every tuple (w, s), supply chain profits are divided differently amongst the players.

In our calculations, an exhaustive search is made in order to determine the optimal (w^*, s^*) combination. According to Theorem 4.1.1 from Ruiz Benítez and Muriel (2007) [42], $s^* > \frac{\alpha}{1-\alpha} \times (c + l_1 - v_r) + v$ has to be satisfied. In the asymmetric set-

		(MC,RI)					(MI,RC)				
v	v_r	w^*	Q^*	Π_M^{CR}	Π_R^{IR}	$\Pi^{MC,RI}$	w^*	Q^*	Π_M^{IR}	Π_R^{CR}	$\Pi^{MI,RC}$
0	0	3.56	2.08	3.10	0.54	3.63	3.47	2.06	2.91	0.69	3.60
0.5	0	3.55	2.15	3.19	0.57	3.76	3.47	2.12	3.00	0.71	3.71
1	0	3.55	2.22	3.31	0.59	3.90	3.46	2.20	3.11	0.75	3.86
1.5	0	3.53	2.34	3.46	0.65	4.10	3.43	2.33	3.25	0.84	4.09
2	0	3.49	2.51	3.66	0.76	4.42	3.40	2.49	3.45	0.94	4.39
v	v_r	w^*	Q^*	Π_M^{CR}	Π_R^{IR}	$\Pi^{MC,RI}$	w^*	Q^*	Π_M^{IR}	Π_R^{CR}	$\Pi^{MI,RC}$
0.5	0.25	3.54	2.16	3.30	0.58	3.88	3.47	2.12	3.11	0.71	3.81
1	0.5	3.51	2.26	3.52	0.66	4.18	3.46	2.20	3.33	0.75	4.08
1.5	0.75	3.49	2.38	3.80	0.72	4.52	3.43	2.33	3.59	0.84	4.43
2	1	3.44	2.56	4.14	0.85	5.00	3.40	2.49	3.93	0.94	4.87
v	v_r	w^*	Q^*	Π_M^{CR}	Π_R^{IR}	$\Pi^{MC,RI}$	w^*	Q^*	Π_M^{IR}	Π_R^{CR}	$\Pi^{MI,RC}$
0.5	0.5	3.53	2.17	3.40	0.60	4.00	3.47	2.12	3.21	0.71	3.92
1	1	3.49	2.28	3.74	0.69	4.43	3.46	2.20	3.54	0.75	4.29
1.5	1.5	3.45	2.42	4.14	0.79	4.93	3.43	2.33	3.93	0.84	4.76
2	2	3.39	2.62	4.63	0.95	5.58	3.40	2.49	4.40	0.94	5.34

Table 4.6. Player and Supply Chain Performance under Asymmetric Settings for Different Unsold Item Values and no Repurchase Option offered

tings this still holds true and buy-back contracts are indeed able to ensure channel coordination. *Although supply chain coordination is possible through a buy-back rebate, this type of coordination scheme leads to a considerable shift in profits amongst the players. Thus, the manufacturer is significantly better off, whereas the retailer is barely profitable at all.* Lau and Lau [34] receive similar results in their work, where in the given newsvendor setup, a return-credit policy can often be used by a shrewd manufacturer to increase only his profits. Comparing the retailer's performance under a wholesale and a buy-back option, his minuscule profits under the latter give him no incentive to accept an offered buy-back contract. In turn, the risk which the retailer faces under a buy-back rebate is also infinitesimal, whereas a wholesale contract exposes him to a far greater risk of not being profitable due to overstocking. *Consequently, the financial theory of risk and returns is satisfied and the buy-back contract is meaningful.* Total supply chain profits are with 4.566 and 4.512 for the cases (MC, RI) and (MI, RC), respectively, reasonably higher than compared to the symmetric cases. The optimal buy-back amount of the manufacturer, s^*, is found to be close to w^*. This is due to the fact that the manufacturer is individually trying to maximize her profits regardless of the performance of the retailer. By giving the retailer the possibility to sell back items with minimal loss (exactly $w^* - s^*$ per item), he tries to satisfy almost all occurring demand, and therefore, place higher order amounts. The optimal wholesale price w^* is the highest possible the vendor can set, due to the restriction $w < r - (\frac{\alpha}{1-\alpha})l_2$ that derives out of formula (3.6). Note that the manufacturer wants the retailer not to order as much as possible but quite a reasonable amount. That is why the optimal buy-back price s^* is only almost at the maximal possible magnitude. The closer s^* gets to w^* the more the retailer orders and, for extreme high values the vendor's profits start declining again. In the following sensitivity analysis, we show that w^* is always close to s^*.

		Wholesale				Buy-Back			
		(CR)	**(IR)**	**(MC,RI)**	**(MI,RC)**	**(CR)**	**(IR)**	**(MC,RI)**	**(MI,RC)**
Decent.	w^*	3.56	3.47	3.56	3.47	3.95	3.96	3.95	3.96
	s^*	-	-	-	-	3.935	3.945	3.935	3.945
	Q^*	1.97	2.16	2.08	2.06	3.14	3.45	3.55	2.90
	Π_M	2.927	3.075	3.097	2.911	4.553	4.569	4.518	4.484
	Π_R	0.541	0.681	0.536	0.686	0.050	0.026	0.048	0.028
	Π_T	3.468	3.755	3.633	3.597	4.603	4.595	4.566	4.512

Table 4.7. Equilibrium Values for Decentralized Symmetric and Asymmetric Policies in the Base Case under a Buy-Back Contract and Stochastic Demand

As a result, for combinations (w^*, s^*) the supply chain in both asymmetric settings (MC, RI) and (MI, RC) can face improved coordination and, hence, better results than under a wholesale contract can be retrieved. (MC, RI) again reaches the better results, what derives from a higher order amount set by the retailer when ignoring returns compared to if he considers them. Table 4.7 compares the decentralized cases (CR) and (IR) with the asymmetric settings provided with a wholesale and a buy-back contract, respectively.

As mentioned, our results are based on an exhaustive search over all possible (w,s)-tuples, whereas the manufacturer is optimizing the wholesale price in order to maximize his profits. Ruiz Benítez and Muriel (2007) [42] present an analytic way to find coordinating solutions for the decentralized supply chain. Accordingly, there is a set of values $(w(s), s)$ satisfying

$$s > \frac{\alpha}{1-\alpha}(c+l_1-v_r)+v \text{ and } w = \frac{(r(1-\alpha)-l_2\alpha)(c-v)+s((1-\alpha)r-\alpha(l-v_r)-c)}{(1-\alpha)r-\alpha(l-v_r+c-v)-v}$$

that achieve supply chain coordination. By applying the formulas, optimal profits can be calculated for a given s (or w). Note, that this solution does not depend on the demand distribution. Table 4.8 compares the analytic solution of Ruiz Benítez and Muriel for the given buy-back price $s = 2$ with the exhaustive search method. Interestingly, we find the total profits to be about the same for the respective policies, but profits among the players are a good deal more fairly distributed. However, it

	Analytical Solution		Exhaustive Search			
	(CR)	(IR)	(CR)	(IR)	(MC,RI)	(MI,RC)
w^*	2.6	2.5	3.95	3.96	3.95	3.96
s^*	2	2	3.94	3.95	3.94	3.95
Π_M	2.82	3.09	4.55	4.57	4.52	4.48
Π_R	1.79	1.48	0.05	0.03	0.05	0.03
Π_T	4.61	4.58	4.60	4.60	4.57	4.51

Table 4.8. Comparison of Analytical and Exhaustive Optimization Methods: Optimal Supply Chain Parameters under a Buy-Back Contract and Stochastic Demand

is now the manufacturer that makes the worse deal of the two since he has reduced profits compared to the wholesale contract. The retailer, in turn, now has a strong incentive to accept a buy-back contract since he can raise his profits considerably. Pasternack (1985) [41] presents values for buy-back contracts where both agents are better off, whereas he also applies an analytical solution. Finally, the results of the exhaustive search represent a possible solution of the given analytical formulas.

4.2.1 Sensitivity Analysis

Provided with a buy-back contract, we find the same basic behavior of manufacturer and retailer as under a wholesale contract when varying the respective parameters. However, a buy-back option allows the manufacturer to shift profits in his interests. For any considered β-value, the manufacturer is always significantly better off than the retailer. This finding extends the initial result over the total range of β. As observable in table 4.9, rising production costs c and higher return volumes lead to lowered profits of both players and the total supply chain. Of course, values with negative profits for the manufacturer or retailers in the setting (MC, RI) or (MI, RC), respectively, mean that no deal is made between the players for the given basic conditions.

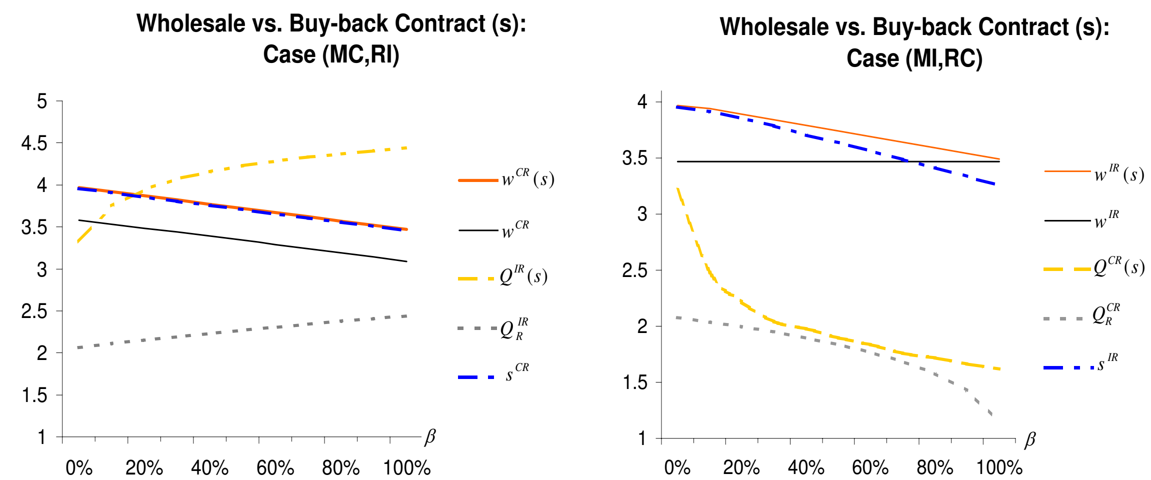

Figure 4.6. Performance of Decision Variables for Different Shares of Logistic Costs: Comparison of Wholesale and Buy-back Contracts for the Asymmetric Policies

Summarizing and compared to the asymmetric settings provided with a wholesale contract, the conducted sensitivity analysis over the respective parameters brings the following results:

- Sensitivity analysis supports the fact that the manufacturer rakes almost all of the profits in the system, whereas the retailer is hardly profitable. Consequently, from the point of profits, the retailer has no incentive to accept a buy-back offer by the manufacturer if no other additional agreements are made (e.g. lump sum transfer).

- Optimal order amounts change more significantly over the range of the varied variables than under a wholesale contract. This follows directly out of the fact that the buy-back incentive offered by the manufacturer shifts profits in her interests.

- As mentioned, higher production costs and more returned products reduce the performance of the supply chain. Table 4.9 shows that the manufacturer tries to compensate this with maximum possible wholesale prices. Still, the best per-

	(MC,RI)				(MI,RC)			
c	0.25	1	2	3	0.25	1	2	3
				$\alpha = 0.2$				
w^*	3.91	3.95	3.96	-	3.94	3.96	3.96	3.96
s^*	3.898	3.935	3.925	-	3.928	3.945	3.915	3.835
Q^*	3.87	3.55	3.06	-	3.37	2.90	2.40	1.98
Π_M	7.163	4.518	1.501	-	7.067	4.484	1.643	-0.501
Π_R	0.142	0.048	0.021	-	0.073	0.028	0.024	0.020
Π_T	7.305	4.566	1.522	-	7.140	4.512	1.667	-0.481
				$\alpha = 0.3$				
w^*	3.88	3.93	3.94	-	3.92	3.94	3.94	3.94
s^*	3.861	3.913	3.811	-	3.901	3.923	3.881	3.750
Q^*	3.83	3.64	2.65	-	3.16	2.83	2.28	1.83
Π_M	5.388	2.736	0.179	-	5.247	2.882	0.284	-1.524
Π_R	0.143	0.043	0.011	-	0.064	0.027	0.023	0.018
Π_T	5.531	2.779	0.189	-	5.311	2.908	0.307	-1.506
				$\alpha = 0.4$				
w^*	3.87	3.92	-	-	3.92	3.92	3.92	3.92
s^*	3.853	3.903	-	-	3.903	3.893	3.840	3.657
Q^*	3.90	3.71	-	-	2.66	2.45	2.00	1.58
Π_M	3.661	0.971	-	-	3.316	1.291	-0.863	-2.241
Π_R	0.096	0.011	-	-	0.017	0.016	0.013	0.010
Π_T	3.757	0.981	-	-	3.334	1.307	-0.850	-2.231

Table 4.9. Sensitivity Analysis for Production Costs and Return Rates in the Asymmetric Settings under a Buy-Back Contract with Stochastic Demand

formance of the total supply chain is reached under (MC, RI). For the retailer, the situation changes: for high production costs and/or increased returns, he finds himself in a better position.

- For (MC, RI) the optimal buy-back amount, s^*, is always close to the optimized wholesale price. For the setting (MI, RC), in turn, the gap between s^* and w^* grows larger for higher c, α and β. The reason is, that the manufacturer assumes the retailer order's more when ignoring returns, why he wants to restrict his order quantity more.

- Positive salvage values improve both players and the total supply chain. Table 4.10 compares the asymmetric settings under a buy-back and wholesale contract. Note that under the latter, v is kept with the retailer and under the former it goes back to the vendor. Due to the fact that returned and unsold items now are valuable, the manufacturer can charge higher prices than under a wholesale contract. The idea behind it is simple: by setting a buy-back price as close as possible to w^* the retailer is almost perfectly hedged against low demand. This means he orders substantial higher amounts than if provided with a wholesale contract, what in turn generates higher profits for the manufacturer. For higher salvage values, the optimal wholesale price reduces, what leads again - together with the hedging argument - to higher Q^*-values. Interestingly, for salvage values close to w^*, the wholesale contract performs better in terms of total supply chain profits. Particularly the retailer can raise his profits considerably, whereas the manufacturer is worse off. Under the buy-back option, setting w^* close to the salvage value will not result in disproportionately higher profits simply because the retailer does not keep v.

Buy-Back Contract

		(MC,RI)						(MI,RC)					
v	v_r	w^*	s^*	Q^*	Π_M^{CR}	Π_R^{IR}	$\Pi^{MC,RI}$	w^*	s^*	Q^*	Π_M^{IR}	Π_R^{CR}	$\Pi^{MI,RC}$
0	0	3.95	3.94	3.73	4.44	0.05	4.49	3.96	3.95	3.09	4.56	0.03	4.59
0.5	0.5	3.94	3.93	3.80	5.09	0.07	5.17	3.96	3.95	3.09	5.01	0.03	5.04
1	1	3.91	3.90	3.96	5.78	0.14	5.93	3.94	3.93	3.48	5.69	0.08	5.76
1.5	1.5	3.87	3.86	4.10	6.57	0.24	6.81	3.91	3.9	3.74	6.42	0.14	6.57
2	2	3.81	3.80	4.23	7.43	0.38	7.81	3.86	3.85	3.97	7.27	0.26	7.53
2.5	2.5	3.75	3.74	4.33	8.36	0.52	8.88	3.82	3.81	4.08	8.14	0.36	8.50

Wholesale Contract

		(MC,RI)						(MI,RC)					
v	v_r	w^*	s^*	Q^*	Π_M^{CR}	Π_R^{IR}	$\Pi^{MC,RI}$	w^*	s^*	Q^*	Π_M^{IR}	Π_R^{CR}	$\Pi^{MI,RC}$
0	0	3.56	-	2.08	3.09	0.53	3.63	3.47	-	2.05	2.91	0.68	3.59
0.5	0.5	3.53	-	2.17	3.40	0.60	4.00	3.47	-	2.11	3.21	0.70	3.91
1	1	3.49	-	2.28	3.74	0.68	4.43	3.46	-	2.20	3.54	0.74	4.29
1.5	1.5	3.45	-	2.42	4.14	0.79	4.93	3.43	-	2.32	3.92	0.83	4.76
2	2	3.39	-	2.61	4.62	0.95	5.58	3.4	-	2.48	4.40	0.93	5.34
2.5	2.5	2.51	-	4.85	6.18	3.49	9.68	2.51	-	4.79	6.08	3.49	9.58

Table 4.10. Supply Chain Behavior for Positive Salvage Values: Comparison of Wholesale and Buy-Back Contracts in the Asymmetric Settings for a Normally Distributed Demand

4.3 Conclusions

For given stochastic demand, we have examined and investigated the asymmetric settings (MC, RI) and (MI, RC). Through extensive computational work we were able to extend the main findings of the decentralized symmetric policies under a simple price-only and a buy-back contract. We further showed the robustness of our results by carrying out sensitivity analysis in the respective model parameters. Finally, the most important findings of this chapter are enumerated:

Results retrieved under a Wholesale Price-Only Contract

1. The performances of the asymmetric settings (MC, RI) and (MI, RC) are in between the decentralized policies (IR) and (CR). Thus, coordination is not reached. (MC, RI) constitutes the case where the manufacturer finds her best profits. The retailer is best off under (MI, RC).

2. Shifting the share of logistic costs predominantly to the retailer leads to rising total profits under (MC, RI), whereas it is detrimental under (MI, RC). By doing so, better coordination can be reached, although an incentive scheme has to be offered to the retailer in order not to lose goodwill.

3. Conducted sensitivity analysis shows that the results for the asymmetric settings are consistent with findings of Ruiz Benítez and Muriel (2007) [42] in the symmetric settings. Rising costs, rate of returns, coefficient of variations and logistic costs lead to declining profits with no shift in profit distribution among the players. Positive salvage values, in turn, increase profits.

Results retrieved under a Buy-Back Contract

1. Buy-back contracts lead to a dramatic shift of profit distribution among the players. The manufacturer rakes almost all profits, whereas the retailer has fairly none. However, total profits are improved compared to a wholesale contract.

2. The best performance of the asymmetric settings is still (MC, RI), whereas both remain in between the decentralized policies (IR) and (CR). The optimal buy-back value s^* is always found close to w^*.

3. Buy-back contracts lead to higher order amounts of the retailer. The fact that s^* is close to w^* allows the retailer to hedge against unsold items almost completely. In turn to his infinitesimal profits, he has almost no risk associated with the deal made under a buy-back contract. Thus, the risk-return ratio is satisfied.

4. Sensitivity analysis shows that the general findings under a wholesale contract for the asymmetric settings hold still true when the system is provided with a buy-back contract. Levels and share of profits are different, though.

CHAPTER 5

STOCHASTIC AND PRICE-DEPENDENT DEMAND

In this chapter, customer demand is assumed to be stochastic and price-dependent. Total consumer returns are considered to be a constant fraction of sales, i.e. $\alpha = 20\%$. Most importantly the retail price is no longer exogenously given and, thus, the retailer has partial control over demand with setting the selling price. As mentioned, the demand distribution is modeled according to Emmons & Gilbert (1998) [16] with $D(r) = b(r - k)$ and is known to both players. Further, the general framework presented in chapter 3 remains valid.

For the case of stochastic and price dependent demand, Ruiz Benitez and Muriel (2007) [42] study the symmetric cases (CR) and (IR) under a wholesale and buy-back contract. In the following, we are focussing on asymmetric decision making and the respective outcome of the settings when varying the model parameters. Retrieved results are compared with symmetric policies, whereas considered coordination schemes are the simple price-only contract, and a buy-back option. A comprehensive sensitivity analysis is performed for each of the latter two options. As under stochastic demand, the main objective of the computational work is to evaluate the effects of asymmetric decision policies on optimal supply chain profits, optimal ordering quantities, wholesale and retail prices and buy-back rebates, as compared to those in the classical problems in which returns are either considered or ignored in the decision making process. In the computational analysis, the simplification of a uniform distribution on the interval [0,2] is made to represent the probability distribution function of the uncertainty term x, i.e. $x \sim U(0; 2)$. The respective parameter values for the

		Symmetric		Asymmetric	
		(CR)	**(IR)**	**(MC,RI)**	**(MI,RC)**
Cent.	r^*	3.64	3.27	-	-
	Q^*	4.90	7.22	-	-
	Π	3.71	3.21	-	-
Decent.	w^*	2.5	2.18	2.5	2.18
	r^*	4.07	3.90	4.05	3.93
	Q^*	1.84	2.90	2.19	2.49
	Π_M	1.4113	1.5848	1.6194	1.2994
	Π_R	1.1409	1.6771	1.1082	1.7172
	Π_T	2.5522	3.2619	2.7276	3.0166

Table 5.1. Optimal Order Amounts, Prices and Profits of Centralized and Decentralized Policies under a Price-Only Contract with Stochastic and Price-dependent Demand

demand function are $(b, k) = (-3, 5)$. The production costs c are set to 1, whereas the salvage values v and v_r are 0 if not stated otherwise. According to a β-value of 0.05, the manufacturer faces 95% of reverse logistic costs, as opposed to the retailer, who bears only 5% of the total logistic costs $l = 2$.

5.1 Wholesale Price-Only Contract

Firstly, we study the simple price-only wholesale contract, where the manufacturer does not offer the retailer to buy back unsold items at the end of the selling period. Accordingly, the parameter s is set to v. Under stochastic and price-dependent demand, the retailer now calculates his optimal profit and also the optimal retail price for different w^* transmitted by the vendor. Table 5.1 shows profits, optimal order quantities as well as the optimized wholesale and retail prices. Similar to price-dependent demand the centralized policy (CR) represent the best possible coordination. However, policy (IR) faces less coordination in a centralized supply chain than in a decentralized one.

For the decentralized symmetric cases, the expected profits of both players and of the total supply chain are shown below in figure 5.1. Figure 5.2 visualizes the asymmetric settings.

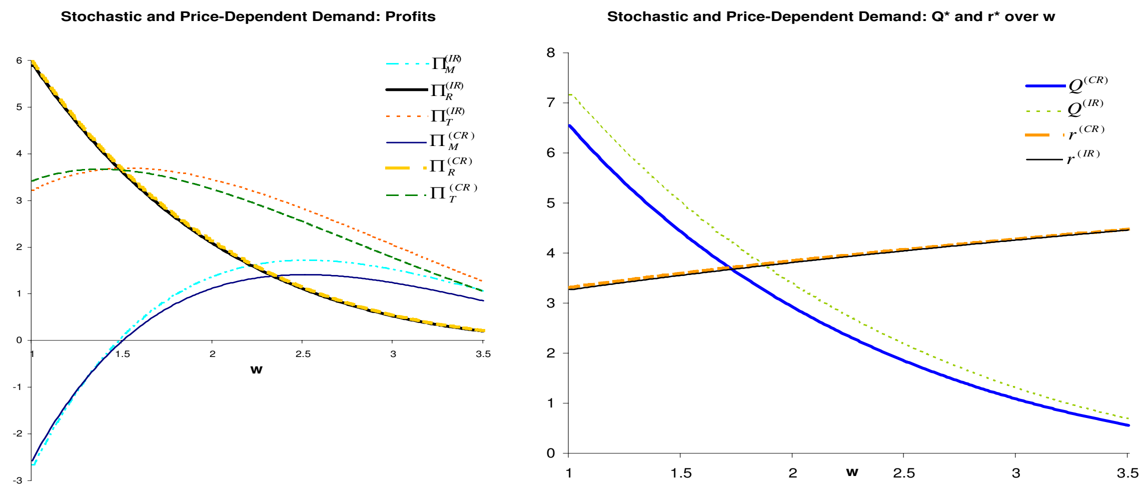

Figure 5.1. Base Case Profits, Order Quantities, Wholesale and Retail Prices under Stochastic and Price-dependent Demand in the Decentralized Symmetric Settings

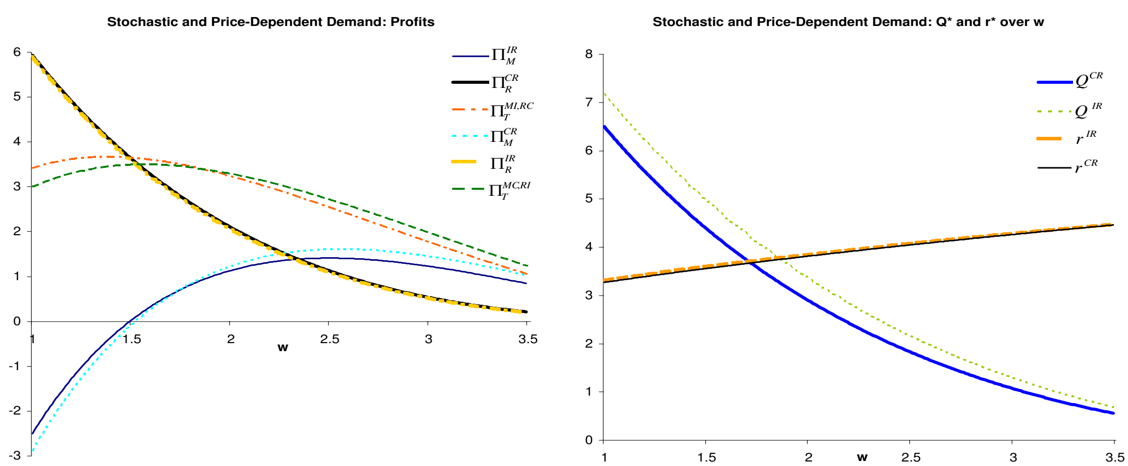

Figure 5.2. Base Case Profits, Order Quantities, Wholesale and Retail Prices under Stochastic and Price-dependent Demand in the Decentralized Asymmetric Settings

In general, mostly similar results as under stochastic demand are obtained. The asymmetric settings behave in the same manner as the decentral symmetric policies do. In addition to the results that are found for the decentralized policies by Ruiz Benitez and Muriel (2007) [42], we can summarize for the asymmetric policies:

- Retail prices are increasing and the optimal order amounts are decreasing in w. $Q^{MC,RI} = Q^{IR} > Q^{CR} = Q^{MI,RC}$ for any specific w. Considering the optimal r^*, the retail price including returns is always higher than if ignoring. This is explained by the fact that the costs caused by returned items are compensated by higher retail prices. However, higher retail prices come along with lower total sales.

- The optimal total profits for the asymmetric cases lie in between the profits of (IR) and (CR). Thus, supply chain coordination is not achieved.

- Optimal decision variables of the asymmetric settings are in between the range of the values of the symmetric policies.

- Other than under stochastic demand, the higher total profits are found for (MI, RC). Interestingly, the retailer outperforms the vendor in the latter setting. Note that under stochastic demand this was also not the case.

- For low values of w the manufacturer faces a loss when ignoring or considering returns. For higher values of w, however, the vendor is significantly better off when considering consumer returns.

- In a specific asymmetric setting, one and only one player is better off than in both symmetric cases, as opposed to the other player, who is facing worse profits than in (CR) and (IR).

5.1.1 Sensitivity Analysis

As we have experienced in the last chapter, the impact of consumer returns on the asymmetric settings is driven by the overall return volume α, the share, β, of total logistic costs l. In order to evaluate the robustness of the obtained results in the base case, a sensitivity analysis in the respective model parameters is conducted. Besides the mentioned variables, the market factors b and k as well as the values which determine the profit margin directly, that is c, v and v_r, are varied.

Different Rates of Returns

Intuitively, higher rates of returns lead to lowered system-wide and individual profits. Table 5.3 shows the performance of system-wide variables as a function of customer returns α for the case of stochastic and price-dependent demand in the base case with $\{c, b, k\} = \{1, -3, 5\}$ and $\beta = 0.05$. Retrieved results, however, are different compared to those of stochastic demand. Firstly, we find both players facing higher profits when they individually consider returns, as opposed the stochastic demand case, where only the manufacturer is better off when including returns in her optimization process.

Policy (MC, RI) does not exist after a threshold value of $\alpha \approx 0.40$, since the manufacturer starts facing losses. Observe, that the threshold value derives out of policy (CR) because the manufacturer assumes the retailer to optimize with consideration of consumer returns as well, i.e. he assumes symmetrical behavior. The asymmetric setting (MI, RC), in turn, faces losses if the return rate is higher than 47% of the total goods sold. Interestingly, after subtracting the costs of returns, the manufacturer ends up facing losses much earlier, whereas his profits before returns are positive over the whole range of α. We therefore find that for higher return rates ignoring returns is detrimental for both players' profits.

The effects that rising consumer returns have on order quantities and prices are visible in figure 5.3. Moreover, the interdependencies of wholesale and retail prices and order quantities are illustrated nicely. If the manufacturer considers reverse logistic costs in the optimization process, transmitted wholesale prices remain constant. This leads directly to retail prices that are fairly constant and are only for higher return rates rising drastically to cover return costs. Under a constant return rate, that is returns are independent of the price, high resale prices allow to insure against high amounts of returns, because reverse logistic costs are simply allocated on buyers that finally keep the product. As both variables, wholesale and retail price, remain relatively unchanged, the order quantity under (MI, RC) is declining steadily in α, whereas the order amount is always higher than $Q^{(MC,RI)}$. If the vendor includes returns, he covers the expenses of returned items by higher wholesale prices. Consequently, the retailer faces a dropping profit margin, why he sets higher retail prices as well. However, the rise in the retail prices is not proportional to that of the wholesale prices because the retailer ignores returns and therefore, has no incentive to cover return costs. Yet, the considerable jump in purchase prices drives the retailer to order less.

To round off our sensitivity analysis for α, we also present the results when $\beta = 0.95$ (see figure 5.4), that is the retailer bears the lion share of return costs. Now the asymmetric case of (MC, RI) performs only better if the return volume is greater than $\sim 30\%$ of sold goods. Both players still are better off when considering returns, whereas the manufacturer's profits are superior to those of the retailer, regardless of including or excluding returns. Regarding prices and order amounts, wholesale prices remain fairly constant under both settings, since the manufacturer has to bear only very little of return costs. Accordingly, the wholesale price does not have to make up for increased reverse logistic costs. Incidentally, the behavior is as described for the case of $\beta = 0.05$.

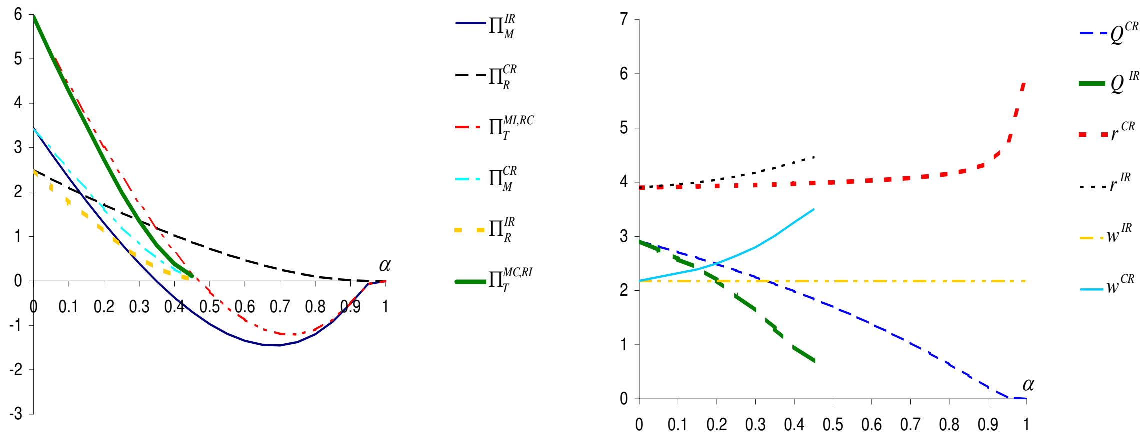

Figure 5.3. Performance of the Asymmetric Cases under Stochastic and Price-dependent for varying Return Rates and $\beta = 0.05$

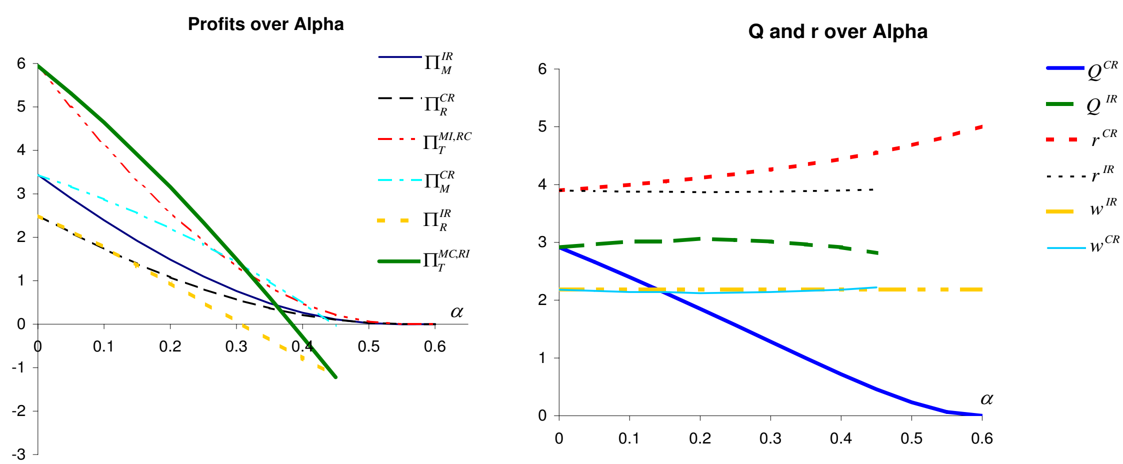

Figure 5.4. Performance of the Asymmetric Cases under Stochastic and Price-dependent for varying Return Rates and $\beta = 0.95$

	Symmetric		Asymmetric	
	(CR)	(IR)	(MC,RI)	(MI,RC)
w^*	2.12	2.18	2.12	2.18
r^*	4.09	3.90	3.87	4.12
Q^*	1.97	2.91	3.07	1.85
Π_M	1.4901	2.4028	2.2071	1.4880
Π_R	1.1776	0.8592	0.9504	1.0819
Π_T	2.6677	3.2620	3.1575	2.5699

Table 5.2. Equilibrium Values of the Asymmetric policies when the retailer faces 95% of total reverse logistic costs

Different Shares of Logistic Costs

As observable in the previous chapter, the share of logistic costs is an important parameter regarding the impacts of consumer returns on relevant decision variables and system-wide profits of the players. As stated in chapter 4, the share of logistic costs faced by the retailer is denoted as $\beta = \frac{l_2}{l_1+l_2} \times 100$. Within the following, we are considering changes in β, whereas we elsewise use the base case settings in order to better understand the dynamics of the supply chain. *For stochastic and price-dependent demand, coordination is not reached with any asymmetric optimization setting when shifting reverse logistic costs amongst the players.*

Table 5.2 presents the equilibrium values if $\beta = 0.95$. *The first eye-catching result is that the retailer's profits in both asymmetric settings are now in between the symmetric policies. Also the manufacturer finds her profits to be in between, except for (MI, RC), where she is worse off than under (CR) and (IR).* According to the results of Ruiz Benitez and Muriel (2007) [42], profits in the symmetric policies remain fairly unchanged if players consider consumer returns in their optimization process. Excluding returns leads to disastrous outcomes for the retailer: over the total range of β, his individual profits lessen by 50%. The manufacturer, however, prefers to ignore returns, since her profits almost double (see table 5.5). *Since the asymmetric cases can be seen as a mixture of the two symmetric policies, (MC, RI) is* *improving its coordination and (MI, RC) is getting worse for a shift in logistic costs towards the retailer. However, the performance is still under that of policy (IR).* However, (MC, RI) almost closes up to the level of (IR). As experienced in chapter 4, the retailer suffers under the burden of additional returned item costs, whereas the manufacturer can benefit. The graphs for $P_R(MI, RC)$ and $P_R(MC, RI)$ show the continuous declining of profits for the retailer. For the manufacturer, the graphs for $P_M(MI, RC)$ and $P_M(MC, RI)$ outline rising profits for higher magnitudes of β. Regarding the asymmetric policies and the respective graphs in table 5.5, it is observable that the player that considers returns in his optimization process has the dominant influence on total supply chain profits. If the retailer bears more of the costs associated with returned items, the optimized wholesale price is declining under policy (MC, RI). According to intuition, order quantities are increasing, what is a direct consequence of lower retail and wholesale prices. For (MI, RC), of course, the wholesale price remains constant and, since the retailer considers returns, the retail price rises to cover return costs. Hence, the order quantities decreases. The results continue to hold true for lower or higher volumes of returns, with respectively less or more accentuated variations.

Different Production Costs

Since the level of production costs, along with overall customer returns and the share of logistic costs, is of paramount importance for the marginal revenue for the manufacturer's profits, they determine whether the asymmetric decision policies are optimal for the supply chain players.

Table 5.3 presents the sensitivity analysis for the production costs c and varying return rates α. Further, we use the parameters specified for the base case. When increasing the manufacturing costs, the dynamics of the asymmetric settings are similar to those under stochastic demand. As higher production cost diminish earnings of

	(MC,RI)				(MI,RC)			
	$\alpha = 0.05$							
c	0.5	1	2	3	0.5	1	2	3
w^*	1.82	2.25	3.03	3.79	1.78	2.18	2.92	3.64
r^*	3.72	3.93	4.27	4.57	3.71	3.91	4.23	4.52
Q^*	3.92	2.74	1.27	0.44	3.92	2.81	1.37	0.54
Π_M	4.6187	2.9735	1.0363	0.2317	4.4803	2.8690	0.9827	0.2084
Π_R	3.4344	2.1134	0.7158	0.1540	3.5857	2.2990	0.8532	0.2224
Π_T	8.0531	5.0869	1.7522	0.3857	8.0660	5.1680	1.8358	0.4308
	$\alpha = 0.1$							
c	0.5	1	2	3	0.5	1	2	3
w^*	1.87	2.32	3.15	3.97	1.780	2.180	2.920	3.640
r^*	3.75	3.96	4.32	4.64	3.720	3.913	4.238	4.522
Q^*	3.77	2.58	1.10	0.31	3.793	2.710	1.313	0.508
Π_M	4.0548	2.5121	0.7747	0.1302	3.8033	2.3217	0.6661	0.0686
Π_R	2.9764	1.7627	0.5252	0.0822	3.2914	2.0998	0.7721	0.1992
Π_T	7.0312	**4.2748**	1.2999	0.2124	7.0947	4.4215	1.4382	0.2678
	$\alpha = 0.2$							
c	0.5	1	2	3	0.5	1	2	3
w^*	2.00	2.50	3.48	4.42	1.780	2.180	2.920	3.640
r^*	3.81	4.05	4.45	4.80	3.740	3.930	4.249	4.530
Q^*	3.39	2.19	0.72	0.09	3.517	2.489	1.186	0.450
Π_M	2.9132	1.6194	0.3433	0.0173	2.5152	1.2994	0.0983	-0.1710
Π_R	2.0820	1.1082	0.2118	0.0093	2.7219	1.7172	0.6187	0.1559
Π_T	4.9952	2.7276	0.5552	**0.0266**	5.2371	3.0166	0.7170	-0.0151
	$\alpha = 0.3$							
c	0.5	1	2	3	0.5	1	2	3
w^*	2.20	2.80	3.95	-	1.780	2.180	2.920	3.640
r^*	3.91	4.18	4.63	-	3.763	3.949	4.263	4.539
Q^*	2.86	1.63	0.33	-	3.213	2.248	1.051	0.391
Π_M	1.7964	0.8310	0.0795	-	1.3329	0.3919	-0.3724	-0.3535
Π_R	1.2316	0.5183	0.0402	-	2.1813	1.3586	0.4782	0.1172
Π_T	3.0280	1.3493	**0.1197**	-	3.5142	1.7505	0.1058	-0.2364

Table 5.3. Asymmetric Settings for Different Production Costs and Rates of Returns under Stochastic and Price-dependent Demand

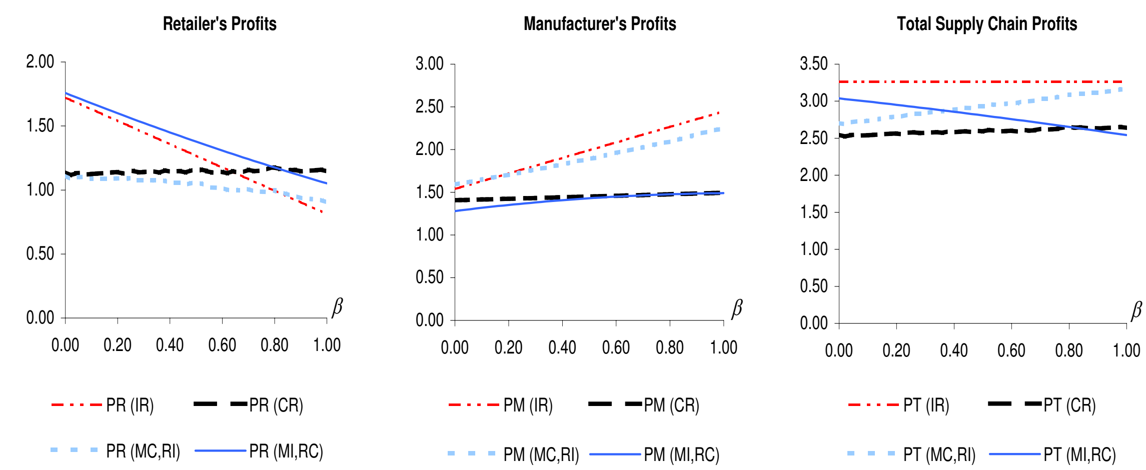

Figure 5.5. Comparison of Manufacturer's and Retailer's Performance under Decentralized Symmetric and Asymmetric Policies over the Range of β

the vendor, she reacts with increased wholesale prices in order to bolster her declining margins, what leads to the impacts on retail prices and order quantities as described earlier. Consequently, the lower wholesale price is given to create an incentive for the retailer to raise his marginal revenue and thus allows him to increase his order quantity. Comparing both order quantities $Q^{IR}*$ and $Q^{CR}*$ in the asymmetric settings, we examine that the difference between the two is small but increasing with higher production costs and return rates. The same holds true for the optimized selling price r^*.

Over the feasible region for α and with the share of logistic costs $\beta = 0.05$ figure 5.3 shows that policy (MC, RI) is always inferior to (MI, RC) in terms of supply chain profits. Contrary to this, the latter relationship is not true for all conditions within the sensitivity analysis for c. The respective cases are highlighted in bold in table 5.3. However, the initial observance allows us to conclude that this happens solely due to the change in production costs, what seems to have erratic influences on the performance of the asymmetric settings.

Observe that for rising return rates and especially for increased production costs, the retailer's performance is better under setting (MI, RC). However, for low rates of returns and costs, the manufacturer also performs better than the retailer if he ignores returns. On one hand, this results certainly from lower return cost, whereas on the other hand, sunk production expenses lead to the mentioned improvements in revenue, making her more flexible in her optimizations. Both issues finally put the manufacturer in the position to optimize the supply chain better in her interests, since she can offer a greater incentive scheme to the retailer. Omitted values in table 5.3 are due to the non-existence of the policy since one player faces negative profits when considering product returns.

Different Reverse Logistic Costs

Total profits for each of the agents and of the total supply chain for different reverse logistic costs l, for respective combinations of α and β, are shown in table 5.4. We consider total return volumes of 5% and 20% and share of logistic costs β of 5% or 95%, respectively, when either the manufacturer or the retailer faces most of the costs associated with returned items. Furthermore, the deviations in percent of total profits for settings (MC, RI) and (MI, RC) compared to the respective decentralized symmetric policies are presented. As stated in the asymmetric optimization process in chapter 3, we consider the manufacturer to have the initial part in the optimization process, that is, if she considers returns, policies (MC, RI) and (CR) and respectively, if she ignores returns, (MI, RC) and (IR) are compared, respectively. Table 5.1 reveals that (IR) performs always better than both asymmetric policies and (CR) is always worse. However, the differences between the respective policies decline or increase with rising costs of returns, α and β. In the following, retrieved results are summarized:

		(MC,RI)				(MI,RC)			
α	β	Π_M	Π_R	Π_T	%Δ to (CR)	Π_M	Π_R	Π_T	%Δ to (IR)
		total logistic costs l = 0.5							
5 %	5 %	3.133	2.225	5.358	1.80%	3.034	2.307	5.341	-1.90%
5 %	95 %	3.183	2.254	5.437	2.54%	3.041	2.258	5.299	-2.71%
20 %	5 %	2.183	1.455	3.638	6.55%	1.893	1.748	3.641	-8.32%
20 %	95 %	2.353	1.449	3.803	9.33%	1.934	1.571	3.505	-12.52%
		total logistic costs l = 1							
5 %	5 %	3.078	2.276	5.354	1.80%	2.979	2.305	5.284	-1.93%
5 %	95 %	3.179	2.200	5.379	3.31%	2.994	2.206	5.201	-3.56%
20 %	5 %	1.984	1.338	3.322	6.52%	1.694	1.737	3.431	-8.32%
20 %	95 %	2.313	1.273	3.586	11.95%	1.780	1.396	3.176	-17.02%
		total logistic costs l = 2							
5 %	5 %	2.974	2.113	5.087	1.92%	2.869	2.299	5.168	-2.01%
5 %	95 %	3.169	2.144	5.313	4.79%	2.900	2.105	5.005	-5.33%
20 %	5 %	1.619	1.108	2.728	6.43%	1.299	1.717	3.017	-8.13%
20 %	95 %	2.207	0.950	3.158	15.51%	1.488	1.082	2.570	-26.93%
		total logistic costs l = 3							
5 %	5 %	2.870	2.083	4.953	1.98%	2.760	2.294	5.053	-2.08%
5 %	95 %	3.159	2.060	5.218	6.26%	2.808	2.007	4.814	-7.15%
20 %	5 %	1.298	0.883	2.181	6.41%	0.910	1.697	2.607	-7.69%
20 %	95 %	2.095	0.551	2.645	17.64%	1.219	0.814	2.033	-38.11%

Table 5.4. Wholesale contract under Stochastic and Price-dependent Demand: Profits of Manufacturer, Retailer and Total Supply Chain for different logistic Costs, l, and Shares, β and Return Volumes α

- (MC, RI) is outperforming (CR). For rising logistic costs l and values of β and α, total profits in policy (MI, RC) are dropping faster than in the respective policy (IR). This relation is a direct effect of lower order quantities (due to the rising costs of returns) submitted by the retailer. For the retailer, order quantities are primarily a consequence of transmitted wholesale prices of the vendor who, on her part, reacts on return costs as well.

- For high logistic costs, that are mostly carried by the manufacturer ($\beta = 0.05$), the supply chain is better off under (MI, RC). Giving the retailer the burden to cover return costs ($\beta = 0.95$) has either extremely positive (MC, RI) or extremely negative (MI, RC) effects on the asymmetric system-wide profits. We also observe that setting (MC, RI) is steadily improving its coordination for rising costs of returns. Policy (MI, RC) is experiencing less coordination.

- The only case in which the retailer faces better profits as the vendor is, if return volumes are high and the associated costs are borne by the latter.

- The detrimental effects of high return rates along with high reverse supply chain costs are visible.

Positive Unsold Item Values

We continue our analysis by examining positive values v and v_r for unsold and returned items. Since the manufacturer does not provide a buy-back option yet, left-over inventory at the end of the selling period remains with the retailer. Returned items from the customer still go back to the vendor for possible salvaging, refurbishment or ulterior use. In the following, we consider two combinations of v and v_r: 1. $\{v, v_r = \frac{v}{2}\}$ and 2. $\{v, v_r = v\}$. For the upcoming tables and figures we use the respective base case values, unless otherwise stated.

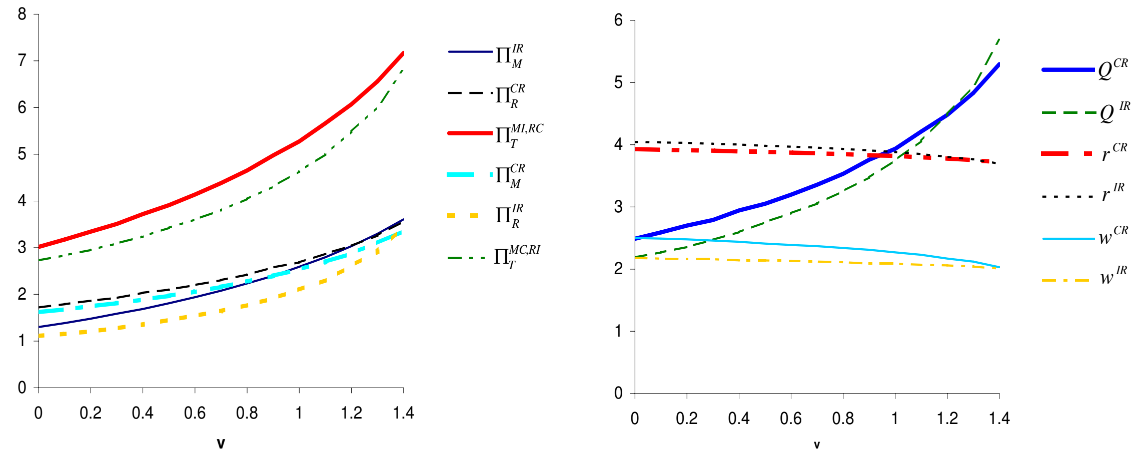

Figure 5.6. Performance of the Asymmetric Cases with Positive Salvage values v and $v_r = \frac{v}{2}$ under Stochastic and Price-dependent Demand for varying Return Rates and $\beta = 0.95$

From figure 5.6 we gain the expected results that rising salvage values lead to a better performance of both players and the total supply chain. Just as under stochastic demand, the costs of returns are reduced by positive returned item salvage values. We also find the retail and wholesale price to be decreasing for higher v and v_r. In fact, the inter-dependencies of order amounts, resale and wholesale prices in the system suggest that lower wholesale prices are initiated by higher transmitted order amounts of the retailer, which he can realize because of reduced reverse logistic costs. As a consequence, the retailer can lower his selling price what attracts more customers as well. As mentioned, a significant difference in the retailer's optimization under a wholesale contract is, that he can consider the value of unsold items (case (MI, RC)) to benefit him. Thus, for rising salvage values, we find higher order amounts when the retailer ignores returns in his optimization process. However, this fact is supported by lower wholesale prices of the vendor. Under the premise of ignoring returns, the costs of returns are partly absorbed by the salvage values. This allows him to be partly better off under policy (MC, RI) when he faces the bigger part of return costs.

		(MC,RI)			(MI,RC)		
v	v_r	Π_M	Π_R	Π_T	Π_M	Π_R	Π_T
		$\beta =$ **0.05**					
0.4	0.2	1.81	1.32	3.12	1.59	2.03	3.63
0.8	0.4	2.08	1.61	3.69	2.02	2.42	4.44
1.2	0.6	2.52	2.25	4.77	2.66	3.04	5.70
		$\beta =$ **0.95**					
0.4	0.2	2.46	1.15	3.61	1.81	1.30	3.11
0.8	0.4	2.82	1.54	4.35	2.25	1.58	3.83
1.2	0.6	3.41	2.38	5.78	2.93	2.03	4.96
		$\beta =$ **0.05**					
0.4	0.4	1.89	1.35	3.24	1.69	2.03	3.72
0.8	0.8	2.27	1.77	4.04	2.23	2.42	4.65
1.2	1.2	2.88	2.61	5.49	3.03	3.04	6.07
		$\beta =$ **0.95**					
0.4	0.4	2.57	1.20	3.77	1.88	1.30	3.18
0.8	0.8	3.07	1.69	4.76	2.42	1.58	3.99
1.2	1.2	3.88	2.73	6.62	3.23	2.03	5.26

Table 5.5. Asymmetric Supply Chain Performance for Positive Item Salvage Values $(v, v_r = v)$ and $(v, v_r = \frac{v}{2})$ under Different Shares of Reverse Logistic Costs

We also find policy (MC, RI) to be inferior to (MI, RC) for low rates of β, whereas it is vice versa for higher magnitudes of the latter coefficient. This is basically an extension of our findings up to now under stochastic and price-dependent demand. Considering the individual profits of the supply chain agents, the gap between the asymmetric policies as well as between the players itself decreases with rising salvage values. This aspect is even more noticeable when costs for returned items are shifted differently between the players. (see table 5.5).

Change in Market Parameters

Finally, we present the robustness of our results when changing market conditions occur. Within the considered model, total market demand $D(r) = b \times (r - k)$ is depending on the variables $b < 0$ and $k > r$. Therefore, k represents the total size of the market, whereas b describes the demand elasticity of the market. The demand elasticity is decreasing in k: $E(r) = -\frac{r*D'(r)}{D(r)} = -\frac{r}{r-k}$. In table 5.6 we present three cases of changed market environments. Besides the base scenario (b=-3, k=5), two additional scenarios with respectively half or double the market size and elasticity than in the base case are compared. For these market data, the optimal individual and system-wide profits under asymmetric settings is presented when varying overall return volumes, reverse logistic costs and share of them.

We observe that for the values under both asymmetric settings, reducing the elasticity and increasing the size of the market results throughout in higher profits, whereas reduced profits are found under smaller markets and higher elasticity. The results for changed values of the elasticity represent the economic theory, which proposes to make less profits when consumers are more price sensitive. The specified return rates influence profits as we have examined it in the previous sensitivity analysis. We also find both policies to be better off if β is higher. However, differences are only marginally. Also, we observe that α has a stronger influence on profits than logistic costs in both settings. *This last comprehensive sensitivity analysis allows us to state that the result of the retailer being better off than the manufacturer in setting* (MI, RC) *(compare table 5.1) is (almost) only valid for our initial base case setting. Consequently, changing the diverse model parameters allow the manufacturer to absolutely outperform the retailer, what is similar to findings under stochastic demand.*

5.2 Buy-Back Contract

For both supply chain agents, buy-back contracts help mitigating the risk associated with consumer returns. Additionally, costs occurring due to consumer returns are balanced more equally among both players. In the last chapter, we have conducted numerical studies in order to show possible supply chain coordination that can be reached with buy-back rebates. In doing so, a severe shift of profits amongst the players became observable which arises because the manufacturer is egoistically

		(MC,RI)				(MI,RC)			
		$\alpha = 0.05$		$\alpha = 0.35$		$\alpha = 0.05$		$\alpha = 0.35$	
		l = 1	**l = 3**	**l = 1**	**l = 3**	**l = 1**	**l = 3**	**l = 1**	**l = 3**
		$\beta = 0.05$							
b = -3 k = 5	Π_M	3.08	2.87	0.94	-	2.98	2.76	0.59	0.23
	Π_R	2.28	2.08	0.55	-	2.30	2.29	1.22	0.12
	Π_T	5.35	4.95	1.49	-	5.28	5.05	1.81	0.36
		$\beta = 0.95$							
	Π_M	3.18	3.16	1.31	0.24	2.99	2.81	0.80	-
	Π_R	2.20	2.06	0.31	0.15	2.21	2.01	0.73	-
	Π_T	5.38	5.22	1.62	0.39	5.20	4.81	1.54	-
		$\beta = 0.05$							
b = -1.5 k = 10	Π_M	9.66	9.38	5.03	3.27	9.40	9.10	4.08	2.39
	Π_R	7.26	7.02	3.23	2.15	7.27	7.25	4.02	3.93
	Π_T	16.93	16.40	8.26	5.42	16.66	16.36	8.10	6.32
		$\beta = 0.95$							
	Π_M	9.80	9.77	5.80	5.08	9.42	9.18	4.24	2.98
	Π_R	7.17	7.03	3.05	1.27	7.14	6.86	3.28	2.00
	Π_T	16.96	16.80	8.84	6.36	16.56	16.04	7.52	4.98
		$\beta = 0.05$							
b = -6 k = 2.5	Π_M	0.52	0.42	0.01	0.00	0.49	0.38	-0.28	-0.79
	Π_R	0.36	0.29	0.00	0.00	0.43	0.42	0.21	0.18
	Π_T	0.88	0.71	0.01	0.00	0.92	0.80	-0.08	-0.61
		$\beta = 0.95$							
	Π_M	0.57	0.55	0.00	-	0.50	0.41	-0.01	-
	Π_R	0.36	0.27	-0.17	-	0.38	0.28	0.03	-
	Π_T	0.93	0.82	-0.17	-	0.88	0.69	0.02	-

Table 5.6. Behavior of the Asymmetric Policies under Different Market Parameters. $\alpha = \{0.05, 0.35\}$, $\beta = \{0.05, 0.95\}$ and $l = \{1, 3\}$

maximizing her profits. In addition, Ruiz Benítez and Muriel (2007) [42] present an analytical solution which also coordinates the system, but, more important, can distribute profits almost equally between the players.

For the case of stochastic and price-dependent demand, it is not possible to receive closed-form expressions because most of the parameters in the manufacturer's expected profit function depend on s and therefore, the expression for the derivative is not obtainable easily. Ignoring returns and facing a multi-retailer environment, Bernstein and Federgruen (2005) [3] also find that buy-back contracts are not suitable to ensure supply chain coordination. Emmons and Gilbert as well as Ruiz Benítez and Muriel (2007) [42] conduct calculatory analyses in order to show the effects of buy-back contracts. When ignoring consumer returns, the former show that there exists a threshold value, say w^t, for the wholesale price ,and thus a buy-back price of $s > 0$, after which both players are indeed benefitting from buy-back contracts, whereas the same results are retrieved by the latter when considering returns in the optimization process. When excluding returns, Ruiz Benítez and Muriel (2007) [42] obtain that the positive effects of a buy-back option no longer exists for all pairs of (w, s).

In the following, we evaluate the effects of consumer returns on the asymmetric cases by solving the manufacturer's problem numerically and show the impacts of consumer returns on the individual agent's and total supply chain profits. Further, we present sensitivity analysis regarding the impacts of changing environmental variables, such as overall return rates, logistic costs, the share of them between the players and positive product salvage values as well as production costs in order to maintain our general observances. Additionally, we vary the parameters of the considered market, i.e. b and k. Note that b and k can be seen according to the parameters of μ and λ under stochastic demand. Of course, optimal order quantities as well as wholesale and retail prices are also a matter of discussion within this section.

	Buy-Back Contract							
	Symmetric				Asymmetric			
	(CR)	%Δ	(IR)	%Δ	(MC,RI)	%Δ	(MI,RC)	%Δ
w^*	3.34	25.1%	2.99	27.1%	3.34	25.1%	2.99	27.1%
s^*	2.84	-	2.49	-	2.84	-	2.49	-
r^*	4.32	5.7%	4.13	5.6%	4.29	5.8%	4.16	5.5%
Q^*	2.47	25.5%	3.63	19.8%	2.79	21.4%	3.27	23.9%
Π_M	1.857	24.0%	1.769	10.4%	1.792	9.6%	1.712	24.1%
Π_R	0.942	-21.1%	1.481	-13.2%	0.932	-18.9%	1.493	-15.0%
Π_T	2.799	8.8%	3.250	-0.4%	2.724	-0.1%	3.205	5.9%

Table 5.7. Comparison of the Decentralized Symmetric and Asymmetric Policies under Wholesale and Buy-Back Contracts

Table 5.7 shows the equilibrium values for all decentralized policies. Additionally, the percent differences (referring to the left cell of it) between the considered policy under a wholesale contract and a buy-back contract are included. Note that for the centralized system a buy-back option is not available. Thus, the system-wide profit of 3.71 of the centralized symmetric policy (CR) presented in table 5.1 on page 56 remains the best coordinated solution of the considered supply chain.

For the asymmetric settings, an improvement of supply chain coordination is possible with a buy-back contract, just as in the decentralized cases (CR) *and* (IR). Although coordination is not reached with buy-back rebates, the asymmetric setting (MI, RC) is close to the decentralized benchmark policy of (IR). However, its total profits have declined marginally compared to the wholesale contract (-0.4%). The development of profits of both players and of the total supply chain under a wholesale contract ($s = 0$) and under a buy-back option is shown in figure 5.7. We find threshold values, indicated as w' and w'' on the abscissas, from where on both players are better off (blue and purple lines). The total supply chain is never better off (red lines). Moreover, the manufacturer sets the wholesale price in order to egoistically maximize his profits and therefore puts the retailer into a worse position.

In short, we examine the following for the asymmetric settings in the base case specifications under a buy-back rebate:

- Coordination is not reached under asymmetric settings. The gained results from table 5.7 show that the profits of the players and of the total supply chain are either within the range or only slightly off of values from policies (CR) and (IR). Decision variables however, have higher magnitudes compared to the wholesale contract.

- We observe relations for the optimal decision values: the buy-back value s^* is $s^* = w^* - \frac{c}{2}$. With the findings of Granot and Yin (2005) [22] and the extension to a linear demand curve done by Ruiz Benítez and Muriel (2007) [42], we get $w^* = \frac{k}{2} + \frac{c}{2}$ and thus $s^* = \frac{k}{2}$.

- After certain threshold values, both players can, as in the decentralized symmetric policies, be better off than if simply provided with a wholesale contract.

- As under stochastic demand, the manufacturer rakes most of the profits in the system. However, the profit shift observed under stochastic and price-dependent demand is not that severe.

The mentioned percent differences allow us to explicitly notice the effects of a buy-back contract. As already stated, buy-back rebates partly hedge the retailer against low demand. In other words, he orders more units to be able to satisfy more demand, whereas the higher risk to overstock is mitigated by the buy-back option offered by the manufacturer. Since this thought of the retailer drives his order decision predominantly under a buy-back contract, the manufacturer can consequently exploit this fact in her optimization process. Figure 5.7 states that under stochastic and price-dependent demand the manufacturer's profits indeed rise with buy-back options, regardless of the policy considered. The reason is a combination of the following: Firstly, the retailer orders more items and, secondly, wholesale prices w are

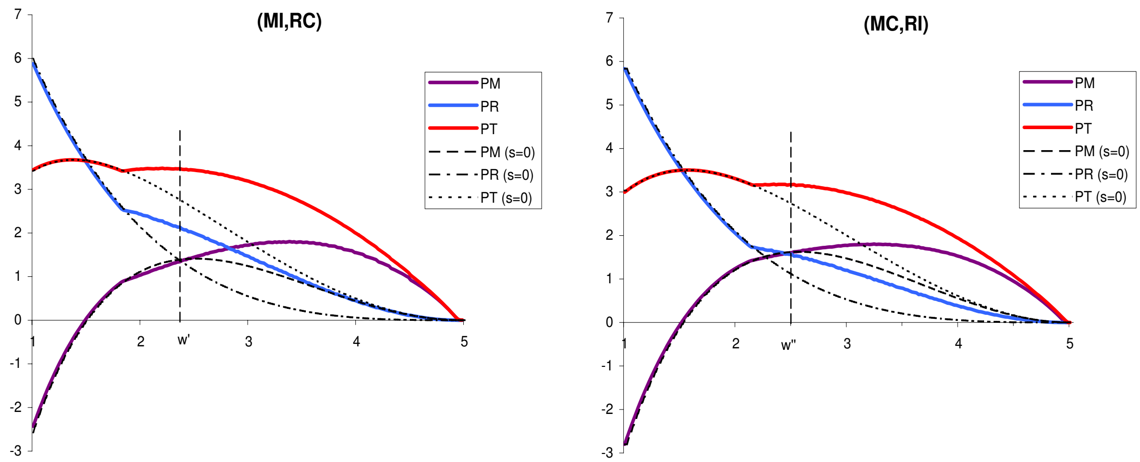

Figure 5.7. Performance of the Asymmetric Cases under a Wholesale and a Buy-Back Contract for Stochastic and Price-Dependent Demand in the Base Case Setting.

higher. The latter happens because it is compensating the buy-back offer and, more important, the vendor takes her part of increased retailer profits. According to earlier observances in this thesis, the retailer reacts in higher purchase costs w with higher retail prices r. However, the percent difference stated for w and Q is roughly between 20% and 30%. The retail price, in turn, only goes up by a comparably small percentage of about 5%. Since the retailer's and manufacturer's income is mainly driven by $r^* \times Q^*$ and $w^* \times Q^*$, it becomes clear that under buy-back contracts, it is the manufacturer who rakes most of the (additional) profits. Considering the effects of returns, in the base case only 20% of the goods sold are returned, what means, the latter finding is not changed throughout the base cases. In order to study the effects of returns on this issue, we vary α below. As a consequence, the retailer is worse off under any decentralized policy if he accepts the buy-back option from the vendor. The absolute values of both supply chain players in tables 5.1 and 5.7 show, that the manufacturer can considerably increase his profits in the settings (CR) and (MI, RC). Aside from the incentive scheme of the retailer, the vendor benefits from an (on a percentage basis) even higher transmitted order quantity, what is the reaction on return costs by the former. If the retailer ignores returns in his decision process, the absolute increase in the manufacturer's profits is smaller. As a result, the level of the manufacturer's profits in both, asymmetric and symmetric policies, is aligning. Coordination, as mentioned, is not reached due to the weak performances of the retailer.

5.2.1 Sensitivity Analysis

In the upcoming sensitivity analysis, we aim at comparing the buy-back rebate with the wholesale contract under stochastic and price-dependent demand and a constant return rate of total goods sold for the case of asymmetric decision making. Profits, optimal order quantities as well as retail and wholesale prices are examined. As buy-back rebates are an option to improve coordination of the system, we are studying changes to the results of a wholesale contract and draw conclusions for the players whether they would benefit from a buy-back contract or not under asymmetric decision making. We shall see that coordination is never reached and therefore the symmetric policy (CR) remains optimal in terms of total supply chain profits.

Different Constant Return Rates

Firstly, we look at different rates for returned products α. Table 5.8 shows the equilibrium values for the considered asymmetric policies (MC, RI) and (MI, RC) under a wholesale and buy-back option, whereas the impact of more returned items on optimal order amounts and prices is equivalently. Further, the relationships between the latter variables is as outlined above. Under the premise that a player considers returns in his optimization process, raising rates of returns, i.e higher reverse logistic costs, lead to higher magnitudes in their relevant decision variables in order to bolster against the negative effects of returned items. Of course, in case of the manufacturer ignoring returns, his decision variables remain unchanged. Since the retailer adjust his retail price by rising it, order quantities are decreasing. Unaltered to the initially

	Wholesale		Buy-Back	
	(MC,RI)	(MI,RC)	(MC,RI)	(MI,RC)
	$\alpha = 0.05$			
w^*	2.24	2.18	3.06	3.00
s^*	-	-	2.54	2.50
r^*	3.93	3.91	4.16	4.14
Q^*	2.77	2.81	3.41	3.53
	$\alpha = 0.2$			
w^*	2.50	2.18	3.34	3.00
s^*	-	-	2.84	2.50
r^*	4.05	3.93	4.29	4.16
Q^*	2.19	2.49	2.79	3.25
	$\alpha = 0.35$			
w^*	3.00	2.18	3.74	3.00
s^*	-	-	3.22	2.50
r^*	4.26	3.96	4.48	4.19
Q^*	1.31	2.12	1.84	2.90

Table 5.8. Decision Variables of the Asymmetric Supply Chains provided with a Buy-Back Contract for different Return Rates α

retrieved results for buy-back contracts, the option to take back left over inventory at the end of the selling period leads to higher magnitudes in the considered parameters as well. The effects of changing return rates on total and individual supply chain profits in the asymmetric settings are studied in the following. We also find that coordination is not reached.

Different Total Logistic Costs and Shares

Total logistic costs and the division of them among the supply chain players directly affect their profit margins. We vary the return volume α, the share of logistic costs β and the total logistic costs k between [5%; 35%], [0.05; 0.95] and [1; 3], respectively. Table 5.9 presents the sensitivity analysis in the latter mentioned parameters and shows optimal profits for the supply chain players and the total system in case of asymmetric optimization. Furthermore, the percent difference of total profits to the system under a wholesale contract is shown.

		(MC,RI)				(MI,RC)			
α	β	Π_M	Π_R	Π_T	%Δ to Wholesale	Π_M	Π_R	Π_T	%Δ to Wholesale
		total logistic costs l = 1							
5 %	5 %	3.621	**1.785**	5.406	0.96%	3.403	**1.701**	5.103	**-3.53**%
5 %	95 %	3.719	**1.788**	5.507	2.32%	3.594	**1.824**	5.418	4.01%
20 %	5 %	2.184	**1.101**	3.285	**-1.13**%	2.148	**1.515**	3.663	6.33%
20 %	95 %	2.428	**1.033**	3.460	**-3.64**%	2.216	**1.142**	3.358	5.43%
		total logistic costs l = 2							
5 %	5 %	3.511	**1.748**	5.259	3.28%	3.473	**1.922**	5.396	4.22%
5 %	95 %	3.703	**1.719**	5.422	2.02%	3.482	**1.718**	5.200	3.75%
20 %	5 %	1.792	**0.932**	2.724	**-0.13**%	1.712	**1.493**	3.205	5.88%
20 %	95 %	**2.171**	**0.757**	2.928	**-7.82**%	1.848	**0.810**	2.658	3.30%
		total logistic costs l = 3							
5 %	5 %	3.403	**1.701**	5.103	2.96%	3.356	**1.916**	5.272	4.15%
5 %	95 %	3.685	**1.687**	5.372	2.87%	3.371	**1.615**	4.986	3.45%
20 %	5 %	1.446	**0.739**	2.185	0.19%	1.282	**1.471**	2.754	5.32%
20 %	95 %	**1.844**	**0.393**	2.237	**-18.27**%	1.488	**0.538**	2.026	**-0.34**%

Table 5.9. Equilibrium Values of the Asymmetric Settings for different α, β and l, and Percent Differences to a Wholesale Contract.

For the considered values in both asymmetric settings, buy-back contracts (mostly) improve the coordination of the system. However, the retailer suffers under the buy-back contract since his outcome is worse than if provided with a wholesale contract. Consequently, it is the manufacturer that rakes the additional profits and is also in the position to further shift supply chain profits in his interests. Again, this extends our initial findings. Note, that if logistic costs are carried predominantly by the retailer, the manufacturer can be worse off. Worse performances of the total system or of the players under a buy-back contract compared to the price-only contract are highlighted in bold in table 5.9. We also find that for low return rates ($\alpha = 0.05$), system-wide profits of (MC, RI) outperform (MI, RC), whereas for higher return rates it is vice versa. Regarding the relative changes, the asymmetric setting (MI, RC) benefits more from the offered option to buy back unsold items. If the retailer ignores returns, rising logistic costs have ruinous effects on his profits and also on the system's performance, especially if he bears the lion share of costs associated with returns. For the asymmetric settings graphs of the optimal order amounts, wholesale and retail prices as well as the changes in the optimal buy-back values, when varying β, are pre-

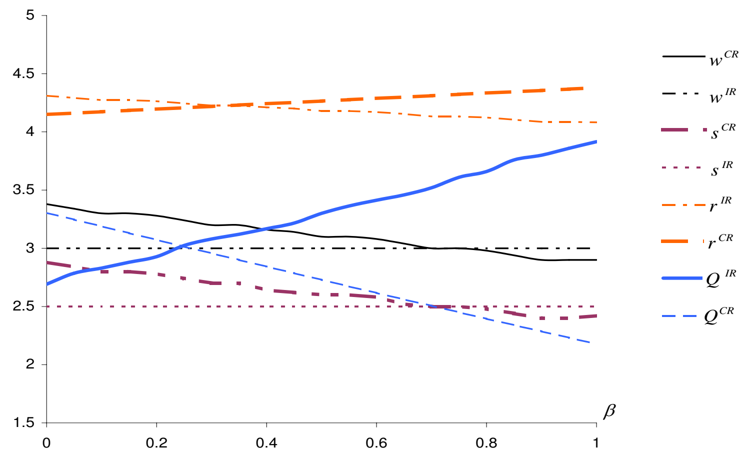

Figure 5.8. Buy-Back Contract vs. Wholesale Contract: Behavior of the Decision Variables for varying Shares of Logistic Costs under Asymmetric Decision Making

sented in figure 5.8. The results are as expected and, moreover, generalize the results that we obtained so far. The undulation in the curves for the setting (MC, RI) are due to rounding restrictions in the calculational process.

Positive Salvage Values

Under a wholesale contract, the bottom line is that positive salvage values for unsold and returned items improve both players absolute profits. Since the unsold item stays with the retailer, this incentive allows him to order more and lowers the optimal retail prices. As mentioned, he is partly hedged against overstocking. Equipped with a buy-back contract, unsold items go back to the vendor, whereas she pays s for each product. Accordingly, just as under a price-only contract positive salvage values have the opposite effects on the supply chain's performance than increased logistic costs, that is α, l and partly β.

Confirming earlier results, table 5.10 shows that positive salvage values are (mostly) improving the coordination of the asymmetric supply chain under buy-back contracts. A declining of profits is indicated by bold numbers. The manufacturer's performance

		(MC,RI)			(MI,RC)		
v	v_r	Π_M	Π_R	Π_T	Π_M	Π_R	Π_T
		$\beta =$ **0.05**					
0.4	0.2	18.98%	-16.29%	4.11%	35.39%	-14.02%	7.71%
0.8	0.4	40.22%	-10.23%	18.21%	39.29%	-12.11%	11.29%
1.2	0.6	59.10%	-8.54%	27.19%	46.68%	-14.31%	14.16%
		$\beta =$ **0.95**					
0.4	0.2	5.43%	-16.80%	**-1.64%**	25.95%	-25.10%	4.57%
0.8	0.4	32.29%	-15.93%	15.27%	29.77%	-21.51%	8.64%
1.2	0.6	45.93%	-21.02%	18.40%	34.34%	-21.15%	11.65%
		$\beta =$ **0.05**					
0.4	0.4	18.23%	-15.34%	4.22%	33.90%	-14.02%	7.71%
0.8	0.8	36.83%	-12.98%	15.01%	36.23%	-12.11%	11.09%
1.2	1.2	51.18%	-14.96%	19.74%	40.99%	-14.31%	13.32%
		$\beta =$ **0.95**					
0.4	0.4	5.83%	-18.43%	**-1.91%**	25.07%	-25.10%	4.53%
0.8	0.8	28.21%	-15.75%	12.61%	27.97%	-21.51%	8.43%
1.2	1.2	38.06%	-25.56%	11.77%	30.99%	-21.15%	10.88%

Table 5.10. Positive Unsold Item Values: Percent Differences of the Asymmetric Settings under a Buy-Back Contract compared to a Price-Only Contract

is considerably better than compared to the wholesale contract. On the other side, the retailer faces a severe declining of his profits.

This is explained as follows: Both, a buy-back option, and positive salvage values, propose incentive schemes to the players. The former hedges the retailer against demand and the latter mitigates the financial charges that occur due to unsold or returned items. In other words, the rise in the order quantity is due to the buy-back offer and due to positive salvage values. As we find higher order amounts and lower wholesale prices, retail prices decrease as well. Under buy-back contracts, in total, the effects of positive salvage values on profits are stronger as changes in α, β or l. Table 5.11 presents the total absolute profits of the policies (MC, RI) and (MI, RC). For the latter setting, the better outcome is reached if the retailer has the major burden of dealing with return costs, whereas the former setting performs better for lower shares of logistic costs β. *Concluding, positive salvage values lead directly (buy-back rebate)*

		(MC,RI)	(MI,RC)
v	v_r	Π_T	Π_T
		$\beta =$ **0.05**	
0.4	0.2	3.25	3.91
1.2	0.6	6.07	6.50
		$\beta =$ **0.95**	
0.4	0.2	3.55	3.25
1.2	0.6	6.85	5.54
		$\beta =$ **0.05**	
0.4	0.4	3.38	4.01
1.2	1.2	6.57	6.88
		$\beta =$ **0.95**	
0.4	0.4	3.70	3.32
1.2	1.2	7.39	5.83

Table 5.11. Positive Unsold Item Values: Total Profits of the Asymmetric Settings under a Buy-Back Contract

and indirectly (positive v allows the manufacturer to lower w) to a "double-incentive" for the retailer to order more items. The manufacturer systematically exploits this fact by shifting the division of total supply chain's profits in her interest.

Change in Market Parameters

Externally given market variables directly affect the performance of the supply chain. As we observed in section (5.1.1), the manufacturer's and retailer's profits ameliorate or decline according to the change in market demand. Neither of them is in the position to rake more profits in different market sizes or for different market elasticities. This holds true under a buy-back contract as well. Table 5.12 shows the relative performance of the vendor and retailer and of the total system. Omitted values are due to the fact that the policy is not existing (one player facing negative profits when considering returns) or because of negative values that lead to unreasonable percentages. The results are as follows:

- Due to the influence of buy-back contracts on the division of profits, in all considered markets the retailer is worse and the manufacturer better off than

		(MC,RI)				(MI,RC)			
		$\alpha = 0.05$		$\alpha = 0.35$		$\alpha = 0.05$		$\alpha = 0.35$	
		l = 1	**l = 3**	**l = 1**	**l = 3**	**l = 1**	**l = 3**	**l = 1**	**l = 3**
b = -3 k = 5	Π_M	17.63%	18.57%	**-19.74%**	-	20.47%	21.60%	41.02%	-
	Π_R	**-21.56%**	**-18.34%**	**-8.08%**	-	**-16.35%**	**-16.45%**	**-8.28%**	-
	Π_T	0.97%	3.05%	**-15.42%**	-	4.41%	4.33%	7.71%	-
b = -1.5 k = 10	Π_M	19.36%	19.93%	0.53%	**-1.28%**	22.20%	22.86%	34.08%	47.71%
	Π_R	**-20.85%**	**-19.15%**	**-13.85%**	**-7.50%**	**-18.27%**	**-18.31%**	**-7.59%**	**-8.07%**
	Π_T	2.10%	3.19%	**-5.09%**	**-3.75%**	4.55%	4.60%	13.39%	12.99%
b = -6 k = 2.5	Π_M	15.35%	16.87%	-	-	18.81%	22.25%	**-7.53%**	**-7.81%**
	Π_R	**-19.05%**	**-16.45%**	-	-	**-17.59%**	**-17.94%**	**-14.40%**	**-18.76%**
	Π_T	1.16%	3.18%	-	-	1.89%	1.05%	66.46%	15.55%

Table 5.12. Change in Exogenous Market Settings: Relative Performance of Total Profits in the Asymmetric Settings under a Buy-Back Contract compared to a Wholesale Contract

		(MC,RI)				(MI,RC)			
		$\alpha = 0.05$		$\alpha = 0.35$		$\alpha = 0.05$		$\alpha = 0.35$	
		l = 1	**l = 3**	**l = 1**	**l = 3**	**l = 1**	**l = 3**	**l = 1**	**l = 3**
b = -3 k = 5	w*	3.05	3.09	3.51	-	2.99	2.99	2.99	2.99
	s*	2.54	2.59	3.01	-	2.49	2.49	2.49	2.49
	r*	4.16	4.18	4.37	-	4.13	4.14	4.17	4.20
	Q*	3.46	3.39	2.39	-	3.56	3.55	2.98	2.86
b = -1.5 k = 10	w*	5.54	5.56	6.00	6.47	5.48	5.48	5.48	5.48
	s*	5.03	5.05	5.50	5.96	4.98	4.98	4.98	4.98
	r*	7.95	7.96	8.17	8.40	7.93	7.93	7.99	8.02
	Q*	5.08	5.05	4.46	3.79	5.12	5.11	4.60	4.53
b = -6 k = 2.5	w*	1.80	1.84	-	-	1.75	1.75	1.75	1.75
	s*	1.30	1.33	-	-	1.25	1.25	1.25	1.25
	r*	2.22	2.24	-	-	2.21	2.21	2.23	2.25
	Q*	1.52	1.36	-	-	1.63	1.62	1.21	1.07

Table 5.13. Change in Exogenous Market Settings: Absolute Performance of Decision Variables in the Asymmetric Settings

under a wholesale contract. However, for high return volumes, the vendor can be worse off as well.

- Except for high magnitudes of α in setting (MC, RI), the total supply chain performs better with a buy-back option than if equipped with a simple price-only contract.

- Table 5.13 shows that policy (MC, RI) results higher wholesale and retail prices, w^* and s^*, and buy-back prices s^*. Consequently, the order quantity Q^* set by the retailer is lower. However, total profits are either better in setting (MI, RC) or (MC, RI), depending on the respective parameters, whereas no rule is observable. This matches with the findings under a wholesale contract.

5.3 Conclusions

In this chapter we investigated asymmetric decision making under stochastic and price-dependent demand at the retail level. We could extend some of the findings in chapter 4 to stochastic and price-dependent demand, whereas we also observed different results:

Results retrieved under a Wholesale Price-Only Contract

1. Under stochastic and price-dependent demand performances of the asymmetric settings (MI, RC) and (MC, RI) are in between the range of the decentralized symmetric policies. Thus, supply chain coordination is not achieved.

2. Contrary to under stochastic demand, higher total profits are found in setting (MI, RC). The retailer also outperforms the vendor in this case. Note that under stochastic demand, the retailer does not outperform the latter in the base case setting.

3. In a specific asymmetric setting, one and only one player is better off than in both symmetric cases, as opposed to the other player who is facing worse profits.

4. Sensitivity analysis shows that a change in the model parameters does not lead to coordination of the asymmetric settings. In other words, the centralized symmetric policy (CR) is not outperformed. However, varying respective parameter leads to different effects on the outcome of the asymmetric settings. In general, we are able to extend the findings of the work of Ruiz Benítez and Muriel (2007) [42] for stochastic and price-dependent demand with a constant return rate:

   - Higher overall return volumes α generally lessen system-wide performances in both asymmetric cases.
   - (MC, RI) improves its coordination and (MI, RC) is getting worse for a shift in logistic costs to the retailer.
   - Setting (MC, RI) is steadily improving its coordination for rising costs of returns, whereas policy (MI, RC) is experiencing less coordination.
   - Positive salvage values and bigger markets with less fluctuations lead to rising profits. Coordination, however, is not reached.

Results retrieved under a Buy-Back Contract

1. When provided with a buy-back contract, coordination is not reached under any asymmetric setting if demand is stochastic and price-dependent. Profits of the players and of the total supply chain are either within the range or only slightly off the values from the decentralized policies (CR) and (IR). After certain threshold values of the wholesale price, however, both players can benefit form a buy-back option.

2. Decision variables have higher magnitudes compared to the wholesale contract and, as under stochastic demand, the manufacturer rakes most of the profits in the system. The retailer faces worse profits than if provided with a wholesale contract. However, the profit shift observed under stochastic and price-dependent demand is not that severe.

3. Granot and Yin (2005) [22] present a relationship between wholesale and buy-back price in their work. Extended to a linear demand curve, this relationship still holds true for the the asymmetric settings. That is, $s^* = w^* - \frac{c}{2}$ and $s^* = \frac{k}{2}$.

4. Sensitivity Analysis further generalized the findings of the base case:

   - Whether coordination in setting (MC, RI) or (MI, RC) is better depends on the parameter specifications

   - For high return volumes, the vendor can be worse off than under a wholesale contract as well.

   - Positive salvage values have the same effects as under a wholesale contract.

   - In the three considered markets, the retailer is worse and the manufacturer better off than under a wholesale contract.

   - The total supply chain (mostly) performs better with a buy-back option than if equipped with a simple price-only contract.

CHAPTER 6

PRICE DEPENDENT RETURN RATES

So far, we assumed consumer returns to be a constant rate of total sold items, i.e. $\alpha = 0.2$. However, regarding diverse kinds of consumer products and also the corresponding prices, it is intuitive that return rates and prices are correlated. Costly products are more likely to be returned than inexpensive ones due to the reason that consumers are more sensitive to higher expenditures. For example, a too noisy microwave is probably be more often returned if the price is very high, whereas if it is a bargain, consumers might just accept it. Another explanation is given by the fact that relaxed return policies allow customers to return a product without any question asked. Some consumers - especially when items are more expensive - buy a certain product when they need it, use it, and then return it as soon as they are finished with the respective work. Anderson et al. (2006) [1] shows through empirical evidence that customer return rates increase with the price paid. In consequence, the return function $\alpha(r)$ can be described using the exponential type, which reflects the fact that returns grow faster than the prices of goods. The function we consider for price-dependent customer returns is:

$$\alpha(r) = \begin{cases} \frac{1}{a} r^d & if\ \frac{1}{a} r^d < 1 \\ 1 & elsewise \end{cases} \tag{6.1}$$

with the parameters $a > 0$ and $d > 0$. D represents the general shape of the return function. That is $d > 1$ models disproportionately high returns, $d < 1$ disproportionately low ones and $d = 1$ stands for linearly growing consumer returns in the retail price. A controls the speed in which consumer returns grow in r. Note that for linear and exponential return functions in the base case settings, $a = 1$ is tantamount to having returned all sold items regardless of the retail price, since we require $r > w > c = 1$. In fact, $a \geq 1$ is just the mathematical constraint to ensure the correctness of the considered formula. For a meaningful problem, we require $a \in [35, 90]$.

The general functions, introduced in section 3.3, after which manufacturer and retailer find their optimal profits and decision variables remain unchanged. However, the constant return rate α is substituted by the variable one $\alpha(r)$. Note that when considering returns, the retailer's optimal selling price is depending on the return rate, which is depending on r itself. This fact makes it even more difficult to receive closed-form expression and perform analytical work. As a result, it is not easy to show that the order quantity decreases when both players include returns in their optimization process. Thus, for stochastic and price-dependent demand with price-sensitive returns we resort again to calculational studies to analyze the performance of the supply chains in the symmetric and asymmetric settings. Results show that for price-dependent returns the order-quantity decreases when considering returns. For similar reasons proves for the convexity of the diverse profit functions are extremely difficult, whereas our calculations show that the found optima are unique and, hence, convexity is still given. Moreover, the dependency of overall consumer returns on the retail price arranges for a stronger decrease than under a constant return rate. For the following numerical experiments an exhaustive approach is used, i.e. the manufacturers searches her best performance under all valid tuples (w,s) of the wholesale and buy-back price.

As under stochastic demand, the main objective of the computational work is to evaluate the effects of customer returns on optimal supply chain profits, optimal ordering quantities, wholesale and retail prices and buy-back rebates. However, for the case of price-dependent returns predominantly the symmetric policies, that is (CR) and (IR), are of importance, as they haven't been studied yet in existing literature. Nevertheless, we present the asymmetric cases and examine its behavior and the differences to the symmetric settings. The considered policies are the same as described in chapter 3, whereas the policies (IR) and (CR) represent the decentralized symmetric decision making policies:

- **Policy (CR)**: Decision variables for both players are calculated taking into account the expected consumer returns that occur at the retail level.
- **Policy (IR)**: Decision variables for manufacturer and retailer are calculated ignoring the expected consumer returns and the expected associated costs. The cost of returns are included a posteriori.
- **Policy (MC,RI)**: The manufacturer is considering consumer returns in her optimization process, whereas the retailer does not consider them.
- **Policy (MI,RC)**: The manufacturer ignores consumer returns when optimizing her profits. The retailer, in turn, considers them.

In order to perform computational studies, we are using the parameter specifications from the base case. Total logistic costs l, the division of them among the players β, and production costs c are set to 2, 0.05 and 1, respectively. Both salvage values, v and v_r, are 0. As before, a uniform distribution on the interval $[0, 2]$ is being applied and expected demand is of the form $D(r) = b(r - k)$ with $b < 0$ and $r < k$. The latter restriction also limits the return rate. Figure 6.1 shows return functions of the exponential types $(d = 2)$ with shape parameter settings of $a = \{35, 70, 200\}$. Since in the equilibrium of the decentralized symmetric policies, $d = 2$ and $a = 70$ are fairly equivalent to having 20% of sold goods returned, we are considering this combination, $(a, d) = (2, 70)$, as our base case specification for the return function in order to have a reference result.

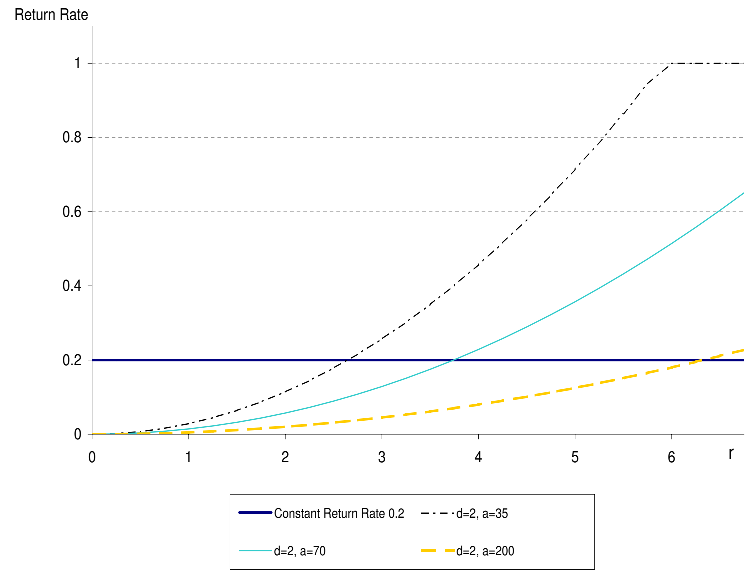

Figure 6.1. Different Types of Consumer Return Functions: Constant Return Rate $\alpha = 0.2$ and Price-Dependent Return Rates with Parameters d=2 and $a = \{35, 70, 200\}$

In the following study, we first consider the simple price-only contract and conduct a sensitivity analysis in the model parameters to prove and widen our findings of price-dependent return rates in the base case. We also vary the parameters a and d as they are critical on overall return volumes and thus on reverse logistic costs. In excess of conducted analysis in the symmetric optimization policies, we consider the asymmetric settings as well. Differences between the latter and the former are evaluated, but we especially attach importance to the comparison of the performances of symmetric and asymmetric settings with price-dependent returns rates versus constant return rates. The last part of this section is dedicated to the buy-back option again.

6.1 Wholesale Price-Only Contract

Table 6.1 shows the supply chains' equilibrium values under stochastic and price-dependent demand for constant and price-dependent returns, whereas we consider

		Symmetric			
		Constant α		Price-Dependent α	
		(CR)	**(IR)**	**(CR)**	**(IR)**
Cent.	r^*	3.46	3.27	2.95	3.27
	α	20.0%	20.0%	12%	15%
	Q^*	4.90	7.22	7.03	7.22
	Π	3.71	3.21	4.69	6.02
Decent.	w^*	2.5	2.18	2.28	2.18
	r^*	4.07	3.90	3.81	3.90
	α	20.0%	20.0%	20.7%	21.7%
	Q^*	1.84	2.91	2.45	2.91
	Π_M	1.4113	1.5848	1.3776	1.4267
	Π_R	1.1409	1.6771	1.461	1.6066
	Π_T	2.5522	3.2619	2.8386	3.0333

Table 6.1. Symmetric Policies: Equilibrium Values under Stochastic and Price-Dependent Demand for Constant and Price-Dependent Returns(a=70,d=2)

the base case settings with $a = 70$ and $d = 2$. Note that the base case is constructed to receive approximately 20% of returns in the *decentralized* cases. Consequently, the return rate is lower for both centralized policies.

For the centralized policies we gain interesting results from the computational work, which partly stand in contrast to the ones obtained under a constant return rate:

- Most important, policy (CR) is outperformed by (IR). Obviously, when ignoring returns, lower total returns improve the profits above the outcome of (CR).

- Ignoring returns induces higher order quantities Q^* and, as opposed to a constant return rate, rising retail prices r^*.

- Due to the higher retial price when ignoring returns, policy (IR) faces a higher return percentage (also absolute due to a higher Q^* as well) than (CR).

As for stochastic and price-dependent demand with a constant proportion of returns, the decision variable r and total profit of the system is independent of the order quantity. Figure 6.2 presents the outcome of policy (CR) over the feasible range of retial prices. It also includes the reference point for the profits when the centralized supply chain ignores returns.

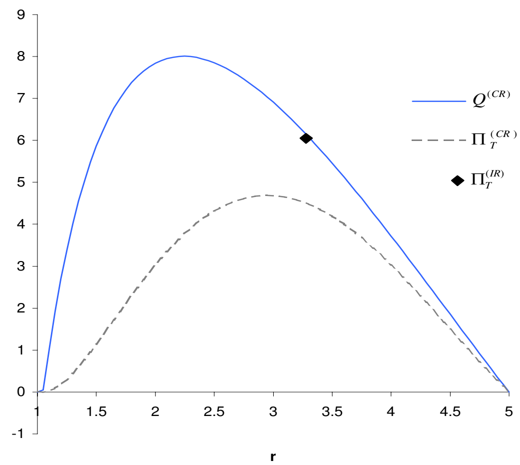

Figure 6.2. Profits and Order Quantity of the Centralized Symmetric Policy (CR) and the Reference Point for Policy (IR) under Stochastic and Price-Dependent Demand with Price-Dependent Returns

For the decentralized policies result mostly confirm the findings of Ruiz Benitez and Muriel (2007) [42] for the model with constant returns:

- Under stochastic and price-dependent demand and price-dependent returns, the order quantity increases when consumer returns are ignored in the optimization processes of both supply chain players.

- The optimal wholesale price, w^*, declines whereas r^* increases when ignoring returns. The latter fact is contrary to the results presented in the previous chapter 5.

For the decentralized system, the optimal wholesale and retail prices as well as the order quantity, are identical to those under a constant return rate of $\alpha = 0.2$ when ignoring returns. In turn, considering returns in the optimization process leads for rising wholesale prices w^* to lower magnitudes in the order quantity and higher retail prices. Comparing the price-dependent and constant return model, we find the gap between the order quantities and retail prices to be decreasing for rising values of w (see figure 6.4).

Having in mind figure 6.1, returns are less at lower selling prices r for a price-dependent return function. As a consequence predominantly the retailer's profit margin is increased since he bears 95% of the total reverse logistic costs. The manufacturer, in turn, benefits from the increase in ordered items by the former as well. *In other words, the fear of high return volumes and an increased demand at lower retail prices drives the vendor to reduce his decision variable w^* and, respectively, the retailer to increase r^*.* However, only the retailer is better off by almost 30% under a price-dependent return rate. The manufacturer faces slightly worse profits (-2.5%). Thus, total coordination is improved compared to the model with a constant return rate. In policy (IR), coordination is not improved due to the simple reasons that overall returns with 21.7% are higher, whereas the relevant decision variables of the supply chain remain unchanged. The manufacturer faces (absolutely and relatively) a greater reduction of profits than the retailer.

Note in figure 6.3 that after a certain threshold value total profits are better under a constant return model. Again, this is due to the fact that high values of w imply high return rates, which diminishes the players' earnings and vice versa. For the manufacturer's performance this is true as well, whereas the retailer favors price-dependent returns for low purchase prices w. However, the difference in profits under the respective models (constant and price-dependent returns) is more articulated for the manufacturer over the range of w.

Results for the asymmetric settings (MC, RI) and (MI, RC) are different to some extent: *Under stochastic and price-dependent demand and a price-dependent returns rate supply chain coordination is still not possible in neither of the asymmetric op-*

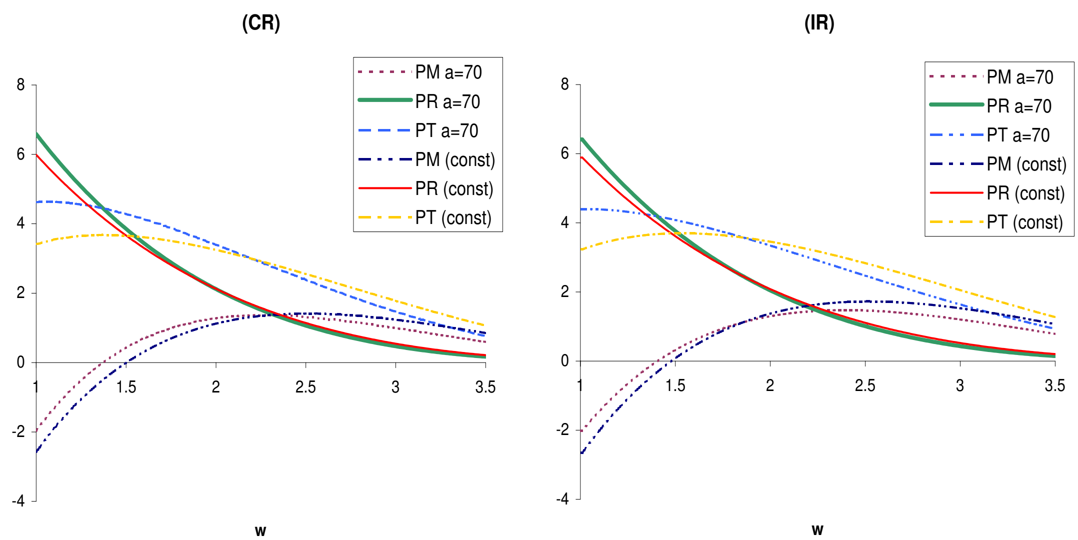

Figure 6.3. Profits over w of the Decentralized Symmetric Policies under Stochastic and Price-Dependent Demand with Constant and Price-Dependent Returns

timization policies. However, total supply chain profits in the asymmetric cases are not in between the range of profits of the decentralized symmetric policies (CR) *and* (IR)*. While for* (MI, RC) *it is still true,* (MC, RI) *faces significant losses and drops below the outcome of* (CR). Further results that can be drawn out of the asymmetric optimization settings are:

- According to table 6.2 the supply chain profits under asymmetric decision making are facing worse profits than in policy (IR). Identical to the constant return model with $\alpha = 0.2$, (MI, RC) outperforms (MC, RI). Note, that for the first time this is true for the individual profits of both players as well.

- The manufacturer's profit is negative for low values of w due to a small profit margin. The profit function of the retailer is steadily decreasing in w.

- Setting (MC, RI) delivers a retail price r^* of 3.95. This gives the retailer a good profit margin, whereas it disregards the high return percentage of 22.29%.

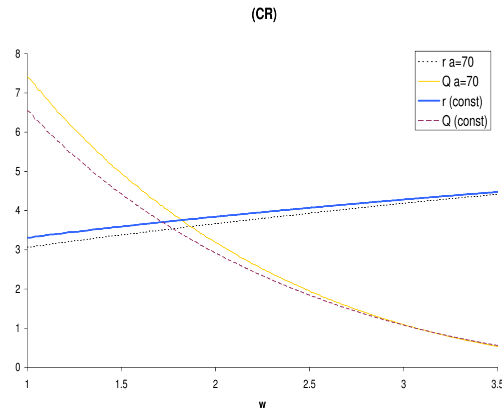

Figure 6.4. Optimal Order Quantity and Retail Price over w of the Decentralized Symmetric Policies under Stochastic and Price-Dependent Demand for Constant and Price-Dependent Returns

		Symmetric				Asymmetric			
		Constant α		Price-Dependent α		Constant α		Price-Dependent α	
		(CR)	**(IR)**	**(CR)**	**(IR)**	**(MC,RI)**	**(MI,RC)**	**(MC,RI)**	**(MI,RC)**
Cent.	r^*	3.64	3.27	2.95	3.27	-	-	-	-
	α	20%	20%	12%	15%	-	-	-	-
	Q^*	4.90	7.22	7.03	7.22	-	-	-	-
	Π	3.71	3.21	4.69	6.02	-	-	-	-
Decent.	w^*	2.5	2.18	2.28	2.18	2.5	2.18	2.29	2.18
	r^*	4.07	3.90	3.81	3.90	4.05	3.93	3.95	3.78
	α	20.0%	20.0%	20.7%	21.7%	20%	20%	22.29%	20.41%
	Q^*	1.84	2.91	2.45	2.91	2.19	2.49	2.65	2.67
	Π_M	1.4113	1.5848	1.3776	1.4267	1.6194	1.2994	1.3040	1.3352
	Π_R	1.1409	1.6771	1.4610	1.6066	1.1082	1.7172	1.3770	1.6738
	Π_T	2.5522	3.2619	2.8386	3.0333	2.7276	3.0166	2.6810	3.0090

Table 6.2. Symmetric and Asymmetric Policies: Equilibrium Values under Stochastic and Price-Dependent Demand for Constant and Price-Dependent Returns(a=70,d=2)

As the manufacturer bears most of the logistic costs associated with customer returns she is worse off as expected due to higher returns .

- Order quantities are for (MC, RI) and (MI, RC), respectively higher and lower than in the policies (CR) and (IR), what is intuitive. Wholesale and retail prices, w^* and r^*, are in between the ranges of the values in the decentralized symmetric policies. Of course, if the vendor ignores return in his optimization process the wholesale price is identical regardless of the policy applied.

- Figure 6.5 shows the profits of the players and the supply chain over w under stochastic and price-dependent demand and returns under the premise of asymmetric decision making. As in the decentralized symmetric policies after a certain threshold the system-wide profits are better off with the constant return model. For low magnitudes of the wholesale price both, manufacturer and retailer, prefer price-dependent returns. After a (different) threshold, they are better off if the return rate is constant. The explanation of this fact is identical to that presented for the symmetric policies: lower wholesale prices imply lower selling prices, what then leads to higher order amounts and customer demand. Moreover, for low values of w return volumes are less under price-dependent returns than under a constant return rate $\alpha = 0.2$.

6.1.1 Sensitivity Analysis

In order to widen the findings of price-dependent return rates in the base case, further sensitivity analysis in the relevant parameters c, β, l, v and v_r is conducted. As external market conditions have great influence on sold items and thus supply chain performance, the market parameters b and k are varied as well. Moreover, we especially focus on different price-dependent return functions $\alpha(r)$ by considering the respective parameters a and d. Since d defines the overall shape of the return function

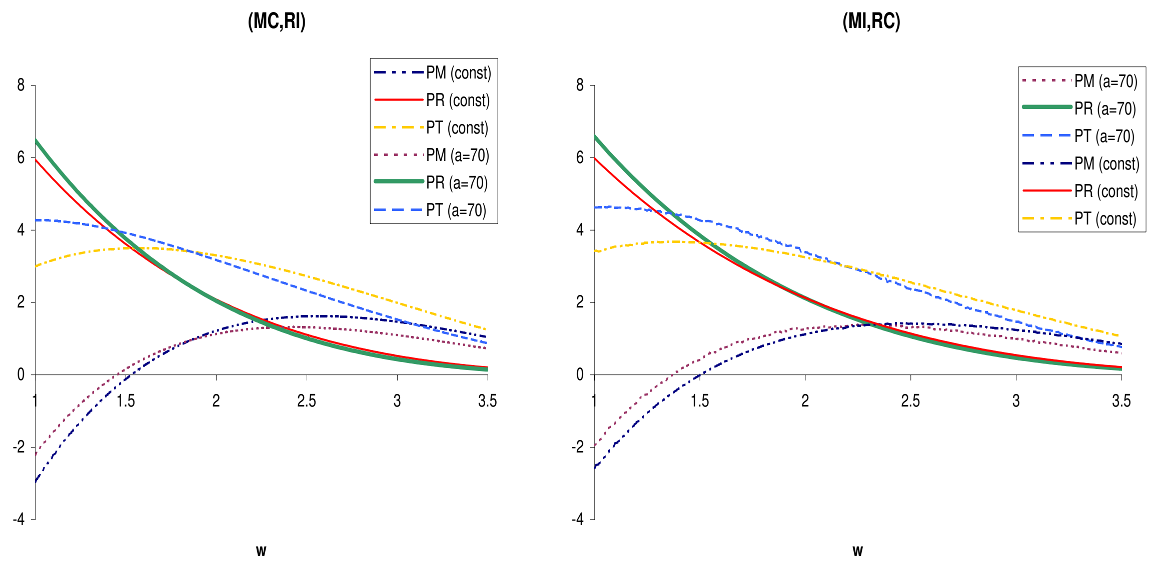

Figure 6.5. Comparison of Individual and Total Supply Chain Profits in the Asymmetric Settings under a Price-Dependent Return Rate and a Constant Return Rate of $\alpha = 0.2$

we consider $d = \{0.5, 1, 2\}$, which is representative for radical, linear and exponential growth, respectively. Note that d=2 is used in the base case setting. In what follows with (IR) and (CR) we refer to the decentralized symmetric policies unless otherwise stated.

Different Total Logistic Costs and Shares

Except for policy (CR), system-wide profits increase under both, decentralized symmetric and asymmetric settings, when shifting the burden of logistic costs to the retailer (figure 6.6). For the case of (IR), profits remain unchanged over the total range of β and thus the system behaves as under a constant return model. Intuitively, a shift in reverse logistic costs improves a player by exactly the share in return costs that is then carried by the other player and vice versa. *Remarkably - and opposed to the constant return model - supply chain coordination is improved when both players* *symmetrically consider returns, whereas only the retailer significantly improves his performance in rising shares of logistic costs β.*

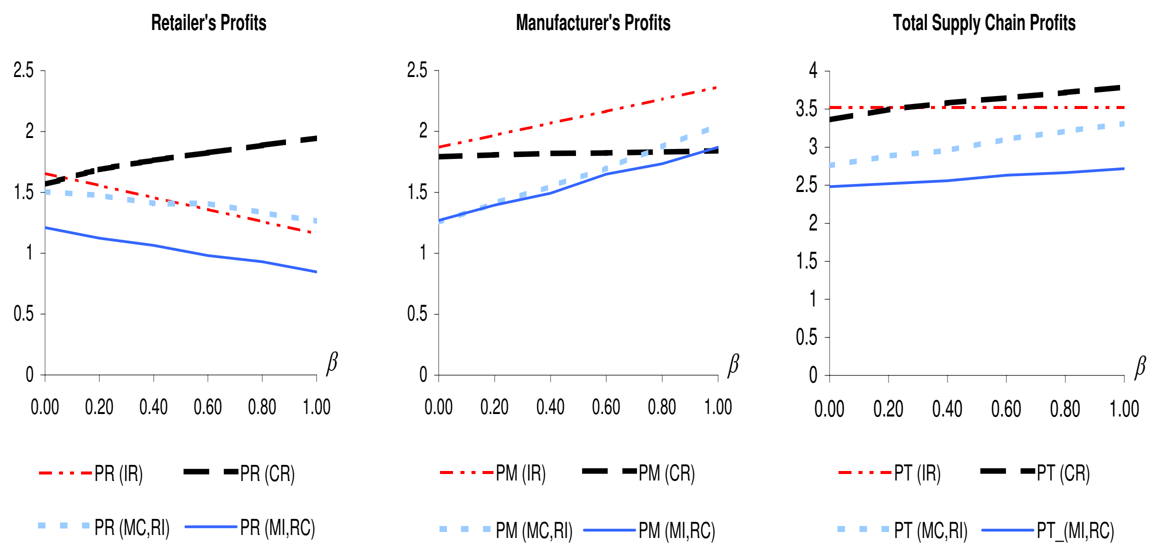

Figure 6.6. Performance of Symmetric and Asymmetric Settings under a Price-Dependent Return Rate for varying $\beta \in [0, 1]$

Table 6.3 presents the equilibrium values under a price-dependent return rate when varying reverse logistic costs and the share of them among the players. Additionally, the percent difference to total supply chain profits under a constant return model is shown. Overall, higher magnitudes of β lead to a lower return rate α^*. Consequently, total supply chain profits improve, what is in accordance to the graphs presented in figure 6.6. Higher logistic costs directly lead to lower profits of both supply chain players, whereas the manufacturer highly benefits when the retailer bears most of the return costs. Surprisingly, the performance under price-dependent return rates is much worse than if returns are constant over the retail price r. Hence, the gap between total supply chain profits under constant and price-dependent returns increases with rising values of l. For logistic costs of $l = 3$ the performance is about 50% worse. Looking at asymmetric behavior, coordination is not achieved. However, compared

	(CR)					(IR)				
β	Π_M	Π_R	Π_T	α^*	%Δ	Π_M	Π_R	Π_T	α^*	%Δ
	total logistic costs l = 0.5									
5 %	2.233	2.008	4.240	19.5%	-19.41%	2.340	1.655	3.995	21.7%	-26.59%
95 %	2.133	1.834	3.967	19.3%	-25.13%	2.351	1.644	3.995	21.7%	-30.67%
	total logistic costs l = 1									
5 %	1.805	1.587	3.391	20.4%	-35.50%	1.895	1.631	3.527	21.7%	-34.52%
95 %	2.015	1.546	3.561	19.5%	-31.54%	2.339	1.187	3.527	21.7%	-34.52%
	total logistic costs l = 2									
5 %	1.378	1.461	2.839	20.7%	-43.10%	1.427	1.607	3.033	21.7%	-42.46%
95 %	1.784	1.455	3.240	18.5%	-35.95%	2.314	0.719	3.033	21.7%	-42.46%
	total logistic costs l = 3									
5 %	0.983	1.286	2.270	21.2%	-53.25%	0.958	1.582	2.540	21.7%	-50.76%
95 %	1.557	1.166	2.722	18.0%	-44.35%	2.290	0.250	2.540	21.7%	-50.76%

	(MC,RI)					(MI,RC)				
β	Π_M	Π_R	Π_T	α^*	%Δ	Π_M	Π_R	Π_T	α^*	%Δ
	total logistic costs l = 0.5									
5 %	2.015	1.781	3.796	21.4%	-29.15%	1.986	1.708	3.694	20.4%	-30.84%
95 %	2.216	1.743	3.959	21.0%	-27.19%	2.105	1.509	3.614	20.2%	-31.80%
	total logistic costs l = 1									
5 %	1.784	1.524	3.308	22.0%	-38.21%	1.798	1.696	3.495	20.2%	-33.86%
95 %	2.186	1.425	3.611	21.1%	-32.87%	1.940	1.309	3.249	20.4%	-37.53%
	total logistic costs l = 2									
5 %	1.303	1.397	2.700	22.2%	-46.92%	1.364	1.674	3.038	20.2%	-41.22%
95 %	2.022	1.244	3.266	20.4%	-38.52%	1.654	0.937	2.590	20.4%	-48.25%
	total logistic costs l = 3									
5 %	0.849	1.223	2.072	22.7%	-58.16%	0.933	1.652	2.584	20.2%	-48.86%
95 %	1.884	0.834	2.718	20.1%	-47.92%	1.343	0.610	1.953	20.4%	-59.43%

Table 6.3. Symmetric and Asymmetric Policies: Equilibrium Values of Supply Chain Profits under Price-Dependent Returns for Varying Reverse Logistic Costs $l = \{0.5, 1, 2, 3\}$ and Percent Difference of System-Wide Profits to those under a Constant Return Model

	Symmetric				Asymmetric			
	Constant α		Price-Dependent α		Constant α		Price-Dependent α	
	(CR)	**(IR)**	**(CR)**	**(IR)**	**(MC,RI)**	**(MI,RC)**	**(MC,RI)**	**(MI,RC)**
	$\beta = 5\%$							
Π_M	1.411	1.585	**1.796**	**1.895**	**1.620**	1.299	1.291	**1.302**
Π_R	1.133	**1.677**	**1.598**	1.631	1.101	**1.717**	**1.498**	1.189
Π_T	2.545	3.262	**3.393**	**3.527**	2.721	**3.017**	**2.789**	2.491
	$\beta = 95\%$							
Π_M	1.490	**2.403**	**1.839**	2.339	2.215	1.488	**2.005**	**1.837**
Π_R	1.153	0.859	**1.931**	**1.187**	0.927	**1.082**	**1.281**	0.867
Π_T	2.643	3.262	**3.770**	**3.527**	3.142	2.570	**3.286**	**2.703**

Table 6.4. Comparison of the Decentralized Policies under Constant or Price-Sensitive Returns for extreme Values of $\beta = 5\%$ and 95%.

to the symmetric policies (CR) and (IR), for a β of 95% the vendor or the retailer, respectively, is better of under setting (MC, RI) or (MI, RC). We also examine that return rates are not diminished through asymmetric decision making.

Table 6.4 compares the decentralized policies when returns are a constant proportion of sales or are variable in the retial price. In most cases the supply chain is better off if consumer returns are price-dependent (highlighted in bold). For the total supply chain this fact is most accentuated if the manufacturer considers returns in his optimization process. *Considering the price-dependent cases, for low values of β, (IR) coordinates the supply chain best, whereas for higher β-values (CR) is the best possible outcome.* Moreover, the supply chain performs better the higher the share of logistic costs is which the retailer has to bear.

Different Production Costs

Production costs directly affect the profit margins of the supply chain members. As higher manufacturing costs decrease the margin, the vendor reacts by increasing the wholesale price w^*. Consequently, the retailer marks up his selling price r^*. However, under a price-dependent return model, high retail prices imply high return volumes, what in turn is detrimental for profits within the system. For production costs of $c = 3$, returns go up as high as 35% of the goods sold. Resulting, for relatively high magnitudes of c, the supply chain is better off under a constant return rate, whereas the agents prefer price-dependent return rates for lower magnitudes (compare table 5.3). Hence, table 6.5 nicely describes the relationship between profits or marginal revenues and return rates. Low profit margins lead to high return volumes and hence increased return costs and vice versa. Interestingly, for extreme profit margins policy (CR), and not (IR), coordinates the decentralized system best, what is in contrast to the findings under a constant α of 20%. The latter is optimal in terms of total profits for the base case setting of $c = 1$. Ruiz Benítez and Muriel (2007) [42] observe under stochastic and price-dependent demand and a constant return rate, that if the manufacturer has a sufficient marginal revenue, she lowers her wholesale price as an incentive for the retailer to order more items. The same is valid under a return rate depending on r. Hence, the optimal order quantity decreases and commercial returns increase.

	(CR)				**(IR)**			
c	**0.25**	**1**	**2**	**3**	**0.25**	**1**	**2**	**3**
w^*	1.49	2.28	3.49	4.83	1.57	2.18	2.92	3.64
r^*	3.31	3.81	4.41	4.84	3.59	3.90	4.23	4.52
α	15.7%	20.7%	27.8%	33.5%	18.4%	21.7%	25.5%	29.1%
Q^*	5.40	2.45	0.55	0.01	4.75	2.91	1.43	0.56
Π_M	4.1645	1.3776	0.0590	0.0023	4.0899	1.4267	-0.1723	-0.4607
Π_R	4.3085	1.4610	0.1738	0.0001	3.4709	1.6066	0.5017	0.1021
Π_T	8.4730	2.8386	0.2328	0.0024	7.5608	3.0333	0.3294	-0.3586

	(MC,RI)				**(MI,RC)**			
c	**0.25**	**1**	**2**	**3**	**0.25**	**1**	**2**	**3**
w^*	1.49	2.28	3.49	4.83	1.57	2.18	2.92	3.64
r^*	3.58	3.95	4.46	4.94	3.42	3.78	4.14	4.48
α	18.3%	22.3%	28.4%	34.9%	16.7%	20.4%	24.5%	28.7%
Q^*	4.83	2.65	0.71	0.01	4.67	2.67	1.21	0.42
Π_M	3.9250	1.3040	0.0268	-0.0046	4.1237	1.3352	-0.1475	-0.3556
Π_R	3.5540	1.3770	0.1509	-0.0001	3.5589	1.6738	0.5436	0.1206
Π_T	7.4790	2.6810	0.1777	-0.0048	7.6826	3.0090	0.3961	-0.2350

Table 6.5. Symmetric and Asymmetric Policies: Equilibrium Values under Price-Dependent Returns for Varying Production Costs c

Positive Salvage Values

In the following, we consider positive salvage values for returned and unsold items. Before exploring the results for price-dependent returns, we shortly recall the main findings under a constant return rate and a price-only contract, where positive salvage values reduce the costs of returns. As a consequence, both, retailer and manufacturer, are in the position to lower their respective decision variables what improves system-wide coordination. Another insight obtained is the interdependency between w^*, r^* and Q^*. Wholesale and retail prices are decreasing and the optimal order quantity, respectively, is increasing in the salvage values v and v_r. Having in mind these results we can draw more general conclusions from tables 6.6 and 6.7, some of which have already been mentioned previously.

- Policy (CR) outperforms policy (IR) with increasing salvage values v and v_r.
- Coordination in the decentralized symmetric cases (CR) and (IR) is better the higher the salvage values are, and the more reverse logistic costs the retailer bears. This extends the results under a wholesale contract with a constant return rate of $\alpha = 0.2$. In the asymmetric settings the influence of β is different: (MC, RI) is better off for lower and (MI, RC) for higher magnitudes of β. The effect of rising salvage values remains identical though. Note that for high salvage values under setting (MC, RI) coordination of the supply chain is improved.
- Under symmetric decision making, the manufacturer has better compared payoffs in policy (IR), whereas the retailer has no preference towards any policy. He is reciprocally better off in the symmetric settings. In the asymmetric cases no rule os observable.
- The mentioned relationship between Q^*, w^* and r^* can be extended to α^*. Identical to the constant return model, salvage values increase marginal revenues

		(CR)			(IR)		
v	v_r	Π_M	Π_R	Π_T	Π_M	Π_R	Π_T
		$\beta = \mathbf{0.05}$					
0.4	0.2	1.60	1.70	3.30	1.79	1.94	3.73
0.8	0.4	1.95	2.44	4.39	2.30	2.35	4.65
1.2	0.6	2.63	3.47	6.09	3.05	3.01	6.05
		$\beta = \mathbf{0.95}$					
0.4	0.2	2.08	1.96	4.03	2.77	0.96	3.73
0.8	0.4	2.56	2.41	4.97	3.38	1.27	4.65
1.2	0.6	3.48	3.31	6.79	4.25	1.81	6.05
		$\beta = \mathbf{0.05}$					
0.4	0.4	1.69	1.84	3.54	1.90	1.94	3.84
0.8	0.8	2.18	2.44	4.62	2.54	2.35	4.89
1.2	1.2	3.04	3.97	7.00	3.45	3.01	6.46
		$\beta = \mathbf{0.95}$					
0.4	0.4	2.18	1.96	4.14	2.88	0.96	3.84
0.8	0.8	2.80	2.41	5.21	3.62	1.27	4.89
1.2	1.2	3.91	3.78	7.69	4.65	1.81	6.46

		(MC,RI)			(MI,RC)		
v	v_r	Π_M	Π_R	Π_T	Π_M	Π_R	Π_T
		$\beta = \mathbf{0.05}$					
0.4	0.2	1.50	1.54	3.05	1.75	2.00	3.75
0.8	0.4	1.77	2.48	4.25	2.27	2.41	4.68
1.2	0.6	2.79	3.91	6.70	3.03	3.06	6.09
		$\beta = \mathbf{0.95}$					
0.4	0.2	2.23	1.77	4.00	2.08	1.16	3.24
0.8	0.4	2.67	2.29	4.96	2.61	1.45	4.06
1.2	0.6	3.44	3.49	6.93	3.60	1.94	5.54
		$\beta = \mathbf{0.05}$					
0.4	0.4	1.61	1.54	3.15	1.85	2.00	3.85
0.8	0.8	2.03	2.48	4.51	2.49	2.41	4.90
1.2	1.2	2.78	4.02	6.80	3.42	3.06	6.48
		$\beta = \mathbf{0.95}$					
0.4	0.4	2.38	1.77	4.14	2.17	1.16	3.33
0.8	0.8	2.99	2.29	5.28	2.81	1.45	4.26
1.2	1.2	3.83	4.07	7.90	3.95	1.94	5.90

Table 6.6. Symmetric and Asymmetric Policies: Equilibrium Values for Supply Chain Profits under Price-Dependent Returns for Varying Unsold and Returned Item Salvage Values v and v_r under a Price-Only Contract

		(CR)				(IR)			
v	v_r	w^*	r^*	α	Q^*	w^*	r^*	α	Q^*
		$\beta =$ **0.05**							
0.4	0.2	2.26	3.78	20.4%	2.86	2.14	3.86	21.3%	3.41
0.8	0.4	2.10	3.67	19.2%	3.91	2.11	3.81	20.8%	4.03
1.2	0.6	1.93	3.55	18.0%	5.43	2.06	3.74	20.0%	4.99
		$\beta =$ **0.95**							
0.4	0.2	1.84	3.52	17.7%	3.74	2.14	3.86	21.3%	3.41
0.8	0.4	1.82	3.48	17.3%	4.61	2.11	3.81	20.8%	4.03
1.2	0.6	1.73	3.39	16.4%	6.30	2.06	3.74	20.0%	4.99
		$\beta =$ **0.05**							
0.4	0.4	2.26	3.75	20.1%	3.03	2.14	3.86	21.3%	3.41
0.8	0.8	2.10	3.67	19.2%	3.91	2.11	3.81	20.8%	4.03
1.2	1.2	1.93	3.48	17.3%	6.04	2.06	3.74	20.0%	4.99
		$\beta =$ **0.95**							
0.4	0.4	1.84	3.52	17.7%	3.74	2.14	3.86	21.3%	3.41
0.8	0.8	1.82	3.48	17.3%	4.61	2.11	3.81	20.8%	4.03
1.2	1.2	1.73	3.33	15.8%	6.95	2.06	3.74	20.0%	4.99

		(MC,RI)				(MI,RC)			
v	v_r	w^*	r^*	α	Q^*	w^*	r^*	α	Q^*
		$\beta =$ **0.05**							
0.4	0.2	2.30	3.94	22.1%	2.95	2.14	3.71	19.7%	3.22
0.8	0.4	2.07	3.79	20.5%	4.17	2.11	3.67	19.2%	3.88
1.2	0.6	1.89	3.71	19.7%	5.24	2.06	3.62	18.7%	4.91
		$\beta =$ **0.95**							
0.4	0.2	1.84	3.70	19.6%	4.39	2.14	3.73	19.9%	2.59
0.8	0.4	1.81	3.65	19.0%	5.24	2.11	3.72	19.8%	3.16
1.2	0.6	1.69	3.52	17.7%	6.94	2.06	3.62	18.7%	4.26
		$\beta =$ **0.05**							
0.4	0.4	2.30	3.94	22.1%	2.95	2.14	3.71	19.7%	3.22
0.8	0.8	2.07	3.79	20.5%	4.17	2.11	3.67	19.2%	3.88
1.2	1.2	1.89	3.61	18.6%	6.08	2.06	3.62	18.7%	4.91
		$\beta =$ **0.95**							
0.4	0.4	1.84	3.70	19.6%	4.39	2.14	3.73	19.9%	2.59
0.8	0.8	1.81	3.65	19.0%	5.24	2.11	3.72	19.8%	3.16
1.2	1.2	1.69	3.45	17.0%	7.55	2.06	3.62	18.7%	4.26

Table 6.7. Symmetric and Asymmetric Policies: Equilibrium Values for Supply Chain Decision Variables under Price-Dependent Returns for Varying Unsold and Returned Item Salvage Values v and v_r under a Price-Only Contract

of the players and therefore the manufacturer has the opportunity to lower her wholesale price. This gives an incentive to the retailer to order more. Additionally, the salvage value v_r of unsold products is staying with the latter as well, what again creates an incentive to increase the order quantity. At this point we also refer to the hedging argument of (positive) salvage values. Thus, r^* and w^* are decreasing and the optimal order amount is increasing in v and v_r. Besides the effect on order volumes, lower retail prices lead to a reduction of returned items (i.e. α) what benefits the total supply chain and both players as well.

- If the retailer bears more of the logistic costs, dependencies are different. The manufacturer reduces his wholesale price since his share in return logistic costs is reduced. However, the retailer has to compensate this additional logistic costs and thus uses the incentive by the manufacturer primarily to stabilize his profit margin instead of trying to increase his total sales. Thus, the effects of positive salvage values on retail and wholesale prices are diminished. Finally, the retailer is worse, and the manufacturer better off.

Different Market Sizes and Elasticities and Types of Price-Dependent Return Functions

Because the retailer is selling his products on a unregulated market, its parameters b and k are crucial for the success of the supply chain. The total market size is represented by k and b describes the demand elasticity present in the market. As mentioned demand elasticity is $\frac{r}{k-r} \leq 1$. In other words, rising the retail price 1% implies an increase in demand by less than 1%. Considered market scenarios are $(b;k) = (-1.5;10)$, $(-6;2.5)$ and the base case setting $(-3;5)$. Further, under the premise of price-dependent returns the values of a and d are determining the overall return rate. Varying solely a leads to faster or slower growing consumer returns in the retail price, whereas varying parameter d simply changes the relationship between

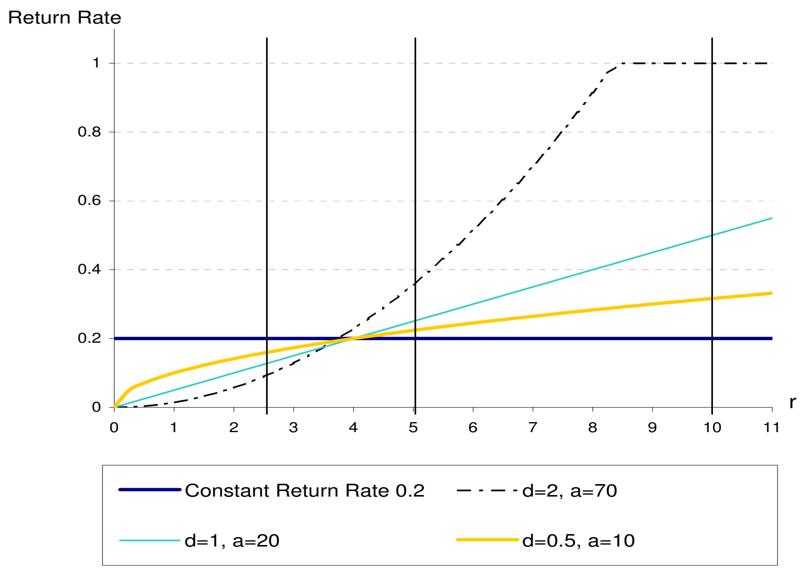

Figure 6.7. Considered Price-Dependent Return Functions with Parameters $(a; d) = (10; 0.5), (20; 1), (70; 2)$

price and returns. The effects of both are intuitive: Rising only a or d directly leads to higher returns for a given retail price r^*. Thus, we are varying both variables simultaneously. The return functions are presented in figure 6.7 below. The three considered functions are (a;d) = (10;0.5), (20;1) and (70;2). Note, that the latter is the base case setting. Again, in order to better compare and explain retrieved results for distinct return functions $\alpha(r)$, the initial thought behind the choice of the tuples is to have the different return types (radically, linearly and exponentially depending on r) facing about 20% of total goods returned in the equilibrium in the base case setting for the decentralized cases.

Tables 6.8 and 6.9 show the equilibrium values for decentralized symmetric decision making of the supply chain players under different market sizes and elasticities when returns are depending on different price-dependent consumer return models. The findings for decentralized symmetric decision making are summarized as follows:

		(CR)					
		d = 0.5, a = 10		**d = 1, a = 20**		**d = 2, a = 70**	
		l = 1	**l = 3**	**l = 1**	**l = 3**	**l = 1**	**l = 3**
		$\beta = 0.05$					
b = -3, k = 5	α^*	19.9%	20.1%	19.4%	20.2%	20.4%	21.2%
	Π_M	1.78	1.13	1.83	1.14	1.80	0.98
	Π_R	1.37	1.05	1.61	1.04	1.59	1.29
	Π_T	3.15	2.17	3.44	2.19	3.39	2.27
		$\beta = 0.95$					
	α^*	19.8%	20.1%	19.3%	19.4%	19.5%	18.0%
	Π_M	1.86	1.28	1.94	1.38	2.01	1.56
	Π_R	1.51	1.10	1.59	1.22	1.55	1.17
	Π_T	3.37	2.38	3.53	2.60	3.56	2.72
		$\beta = 0.05$					
b = -1.5, k = 10	α^*	27.1%	27.3%	34.4%	35.9%	40.6%	45.1%
	Π_M	5.59	4.22	4.43	2.53	2.63	-
	Π_R	4.73	4.05	4.52	3.24	3.60	-
	Π_T	10.33	8.27	8.95	5.77	6.22	-
		$\beta = 0.95$					
	α^*	27.0%	27.3%	33.9%	33.7%	35.0%	27.0%
	Π_M	5.79	4.70	4.85	3.57	3.81	2.90
	Π_R	4.87	3.79	4.33	3.13	3.34	2.13
	Π_T	10.66	8.48	9.18	6.70	7.15	5.02
		$\beta = 0.05$					
b = -6, k = 2.5	α^*	14.8%	15.1%	10.8%	11.1%	6.5%	6.5%
	Π_M	0.25	0.08	0.34	0.18	0.46	0.33
	Π_R	0.20	0.07	0.27	0.16	0.33	0.30
	Π_T	0.44	0.16	0.61	0.33	0.79	0.64
		$\beta = 0.95$					
	α^*	14.8%	15.2%	10.8%	11.2%	6.5%	6.7%
	Π_M	0.26	0.09	0.35	0.19	0.47	0.36
	Π_R	0.18	0.04	0.24	0.10	0.28	0.19
	Π_T	0.43	0.13	0.60	0.29	0.76	0.56

Table 6.8. Equilibrium Values for Symmetric Supply Chain Behavior (CR) for Different Market Sizes and Elasticities and Different Price-Dependent Return Functions

		(IR)					
		d = 0.5, a = 10		**d = 1, a = 20**		**d = 2, a = 70**	
		l = 1	**l = 3**	**l = 1**	**l = 3**	**l = 1**	**l = 3**
		$\beta = 0.05$					
b = -3 k = 5	α^*	19.7%	19.7%	19.5%	19.5%	21.7%	21.7%
	Π_M	2.03	1.18	2.05	1.21	1.90	0.96
	Π_R	1.71	1.67	1.72	1.68	1.63	1.58
	Π_T	3.74	2.85	3.77	2.89	3.53	2.54
		$\beta = 0.95$					
	α^*	19.7%	19.7%	19.5%	19.5%	21.7%	21.7%
	Π_M	2.44	2.39	2.45	2.41	2.34	2.29
	Π_R	1.31	0.45	1.32	0.48	1.19	0.25
	Π_T	3.74	2.85	3.77	2.89	3.53	2.54
		$\beta = 0.05$					
b = -1.5 k = 10	α^*	27.2%	27.2%	37.0%	37.0%	78.1%	78.1%
	Π_M	6.67	5.12	5.35	3.23	-0.21	-4.69
	Π_R	4.65	4.57	3.50	3.39	-1.33	-1.57
	Π_T	11.33	9.69	8.85	6.63	-1.55	-6.25
		$\beta = 0.95$					
	α^*	27.2%	27.2%	37.0%	37.0%	78.1%	78.1%
	Π_M	7.41	7.33	6.35	6.24	1.90	1.67
	Π_R	3.92	2.36	2.50	0.39	-3.45	-7.92
	Π_T	11.33	9.69	8.85	6.63	-1.55	-6.25
		$\beta = 0.05$					
b = -6 k = 2.5	α^*	14.6%	14.6%	10.7%	10.7%	6.5%	6.5%
	Π_M	0.26	-0.05	0.36	0.14	0.48	0.34
	Π_R	0.30	0.29	0.33	0.32	0.36	0.36
	Π_T	0.56	0.23	0.70	0.46	0.84	0.70
		$\beta = 0.95$					
	α^*	14.6%	14.6%	10.7%	10.7%	6.5%	6.5%
	Π_M	0.40	0.39	0.47	0.46	0.54	0.54
	Π_R	0.16	-0.15	0.23	0.00	0.30	0.16
	Π_T	0.56	0.23	0.70	0.46	0.84	0.70

Table 6.9. Equilibrium Values for Symmetric Supply Chain Behavior (IR) for Different Market Sizes and Elasticities and Different Price-Dependent Return Functions

- A general rule whether policy (IR) or (CR) performs better in the considered markets with price-dependent return functions is not observable. We find that total logistic costs and the share of them between the players have varying effects on both, individual, and system-wide performances. However, the manufacturer is always better off when the retailer bears most of reverse logistic costs, what extends the sensitivity analysis for β. The retailer, in turn, is always worse off for the considered values of l. Identical to under constant returns, players try to compensate higher costs associated with returns by a positive adjustment in the retail price. However, this leads to higher return rates α^*. The outcome of the total profits π_T is highly dependent on the type of return function and market.

- We further investigate the results according to the three different markets:

    1. Large markets and high demand elasticities (k=10, b=-5) are detrimental on supply chain coordination, particularly if the players ignore return costs. Instead, when making his pricing decision the retailer only looks at his profit margin and thus increases the retail price considerably. As a consequence consumer returns increase up to levels where the supply chain is far in the reds. The manufacturer is in a better position if he has not to deal with reverse logistic costs. The highest α^* is found under an exponential return function, what is intuitive.

    2. Smaller markets with lower elasticities behave contrary to the first mentioned. As the parameter k limits the retail price r before demand or return functions do, we experience lower rates of returns for higher values of d. As the return functions subtend approximately at a retail price of 3.75, the profits of the player's and of the total supply chain is best off under exponential return functions (compare figure 6.7). However, a

smaller market size entails lower sales. In other words, the level of profits is comparably small, whereas the risk associated with consumer returns is mitigated by the exponential type return function.

3. Medium-sized markets and elasticities are consequently performing in between the latter two. Total and individual profits decrease for higher return logistic costs and for rising values of d.

Under asymmetric decision making results vary more significantly. We especially obtain that for some of the presented market sizes and return models coordination is improved in the asymmetric settings. Whether (MC, RI) or (MI, RC) performs better when varying l or β is not generally observable. Extending the findings throughout this thesis, (MC, RI) behaves according to (CR) and (MI, RC) to (IR), respectively. Tables 6.10 and 6.11 show the optimal profits of the players and of the total supply chain under the premise of asymmetric optimization behavior for different market parameters and price-depending return functions.

The effect of different market parameters and return functions is not predictable. However, in both settings it is the retailer that has the greater influence on the performance of the supply chain with his pricing decision. Ignoring returns, he drives up his profit margin, not knowing that subsequent high return volumes have the opposite effect and put profits in the red. Considering returns and, hence, steering the supply chain with adequate retail prices allows good performances. This fact is most noticeable in large markets, since then the retail price r is not limited by k, as in small markets. The greatest benefit of asymmetric behavior is that profits, regardless of markets and return functions, are never negative. If one player recognizes he would face losses when making this deal, he will simply negate it. As a consequence of the latter argumentation, (MC, RI) is not existing under returns that depend exponentially on the retail price.

		(MC,RI)					
		d = 0.5, a = 10		**d = 1, a = 20**		**d = 2, a = 70**	
		l = 1	**l = 3**	**l = 1**	**l = 3**	**l = 1**	**l = 3**
		$\beta = 0.05$					
b = -3, k = 5	α^*	20.0%	20.2%	19.6%	20.3%	22.0%	22.7%
	Π_M	1.98	1.26	1.97	1.24	1.78	0.85
	Π_R	1.34	1.01	1.61	1.01	1.52	1.22
	Π_T	3.32	2.27	3.59	2.25	3.31	2.07
		$\beta = 0.95$					
	α^*	19.7%	19.5%	19.3%	18.8%	21.1%	20.1%
	Π_M	2.31	2.04	2.32	2.03	2.19	1.88
	Π_R	1.42	0.77	1.51	0.95	1.43	0.83
	Π_T	3.73	2.81	3.82	2.98	3.61	2.72
		$\beta = 0.05$					
b = -1.5, k = 10	α^*	27.1%	27.4%	36.4%	37.6%	70.0%	76.2%
	Π_M	6.25	4.69	4.47	2.24	-	-
	Π_R	4.88	3.88	4.13	2.85	-	-
	Π_T	11.13	8.57	8.60	5.10	-	-
		$\beta = 0.95$					
	α^*	26.9%	26.7%	35.6%	34.9%	66.2%	62.2%
	Π_M	6.93	6.48	5.41	4.55	-	-
	Π_R	4.62	3.46	3.80	2.15	-	-
	Π_T	11.56	9.94	9.21	6.70	-	-
		$\beta = 0.05$					
b = -6, k = 2.5	α^*	14.8%	15.1%	10.8%	11.1%	6.6%	6.6%
	Π_M	0.27	0.09	0.37	0.19	0.48	0.35
	Π_R	0.19	0.07	0.27	0.15	0.33	0.30
	Π_T	0.47	0.16	0.64	0.35	0.81	0.65
		$\beta = 0.95$					
	α^*	14.6%	14.6%	10.7%	10.7%	6.5%	6.5%
	Π_M	0.38	0.32	0.46	0.43	0.54	0.53
	Π_R	0.14	-0.16	0.23	0.00	0.28	0.16
	Π_T	0.52	0.16	0.68	0.42	0.82	0.69

Table 6.10. : Equilibrium Values for the Asymmetric Supply Chain Behavior (MC, RI) for Different Market Sizes and Elasticities and Different Price-Dependent Return Functions

		(MI,RC)					
		d = 0.5, a = 10		**d = 1, a = 20**		**d = 2, a = 70**	
		l = 1	**l = 3**	**l = 1**	**l = 3**	**l = 1**	**l = 3**
		$\beta = 0.05$					
b = -3 k = 5	α^*	19.7%	19.7%	19.3%	19.3%	20.2%	20.2%
	Π_M	1.75	0.96	1.82	1.03	1.80	0.93
	Π_R	1.75	1.71	1.76	1.72	1.70	1.65
	Π_T	3.49	2.66	3.57	2.74	3.49	2.58
		$\beta = 0.95$					
	α^*	19.9%	20.3%	19.5%	20.3%	20.4%	20.4%
	Π_M	1.84	1.25	1.93	1.31	1.94	1.34
	Π_R	1.40	0.79	1.40	0.77	1.31	0.61
	Π_T	3.24	2.03	3.33	2.08	3.25	1.95
		$\beta = 0.05$					
b = -1.5 k = 10	α^*	27.1%	27.1%	35.2%	35.3%	47.2%	46.7%
	Π_M	5.58	4.14	4.39	2.46	2.11	-0.29
	Π_R	4.82	4.74	3.88	3.79	1.78	1.65
	Π_T	10.40	8.88	8.27	6.25	3.89	1.36
		$\beta = 0.95$					
	α^*	27.3%	27.8%	35.7%	36.8%	44.0%	18.4%
	Π_M	5.72	4.54	4.59	3.03	2.43	0.00
	Π_R	4.17	2.94	3.04	1.51	0.79	0.74
	Π_T	9.89	7.48	7.62	4.54	3.21	0.74
		$\beta = 0.05$					
b = -6 k = 2.5	α^*	14.6%	14.6%	10.7%	10.7%	6.4%	6.4%
	Π_M	0.22	-0.06	0.33	0.12	0.46	0.33
	Π_R	0.31	0.29	0.34	0.32	0.37	0.36
	Π_T	0.53	0.23	0.67	0.44	0.83	0.68
		$\beta = 0.95$					
	α^*	14.8%	15.2%	10.8%	11.2%	6.5%	6.7%
	Π_M	0.25	0.09	0.35	0.19	0.47	0.36
	Π_R	0.19	0.04	0.24	0.10	0.30	0.19
	Π_T	0.44	0.13	0.60	0.29	0.77	0.56

Table 6.11. : Equilibrium Values for Asymmetric Supply Chain Behavior (MI, RC) for Different Market Sizes and Elasticities and Different Price-Dependent Return Functions

6.2 Buy-Back Contract

Finally, we study the option of a buy-back contract and the results obtained when returns are price-dependent. In chapter 4 (stochastic demand and constant return rate), we observed that buy-back contracts can help to improve supply chain coordination, either according to the analytical solution of Ruiz Benítez and Muriel (2007) [42], or with the values gained if the manufacturer is egoistically optimizing his wholesale price. When doing the latter the shift in profits to the side of the vendor was eminent. Thus, pricing gives the retailer no incentive to accept a buy-back option. However, since the manufacturer buys back every unsold item at nearly the wholesale price, the retailer is (almost) completely hedged against uncertain demand. In other words, the risk to face losses due to overstocking is marginally small for him under buy-back contracts. As a consequence, the return-risk ratio is satisfied.

Under stochastic and price-dependent demand and a constant return rate α, Ruiz Benítez and Muriel (2007) [42] find that in case of policy (CR) buy-back contracts do improve channel coordination. Moreover, they find a threshold value from where on both players are better off. However, for high return rates ($\alpha > 20\%$) policy (IR) is detrimental for supply chain performance. The relationship between wholesale and buy-back price is $s^* = w^* \frac{c}{2}$. More important, under stochastic and price-dependent demand, the profit shift is not as significant as under stochastic demand, but still the manufacturer is better and the retailer worse off, if both accept the buy-back option. We extended these findings (mainly) unaltered to the case of asymmetric decision making, whereas total profits are in between those of the symmetric cases.

Table 6.12 presents the results for buy-back and wholesale contracts under asymmetric and symmetric decision making and compares the equilibrium values under constant and price-dependent return models. *As a main result we find that for the base case setting buy-back contracts improve the coordination of the supply chain when returns are considered in the optimization process by both players. Ignoring returns* *leads to worse outcomes than under a wholesale contract.* This extends the findings described initially in this section.

Further results are:

1. Similar to the findings for constant return rates (stochastic, and stochastic and price-dependent demand) only the manufacturer is in the position to improve her performance under buy-back contracts. However, this is not always the case: in policy (IR) she faces worse profits. Although the shift in profits still exists, it is less articulated for price-dependent returns.

2. Comparing price-dependent and constant return rates, in policy (CR) the supply chain is better off under the former and accordingly the latter leads to better results if both players ignore returns. For the asymmetric settings this fact is true as well: (MC, RI) performs better with a constant and (MI, RC) with a variable α.

3. When ignoring returns, the relationship $s^* = w^* - \frac{c}{2}$ holds. However, for (IR) a difference of c is between (w^*) and (s^*).

4. Under price-dependent returns, (if players consider returns) the manufacturer reacts with higher wholesale prices and the retailer with lower retail prices on return costs. Consequently the profit margin increases for the former and, respectively, decreases for the latter. Thus, the incentive scheme under buy-back contracts that leads the retailer to order more (also implies higher selling prices) due to the hedging argument is heavily affected by growing costs associated with consumer returns over the retail price. In fact, for increasing returns in the retail price this incentive scheme (mostly) vanishes. Thus, when considering returns, the optimal wholesale price $w^* = 2.78$ is lower as under a constant return rate. The manufacturer also set a remarkable lower buy-back price $s^* = 1.78$. The idea is to give the retailer less marginal profit so that he is not in the position

		Price-Dependent Return Rate							
		Buy-Back Contract				Wholesale Contract			
		Symmetric		Asymmetric		Symmetric		Asymmetric	
		(CR)	(IR)	(MC,RI)	(MI,RC)	(CR)	(IR)	(MC,RI)	(MI,RC)
Cent.	r^*	-	-	-	-	2.95	3.27	-	-
	α^*	-	-	-	-	12.4%	15.2%	-	-
	Q^*	-	-	-	-	7.03	7.22	-	-
	Π_M	-	-	-	-	4.69	6.02	-	-
Decent.	w^*	2.78	3.00	2.78	3.00	2.28	2.18	2.29	2.18
	s^*	1.78	2.50	1.78	2.50	-	-	-	-
	r^*	4.00	4.13	4.09	4.08	3.81	3.90	3.95	3.78
	α^*	22.9%	24.4%	23.9%	23.8%	20.7%	21.7%	22.3%	20.4%
	Q^*	2.87	3.61	3.10	3.40	2.45	2.91	2.65	2.67
	Π_M	1.552	1.270	1.218	1.441	1.3776	1.4267	1.3040	1.3352
	Π_R	1.319	1.335	1.281	1.357	1.4610	1.6066	1.3770	1.6738
	Π_T	2.871	2.606	2.499	2.798	2.8386	3.0333	2.6810	3.0090

		Constant Return Rate $\alpha = 20\%$							
		Buy-Back Contract				Wholesale Contract			
		Symmetric		Asymmetric		Symmetric		Asymmetric	
		(CR)	(IR)	(MC,RI)	(MI,RC)	(CR)	(IR)	(MC,RI)	(MI,RC)
Cent.	r^*	-	-	-	-	3.64	3.27	-	-
	Q^*	-	-	-	-	4.90	7.22	-	-
	Π_M	-	-	-	-	3.71	3.21	-	-
Decent.	w^*	3.34	3.00	3.34	3.00	2.50	2.18	2.50	2.18
	s^*	2.84	2.50	2.84	2.50	-	-	-	-
	r^*	4.32	4.13	4.29	4.16	4.07	3.90	4.05	3.93
	Q^*	2.47	3.61	2.79	3.27	1.84	2.91	2.19	2.49
	Π_M	1.857	1.769	1.792	1.712	1.4113	1.5848	1.6194	1.2994
	Π_R	0.942	1.481	0.932	1.493	1.1409	1.6771	1.1082	1.7172
	Π_T	2.799	3.250	2.724	3.205	2.5522	3.2619	2.7276	3.0166

Table 6.12. Comparison of Decentralized Symmetric and Asymmetric Decision Policies under Wholesale and Buy-Back Contracts when Consumer Returns are either Constant or Price-Dependent.

to rise retail prices, since this would mean that the manufacturer has to cope with additional reverse logistic costs (since $\beta = 0.05$). Resulting, the optimal selling price r^* is with 4.00 lower than in policy (IR) but still higher than under setting (CR) in a price-only contract. For price-dependent returns the optimal order quantity is consequently lower and, important for the vendor, the return volume α^* is decreased by about 2% when considering returns.

6.3 Conclusions

Results retrieved under a Wholesale Price-Only Contract

1. Under stochastic and price-dependent demand with price-sensitive returns, optimal supply chain coordination is reached in the centralized policy (IR), what is contrary to the reuslts in the previous chapters.

2. Concerning the decentralized symmetric settings, policy (IR) outperforms (CR) in terms of individual and system-wide profits. The asymmetric settings do not reach coordination. (MI, RC) outperforms (MC, RI).

3. For the asymmetric settings, wholesale and retail prices, w^* and r^*, are in between the ranges of the values in the decentralized symmetric policies. The relationship between both variables remains valid, however, changes in the wholesale price have a stronger influence on profits since returns are price-sensitive. This explains that (MC, RI) faces significant losses and drops below the outcome of (CR), whereas (MI, RC) is still above.

4. The impact if the retailer is ignoring returns is greater than under a constant return rate. This is even more crucial in the asymmetric settings, as return rates are not diminished through asymmetric decision making. In fact, they increase. Thus, through his pricing decision, the retailer has the greater influence on the performance of the supply chain.

5. More findings obtained by the conducted sensitivity analysis are:

    - For extreme profit margins, policy (CR), and not (IR), coordinates the system best, what is in contrast to the findings under a constant α of 20%.
    - Higher logistic costs lead to lower profits of both supply chain players. The manufacturer highly benefits when the retailer bears most of the return costs.
    - Policy (CR) outperforms policy (IR) with increasing salvage values v and v_r.

Results retrieved under a Buy-Back Contract

1. Under price-dependent returns, buy-back contracts improve the coordination of the supply chain when returns are considered in the optimization process by both players. Ignoring returns leads to worse outcomes than under a wholesale contract. For the asymmetric settings, (MC, RI) performs better with a constant and (MI, RC) with a variable α.

2. Identical to the findings for constant returns (stochastic and, stochastic and price-dependent demand) only the manufacturer is in the position to improve his performance under buy-back contracts, that is the shift in profits still exists. However, it is less articulated for price-dependent returns.

CHAPTER 7

GAME THEORETIC IMPLICATIONS AND STRATEGIC DECISION MAKING

In the previous chapters, we focussed on performing and evaluating computational work. We compared the performances of the asymmetric settings to those of the symmetric policies for different types of demand and return functions. However, the reasons and implications of asymmetric decision making have not been outlined yet.

Asymmetric behavior can arise due to two reasons: (1) Both players decide individually whether they consider returns or not in their optimization process. Of course, they have no knowledge about the other player's optimization decision. In other words, the asymmetric behavior occurs accidentally. (2) One of the players has knowledge about how the other player acts and thus, he can decide to act asymmetrically, since his payoffs might be better compared to the respective symmetric policy.

If both players can individually decide whether to include returns or not in their optimization processes, they also have to consider their final profits. However, the latter are depending on the decision of the other player. Thus, it makes sense for the agents to consider the possible performances of the supply chain under symmetric and asymmetric settings in order to find their optimal optimization policy. This is equivalent to a game theoretic analysis where each supply chain member tries to maximize his outcome regardless of the other players behavior. In this chapter we therefore examine the consequences on decision making according to game theory. Further, strategic options arise when either the manufacturer or the retailer has knowledge about the optimization process of the respective other player. Hence, the players can be in a position to raise their profits on the expense of the other player. This matter is studied after we outline the game theoretic implications.

7.1 Consequences of Asymmetric Behavior on Decision Making

For asymmetric decision making, game theoretic approaches propose good insight into the behavior of players in the real world. Under the assumption of rationally behaving actors with private information (i.e. the general settings of the supply chain is known, but not the optimization process of the other player) we can draw conclusions about the optimization strategy that the supply chain members should choose.

So far, we found the total profits of the asymmetric settings to be within the range of the symmetric ones. However, individual profits of the players are either better or worse in the asymmetric cases. In the following, we focus on the results obtained in the previous chapters and interpret them according to game theory. Thus, we examine the outcomes of the decentralized asymmetric policies in order to find the specific optimization strategy, according to which a player should act to reach best performance. We start out by looking at stochastic demand and then go over to stochastic and price-dependent demand under both, constant, and price-sensitive return rates.

7.1.1 Stochastic Demand

Looking at the results in table 4.1, it is visible that in the asymmetric cases only one player is better off, whereas the other one is facing worse profits compared to the decentralized symmetric settings. Accordingly, following policy (MI, RC) gives the retailer the best profits and the manufacturer the worst outcome. In case of (MC, RI)

it is vice versa. In other words, the players receive their best profits if and only if they choose to consider returns and the other one not. However, if both players do consider consumer returns, they end up at the worst possible case (CR). This situation perfectly describes the prisoner's dilemma in the subject of game theory.

Under the assumption that both players decide independently and do not cooperate, rational actors always choose to consider returns. This results out of the fact that, no matter if one supply chain member chooses to or not to consider returns, the best option for the other player is always to consider returns since this gives him/her the higher compared pay-off. Due to this, the strategy to include returns in the optimization process is a so-called dominant strategy (see Varian (1992) [50], page 262). As a result, the situation ends up in a pareto-inefficient Nash-equilibrium (i.e. policy (CR)), where the total supply chain faces its minimum possible profits. Policy (CR) is also called a pareto-suboptimal situation, since both players can improve their profits without harming the other player. In other words, a pareto improvement is possible. According to their dominant decision strategies, policy (IR) is never followed and consequently the best outcome is not reached. Furthermore, the conducted calculations for wholesale contracts, which show the robustness of our initial results, allow us to extent the mentioned prisoner's dilemma. For changes in the model parameters, (CR) still is the pareto-inefficient Nash-equilibrium, reached by dominant strategies of both supply chain players. Thus, the consequences on decision making remain unchanged. Under a buy-back option, however, the situation is different. According to table 4.7, the retailer's dominant strategy is (CR), since this gives him the best profits regardless of the manufacturer's decision. For the manufacturer there is no dominant strategy, because his outcome is not independent of the retailer's strategy. Assuming that the retailer is a rational actor, the vendor knows for sure that the retailer includes returns in his optimization process. Thus, the vendor's non-dominant strategy is to consider returns as well, since this results in higher profits for her than ignoring them. Note, that with a buy-back rebate the supply chain players end up in the situation (CR), which is pareto-optimal instead of pareto-suboptimal. A player can only be better off if he concurrently makes the other player worse off. Policy (CR) actually constitutes the best outcome the retailer can reach under a buy-back contract, whereas the manufacturer, in turn, is in a suboptimal position. She could face higher profits in case (IR). Additional sensitivity analysis shows that the presented game theoretic implications hold and, thus, strategy (CR) should be followed by both players if demand is stochastic.

7.1.2 Stochastic and Price-Dependent Demand

Constant Return Rate

Under stochastic and price-dependent demand (with a constant return rate), total profits of the asymmetric cases are in between the decentralized symmetric settings - just as under simple stochastic demand. However, as a major difference to stochastic demand, the retailer outperforms the vendor under setting (MI, RC) and also faces higher profits as in policy (IR). The same holds true for the manufacturer with policies (MC, RI) and (CR), respectively. General game theoretic implications and the consequences on decision making are unaltered, though. Table 5.1 also shows that in a specific asymmetric setting one player faces higher profits, whereas the other one is worse off compared to the symmetric cases. According to the game theoretic propositions we introduced so far in this chapter, this game, again, has dominant strategies for both players and, hence, a Nash-equilibrium that is suboptimal for both players and the total supply chain. In other words, the prisoner's dilemma is present as well.

Both players find their best compared profits if they choose to consider returns, independently of the respective other player's choice. Since both players decide to include consumer returns to maximize their outcomes independently, they end up at policy (CR), what is the least favorable for both. Moreover, the strategy to include returns is a dominant strategy for the supply chain players, resulting in the pareto-inefficient Nash-equilibrium (Varian (1992) [50]), with the detrimental effects on total supply chain profits. The profits which the agents face in setting CR can be improved by concurrently not putting the other player into a worse position by switching to strategy (IR). This matches with the findings under stochastic demand. As the dominant strategy of both players is to consider returns, the outcome of policy (IR) is not reached. As we observe in the conducted sensitivity analysis, the general prisoner's dilemma is valid for most variations of the base case parameters under stochastic and price-dependent demand. An exception is shifting logistic costs among the players. Looking at the graphs in figure 5.5 we find the decision strategy for the retailer to remain unaltered. For the manufacturer, in turn, a dominant strategy over the total range of β is not available. Given the retailer considers returns, his best outcome is reached if he chooses to consider returns as well. When the retailer ignores returns, things chance. He prefers to consider or ignore returns for extremely high or medium to low share of reverse logistic costs, respectively. This is indicated by the red and light-blue dashed lines for the manufacturers profits. Now, knowing the retailer always considers returns, the rationally acting manufacturer reacts by doing so as well, since this gives her the best compared pay-off. Thus, despite of the explained missing dominant strategy for one agent, the overall strategy for both players still is (CR) and consequences on decision making remain unchanged.

If a buy-back option is offered mainly similar result to those under a price-only contract are obtained. According to table 4.7 both players are facing worse profits in the respective setting where they ignore returns. The manufacturer finds his best outcome in policy (IR), whereas the retailer prefers the asymmetric setting (MI, RC). All in all, for stochastic and price-dependent demand with a constant return rate and under a buy-back option the pure prisoner's dilemma with the retailer's and manufacturer's dominant strategy (CR) is present. However, the situation if both simultaneously consider returns in the decision process is pareto-suboptimal. For the vendor (CR) yet constitutes the best outcome she can reach under a buy-back contract. The retailer's performance is suboptimal and could be increased if solely the manufacturer or both players switch to considering returns. However, this would imply lower profits for the former. Through further sensitivity analysis we are also able to confirm that (CR) remains the Nash-equilibrium when varying specific model parameters. Ultimately, under stochastic and price dependent demand and a constant return rate, rational supply chain players act according to policy (CR).

Price-Dependent Return Rate

Table 6.2 on page 95 compares symmetric and asymmetric settings for the base case if returns are price-dependent. The outcome (MC, RI) is the worst possible for both players and the total supply chain, whereas the retailer is better off in setting (MI, RC) compared to (IR). Asymmetric settings do not benefit the vendor's profits at all. Consequently, the manufacturer has no dominant strategy. She simply prefers the same strategy that the retailer chooses. However, the latter prefers to consider returns - independently of the vendors decision. With the premise of rationally acting supply chain members, the vendor knows that she has to consider returns in order to reach the best possible outcome. Although this decision is not dominant, it is the corollary on the retailer's (dominant) strategy to consider returns. Thus, we do not find the prisoner's dilemma, but still the players end up in the pareto-inefficient case of (CR). The effect of this strategy on individual and total supply chain profits is detrimental and, moreover, the best outcome (IR) is not reached. Note, that under price-dependent returns (CR) is pareto-inefficient or equivalently pareto-suboptimal. Both players can improve their performances without harming the other one by switching to ignoring returns.

As we observe in the conducted sensitivity analysis, the general prisoner's dilemma is valid for most variations of the base case parameters under stochastic and price-dependent demand with a price-dependent return rate. Whenever we find no pure prisoner's dilemma, a mix of non-dominant and dominant strategies of the players still lead to the outcome of policy (CR).

Under a buy-back option no Nash-equilibrium is found. Moreover, the retailer lacks a dominant strategy. Note the ruinous profit situation in setting (MC, RI). However, the retailer faces his best outcome in the other asymmetric setting (MI, RC). The manufacturer prefers the symmetric setting when both players ignore returns. Consequently, the same results as under a buy-back rebate when demand is stochastic are gained. According to game theory (CR) is reached and it represents a pareto-optimal solution.

For the considered demand models and return functions within this thesis we studied game theoretic implications on the decision process of the supply chain players. Throughout policy (CR) is reached when both players act rationally and do not have knowledge about the optimization decision of the other player beforehand. This holds true under a wholesale and a buy-back contract. The equilibrium is either reached with dominant strategies of both players, that is the prisoner's dilemma is present, or since one player reacts on the dominant strategy of the other player to consider returns. Furthermore, the situation (CR) is either pareto-suboptimal or pareto-optimal. However, regarding the total profits, the situation is always suboptimal. Regarding possible ways to overcome the prisoner's dilemma, individual self-interest is simply a trap rather than a sufficient mechanism for efficiency. Consequently, individual interest does not improve the situation sufficiently and instead cooperative actions of the players have to be undertaken.

First of all, there is communication. Both players could agree on ignoring returns what puts them in a better position than considering returns. However, mistrust, egoism and also psychology comes into play. Each player might think that they could further increase their profits if the other player sticks to the agreed compact by individually switching to considering returns. Eventually they might also consider that the other player probably is having this thought as well. Obviously, simple communication is not sufficient to escape the dilemma. Instead, mechanisms are needed that either tie the players to agreed decisions or stimulate the players to act in the (best) interest for the group. Repeating the game or decision about the optimization strategy multiple times also alters the results presented. However, the prisoner's dilemma shows how mutual trust and understanding, and communication as well as coordination are essential for an optimal supply chain performance. In failing to do so, results are poor and a break-up of the supply chain may occur. Additionally, it becomes clear that a better coordination is difficult to reach since both members have an incentive not to cooperate unless they both simultaneously do.

Game theory provided the background for the cases when both players act rationally with no additional information given about the behavior of the other one. When such information is available, the picture changes. Now the manufacturer can exploit information in order to raise her profits. The retailer, though, has the option to react to the vendors strategy. This matters are discussed in the next section.

7.2 Strategic Decision Making

In the asymmetric cases the manufacturer always makes the assumption about how the retailer acts prior to optimizing. In other words, she estimates how the retailer acts, whereas she could not foresee possible asymmetric behavior of him.

	Symmetric		Asymmetric			
	(CR)	(IR)	(MC, RI)	(MI, RC)	(MC^k, RI)	(MI^k, RC)
w^*	2.28	2.18	2.29	2.18	2.43	1.98
r^*	3.81	3.90	3.95	3.78	4.01	3.67
α	20.7%	21.7%	22.29%	20.41%	23.00%	19.24%
Q^*	2.45	2.91	2.65	2.67	2.338	3.23
Π_M	1.378	1.427	1.304	1.335	1.323	1.242
Π_R	1.461	1.607	1.377	1.674	1.123	2.172
Π_T	2.839	3.033	2.681	3.009	2.446	3.414

Table 7.1. Equilibrium Values for Symmetric and Asymmetric Policies under Stochastic and Price-Dependent Demand and Price-Dependent Return Rates

In case that the manufacturer has knowledge about how the retailer acts, she might be able to raise her profits compared to the symmetric cases. Note that under strategic decision making one player explicitly uses the additional given information to raise his/her profits, regardless of the change in the performance of the other player. However, it is obvious that strategic options are only given if a player reaches its best performance in any of the asymmetric settings. In general the manufacturer benefits from two reasons when making use of a strategic decision: (1) The retailer orders more units when ignoring returns compared to the case when considering returns as stated in chapter 3, whereas the manufacturer consequently exploits this fact in her optimizations. (2) She can increase her optimal wholesale price and thus increase her marginal profit. However, an improvement is not possible in all cases. Observe, that for price-dependent returns the vendor is not better off in the asymmetric settings under both, a wholesale and buy-back contract, and thus lacks strategic options in this case (see table 7.1). The retailer has the possibility to improve his profits in all of the three considered models in the thesis. Also, he does not need any information about how the supplier acts in order to improve his performance. He simply can recognize the optimization process from the given wholesale price w^*. The respective outcome of any policy chosen by the retailer can directly be identified by means of w^*.

In order to calculate and compare the new strategic options, we introduce new notations. (MI^k, RC) indicates that the vendor herself ignores returns but knows about the optimization process of the retailer to include returns. (MC^k, RI) describes the respective other case if the manufacturer has knowledge that the retailer ignores returns while she considers them. As we will see, the latter case does not improve the manufacturer's situation, what follows out of our initial results (compare table 4.1) as well. Calculations are done similarly to the asymmetric cases except for the order amount assumed by the manufacturer. She now uses the order amount Q according to Q^{CR*} for the case (MI^k, RC) and Q^{IR*} for (MC^k, RI). The considered profit functions of the retailer and manufacturer stay unaltered. We start out by analyzing the case of stochastic demand and then continue with stochastic and price-dependent demand with a constant return rate. For price-dependent returns, as mentioned, there is no strategic option.

7.2.1 Stochastic Demand

Listed together with the initial results of the symmetric and asymmetric cases, the new strategic policies under a wholesale contract are shown in table 7.2. According to the reasoning in the beginning of this section, if the retailer considers returns the manufacturer can not be better off by using this information. In turn, if the retailer ignores returns, (MC^k, RI) improves the performance of the vendor. The differences between (MC, RI) and (MC^k, RI) are only marginally, though. Observe that the profits for the manufacturer improve by about 0.02 or less than 1%, whereas the retailer suffers a loss of 0.18 or equivalently 36% of his total profits. The retailer has the strategic option to improve his profits by switching from the policy (IR) to (MI, RC). As a result he can maximize his profits, but in turn the manufacturer and the total supply chain are facing lower profits. Thus, the retailer can react on any attempt of the manufacturer to raise her profits on his own expenses by simply

		Symmetric		Asymmetric		Strategic	
		(CR)	(IR)	(MC, RI)	(MI, RC)	(MC^k, RI)	(MI^k, RC)
Cent.	Q^*	3.27	3.50	-	-	-	-
	Π	4.61	4.58	-	-	-	-
Decent.	Q^*	1.97	2.16	2.08	2.06	2.05	2.08
	w^*	3.56	3.47	3.56	3.47	3.58	3.44
	Π_R	0.5405	0.6805	0.5355	0.6862	0.5044	0.7363
	Π_M	2.9273	3.0746	3.0970	2.9112	3.0980	2.9003
	Π_T	3.4678	3.7551	3.6325	3.5974	3.6024	3.6366

Table 7.2. Optimal Values for Symmetric and Asymmetric Policies and the Strategic Options in the Base Case with a Normally Distributed Demand

switching to considering returns when making his order amount. Again, this is a dominant strategy that leads to a pareto inefficient Nash-Equilibrium. However, by doing so, his profits are higher than in (MC^k, RI).

In order to extend the initial findings for the strategic policies (MC^k, RI) and (MI^k, RC) under a wholesale contract in case of stochastic demand, and to show that the manufacturer can always exploit information - if available - to raise her profits, we further vary specific model parameters and consider the option of a buy-back contract.

Return Rates and Share of Logistic Costs

Table 7.3 compares the base cases with the strategic settings for relevant β-values, whereas the vendor is also in the position to improve her performance under (MI^k, RC), when shifting the major burden of logistic costs to the retailer. Interestingly, for the case of (MI^k, RC) at one hand the retailer is facing worse profits and on the other hand the total supply chain profits are higher when the retailer has to bear more of the reverse logistic costs. For (MC^k, RI) only the manufacturer's profits are increasing for higher magnitudes of β. However, since the manufacturer faces worse in the former case, he will not consider it as a strategic option.

For different rates of consumer returns α, computational work shows that the manufacturer has again only one option to raise profits, that is (MC^k, RI). However, higher values of α lead to a lower level of all profits and optimal order quantities. This represents the initial findings in the strategic part and does not need further investigation.

	(MC^k, RI)						(MI^k, RC)					
β	w^*	Q^*	P_M	P_R	P_T	$\%\Delta$	w^*	Q^*	P_M	P_R	P_T	$\%\Delta$
0.05	3.58	2.06	3.0980	0.5043	3.6024	+ 3.9%	3.44	2.08	2.1973	0.7363	2.9336	- 21.9%
0.5	3.54	2.10	3.4649	0.1966	3.6616	+ 4.7%	3.26	2.07	2.3757	0.6699	3.0456	- 18.9%
0.95	3.51	2.13	3.8378	-0.1343	3.7035	+ 4.9%	3.08	2.05	2.5548	0.6038	3.1586	- 15.9%

	(MC,RI)						(MI,RC)					
β	w^*	Q^*	P_M	P_R	P_T	$\%\Delta$	w^*	Q^*	P_M	P_R	P_T	$\%\Delta$
0.05	3.56	2.08	3.0971	0.5356	3.6328	+ 4.7%	3.47	2.06	2.9115	0.6861	3.5976	- 4.2%
0.5	3.34	2.27	3.3975	0.5037	3.9012	+ 11.5%	3.47	1.84	2.9141	0.3389	3.2530	- 13.4%
0.95	3.12	2.42	3.6342	0.4582	4.0924	+ 15.9%	3.47	1.32	2.3191	0.0468	2.3659	- 37.0%

Table 7.3. Strategic Policies for Different Values of β in Comparison to the Asymmetric Settings under Stochastic Demand and a Price-Only Contract and Percent Delta to the respective Decentralized Symmetric Cases

Positive Salvage Values

We observe, that both agents can improve their profits under both strategic settings. This is rather surprising, since positive salvage values simply put more "money" in the supply chain and also reduce the financial risk associated with overstocking. As an incentive for the retailer to order more the manufacturer transmits lower wholesale prices, whereas her lessened profits are overcompensated by the returned item values. The retailer, in turn, benefits from lower wholesale prices as well. Below is figure 7.1, where we choose to show the graphs for $v_r = \frac{v}{2}$. Note that they behave in the same manner as any other feasible values of v_r. As previously stated the effect of positive salvage values on supply chain profits are equivalent to lower logistic costs or a shift in them. Therefore, the curve progressions in figure 7.1 are also representative for changes in the logistic costs l. Finally, we can conclude, that the strategic options are still present for positive unsold and returned item salvage values.

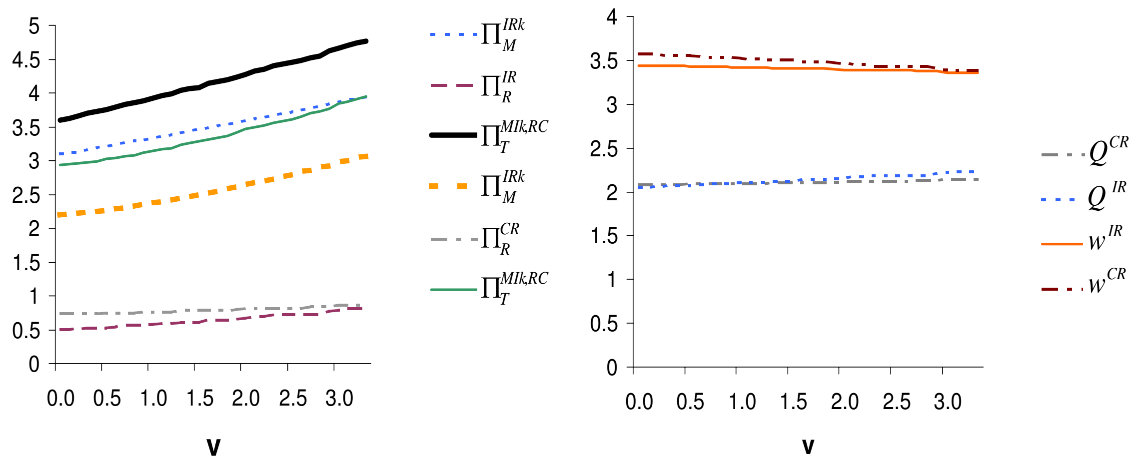

Figure 7.1. Profits and Order Quantities for salvage values v and $vr = \frac{v}{2}$ in the Strategic Cases

Buy-Back Option

When giving the retailer the option to sell back unsold items to the manufacturer we can observe the same results as under the asymmetric policies, i.e. the manufacturer rakes almost all of the profits, whereas the retailer's profits reduce to a minimum and are barely positive. *Contrary to the hitherto retrieved results is that within the strategic options under a buy-back rebate, the total supply chain and both players perform better in the setting* (MI^k, RC). This is due to the fact that the manufacturer now can exploit the incentive (that the buy-back contract proposes) given to the retailer even better. *Thus, if a buy-back contract is given, strategic behavior of the manufacturer can help to improve the coordination of supply chains. For moderate levels of production costs and return volumes, both strategic options have improved total supply chain profits.* Table 7.4 shows the profits for different rates of returns $\alpha = \{0.2, 0.4\}$ and production costs $c = \{0.5, 1, 2\}$. Moreover, the percent differences of the total channel profits to the comparable policies are presented. Observe that the optimal buy-back value s found by the manufacturer is just below the optimal value of the wholesale price w - just as in the asymmetric and symmetric settings that are

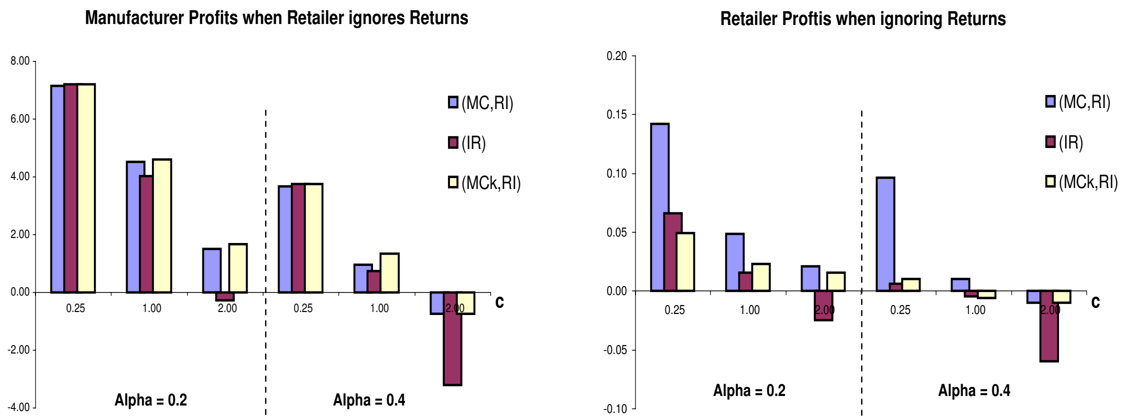

Figure 7.2. Manufacturer and Retailer Profits (Retailer ignores Returns in all Cases) under Different Optimization Strategies for Different α and c under a Buy-Back Contract and Stochastic Demand

studied in the previous chapters. Except for higher values of c and α, both strategic options are better in terms of total profits. Omitted values are due to negative profits of any of the supply chains considered.

The development of the vendor's and retailer's profits for different return rates and production costs compared to the respective decentralized symmetric and asymmetric policies can be seen in figures 7.2 and 7.3. Notice that the manufacturer is (mostly) better off in both strategic settings. The retailer, in turn, is only better off when he considers customer returns. This is in accordance with the previous findings and further sensitivity analysis shows that buy-back options do not alter the basic results we retrieved for the strategic options under a wholesale contract.

Shifting logistic cost to the retailer does not help improving the coordination of the supply chain. However, the strategic option for the vendor is available, whereas in setting (MC^k, RI) the retailer is even facing negative profits. Table 7.5 shows the equilibrium values for the asymmetric settings with and without knowledge of the optimization process for varied values of β and total logistic costs l. The outcomes of the strategic policies for positive salvage values v and $v_r = \frac{v}{2}$ are presented in

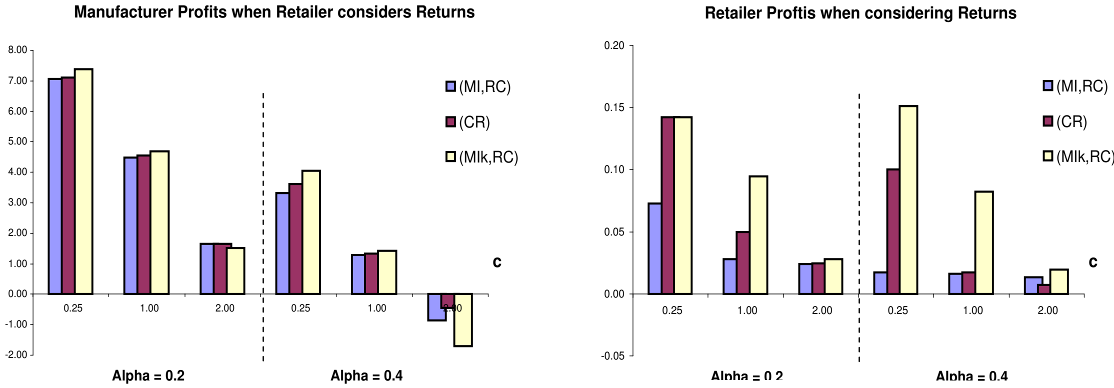

Figure 7.3. Manufacturer and Retailer Profits (Retailer considers Returns in all Cases) under Different Optimization Strategies for Different α and c under a Buy-Back Contract and Stochastic Demand

	(MC^k, RI)			(MI^k, RC)		
	$\alpha = 0.2$					
c	0.25	1	2	0.25	1	2
P_M	7.2085	4.5914	1.6701	7.3747	4.6968	1.5241
P_R	0.0495	0.0231	0.0159	0.1421	0.0947	0.0281
P_T	7.258	4.6146	1.6861	7.5168	4.7915	1.5522
$\%\Delta(MC, RI)\|\|(MI, RC)$	-0.6%	1.1%	10.8%	5.3%	6.2%	-6.9%
$\%\Delta(IR)\|\|(CR)$	-0.4%	14.3%	-	3.5%	4.1%	-7.8%
	$\alpha = 0.4$					
c	0.25	1	2	0.25	1	2
P_M	3.7514	1.3505	-	4.057	1.4343	-1.7051
P_R	0.0106	-0.0055	-	0.1513	0.0823	0.0194
P_T	3.762	1.345	-	4.2083	1.5166	-1.6857
$\%\Delta(MC, RI)\|\|(MI, RC)$	0.1%	37.1%	-	26.2%	16.0%	-
$\%\Delta(IR)\|\|(CR)$	0.4%	82.1%	-	13.1%	13.1%	-

Table 7.4. Profits and Order Quantities for varying Production Costs c and return rates α under a buy-back contract, when the Manufacturer has Knowledge about the Retailers Optimization Process and Percent Differences to the Respective Asymmetric and Symmetric Policies

	(MI^k, RC)						**(MI,RC)**					
	$\beta = 0.05$			$\beta = 0.95$			$\beta = 0.05$			$\beta = 0.95$		
l	0.5	1	2	0.5	1	2	0.5	1	2	0.5	1	2
w^*	3.96	3.95	3.93	3.84	3.72	3.49	3.97	3.97	3.96	3.87	3.75	3.51
s^*	3.95	3.94	3.92	3.83	3.70	3.48	3.96	3.96	3.95	3.83	3.66	3.29
Q^*	3.41	3.41	3.41	3.40	3.31	3.29	3.11	2.97	2.90	2.27	2.02	1.77
Π_M	5.53	5.26	4.70	5.50	5.19	4.63	5.38	5.05	4.48	4.55	3.92	3.13
Π_R	0.07	0.08	0.09	0.09	0.09	0.07	0.05	0.03	0.03	0.02	0.02	0.02
Π_T	5.61	5.33	4.79	5.59	5.28	4.70	5.42	5.09	4.51	4.57	3.94	3.14
	(MC^k, RI)						**(MC,RI)**					
	$\beta = 0.05$			$\beta = 0.95$			$\beta = 0.05$			$\beta = 0.95$		
l	0.5	1	2	0.5	1	2	0.5	1	2	0.5	1	2
w^*	3.98	3.97	3.96	3.87	3.75	3.51	3.96	3.96	3.95	3.85	3.73	3.50
s^*	3.97	3.96	3.94	3.81	3.61	3.20	3.95	3.95	3.94	3.84	3.72	3.49
Q^*	3.27	3.41	3.22	3.33	3.28	3.21	3.45	3.45	3.55	4.00	4.21	4.42
Π_M	5.44	5.14	4.59	5.47	5.22	4.71	5.39	5.12	4.52	5.14	4.68	3.92
Π_R	0.03	0.03	0.02	-0.01	-0.03	-0.10	0.07	0.05	0.05	0.06	0.06	0.04
Π_T	5.46	5.18	4.61	5.47	5.18	4.61	5.46	5.17	4.57	5.20	4.74	3.96

Table 7.5. Comparison of Profits and Order Quantities for Asymmetric Policies with and without the Availability of Knowledge under a Buy-Back Contract for $\beta = 0.05$ and 0.95 and Different Total Logistic Costs $l = \{0.5, 1, 2\}$.

table 7.6. Similar to the result so far, we obtain the coordinating effects of buy-back contracts on supply chains, whereas under (MI^k, RC) the effect is only infinitesimal.

7.2.2 Stochastic and Price-Dependent Demand

In the incipient discussion of this section we stressed that if returns are price-dependent there is no strategic option available for the manufacturer since his compared pay-offs are extremely worse in the asymmetric settings. Thus, we focus on the strategic options if returns are a constant fraction of a period's sales. We first present the simple wholesale contract. Afterwards we consider the option of a buy-back rebate.

Table 7.7 presents the cases of strategic optimization (MC^k, RI) and (MI^k, RC) and compares them to the respective symmetric and asymmetric settings under stochastic and price-dependent demand. Results are identical to those under stochas-

Buy-Back Option

	(MC^k, RI)						(MI^k, RC)					
v	w^*	s^*	Q^*	Π_M	Π_R	Π_T	w^*	s^*	Q^*	Π_M	Π_R	Π_T
0	3.96	3.94	3.22	4.59	0.02	4.61	3.93	3.915	3.41	4.70	0.09	4.79
0.5	3.96	3.95	3.45	4.86	0.03	4.89	3.92	3.905	3.50	4.99	0.12	5.10
1	3.94	3.93	3.63	5.18	0.07	5.25	3.89	3.875	3.68	5.34	0.19	5.53
1.5	3.89	3.88	3.88	5.60	0.19	5.78	3.86	3.845	3.81	5.76	0.26	6.02
2	3.83	3.82	4.05	6.10	0.33	6.43	3.82	3.805	3.93	6.24	0.35	6.60

No Buy-Back Option

	(MC^k, RI)						(MI^k, RC)					
v	w^*	s^*	Q^*	Π_M	Π_R	Π_T	w^*	s^*	Q^*	Π_M	Π_R	Π_T
0	3.58	-	2.08	2.20	0.74	2.93	3.58	-	2.06	3.10	0.50	3.60
0.5	3.57	-	2.09	2.22	0.75	2.98	3.57	-	2.07	3.12	0.52	3.64
1	3.55	-	2.10	2.25	0.77	3.02	3.55	-	2.09	3.14	0.55	3.69
1.5	3.54	-	2.11	2.28	0.79	3.06	3.54	-	2.10	3.16	0.57	3.72
2	3.52	-	2.12	2.31	0.82	3.13	3.52	-	2.12	3.18	0.60	3.78

Table 7.6. Results for Positive Salvage Values v and $v_r = 0$ with and without a Buy-Back Option, when the Manufacturer has Knowledge about the Retailers Optimization Process

tic demand: In policy (MC^k, RI) the manufacturer is performing best and thus he has a strategic option if the retailer ignores returns in his optimization process. The latter is facing the worst possible outcome and total supply chain coordination is also not reached. (MI^k, RC) is not important as a strategic option since the vendor performs extremely poor. Again, the rise in the profits of the supplier is incommensurate to the losses that the retailer faces. An increase of minimal 2,5% stands in contrast to a decline of 40%. Further we observe that the improved performance of the vendor is due to an increased order quantity, Q^*, and wholesale price w^*, what leads to a greater marginal revenue.

Different Shares of Logistic Costs

In the strategic policies the retailer is always worse off if he has to bear more of the costs associated with customer returns, that is for rising values of β. He finds his best outcome in the strategic setting (MI^k, RC), whereas the retailer is

	Symmetric		**Asymmetric**		**Strategic**	
	(CR)	**(IR)**	**(MC,RI)**	**(MI,RC)**	(MC^k, RI)	(MI^k, RC)
w^*	2.5	2.18	2.5	2.18	2.57	2.12
r^*	4.07	3.90	4.05	3.93	4.08	3.90
Q^*	1.84	2.91	2.19	2.49	2.05	2.63
Π_M	1.411	1.585	1.619	1.299	1.624	1.251
Π_R	1.141	1.677	1.108	1.717	1.006	1.846
Π_T	2.552	3.262	2.728	3.017	2.630	3.097

Table 7.7. Optimality Values for the Base Case under Stochastic and Price-Dependent Demand and a Constant Return Rate of the Decentralized Symmetric and the Asymmetric Policies with and without Knowledge about the Retailers Optimization Process

	(MC^k, RI)						(MI^k, RC)					
β	w^*	r^*	Q^*	Π_M	Π_R	Π_T	w^*	r^*	Q^*	Π_M	Π_R	Π_T
5%	2.57	4.08	2.05	1.624	1.006	2.630	2.12	3.90	2.63	1.251	1.846	3.097
50%	2.44	4.02	2.31	1.910	0.867	2.777	2.07	3.97	2.40	1.383	1.588	2.971
95%	2.31	3.96	2.60	2.256	0.683	2.939	2.00	4.03	2.23	1.470	1.388	2.858
	(IR)						(CR)					
5%	2.18	3.90	2.91	1.585	1.677	3.262	2.50	4.07	1.84	1.411	1.141	2.552
50%	2.18	3.90	2.91	1.994	1.268	3.262	2.32	4.09	1.88	1.450	1.142	2.592
95%	2.18	3.90	2.91	2.403	0.859	3.262	2.12	4.09	1.97	1.490	1.178	2.668

Table 7.8. Optimality Values for Strategic and Decentralized Symmetric Policies under Stochastic and Price-Dependent Demand and a Constant Return Rate for varying Shares of Reverse Logistic Costs among the Players

never better off than in (MC^k, RI). As an extension to previously retrieved results, the manufacturer benefits from a declining share of logistic costs. Further, different shares of return costs do not coordinate the supply chain under stochastic and price-dependent demand. Although coordination in terms of total profits is suboptimal in setting (MI^k, RC), the distribution of profits among the players is almost equally distributed for $\beta = 0.95$. Summarizing, the strategic option for the manufacturer is only present if he bears the lion share of logistic costs.

Different Return Rates and Production Costs

Varying the parameters α (return percentage) and c (production costs) in the intervals [10%; 30%] and [1; 3] respectively, allows us to further generalize the existence of tactical options. Table 7.9 shows retrieved results of the computational work for variations the parameters in the latter stated intervals and reveals an interesting insight: *For higher overall return volumes and extreme values of production costs, strategic options are able to improve the coordination of the supply chain for stochastic and price-dependent demand and a constant return rate.* However, only for higher production costs and low to medium return rates the manufacturer has the option to egoistically increase her profits. Especially for lower return volumes and production costs, the strategic options are detrimental for total and individual system-wide profits. Further, we find the deteriorating effect on the retailer's profits, if the vendor chooses to exploit available information about the optimization process. Note, that the retailer has the option to react on egoistical behavior of the manufacturer by switching to considering returns as well. As described in the game theoretic section this situation then ends up in policy (CR), which is pareto-suboptimal for both players. However, it is important for the retailer to have this option, because this balks the manufacturer in solely acting in her own best interest.

Positive Salvage Values and Change in Market Parameters

Finally, we study different market conditions and positive unsold and returned item salvage values if the supply chain is coordinated with a simple price-only contract. In each of the three considered markets strategic options are not available to the manufacturer. This is indicated by the percent differences next to the manufacturer, which describe the percentage gap to her profits under decentralized symmetric optimization procedures. The difference between total profits of the latter and the strategic cases is also shown in percent. Interestingly, for the considered market sizes,

	c = 0.25											
	(MC^k, RI)						(MI^k, RC)					
α	w^*	r^*	Q^*	Π_M	Π_R	Π_T	w^*	r^*	Q^*	Π_M	Π_R	Π_T
10%	1.67	3.65	4.40	5.06	3.68	8.75	1.54	3.60	4.59	4.77	4.22	8.99
20%	1.81	3.72	3.95	3.81	2.59	6.40	1.50	3.60	4.42	3.31	3.66	6.97
30%	2.03	3.83	3.31	2.54	1.53	4.07	1.45	3.60	4.25	1.90	3.12	5.03
	(IR)						**(CR)**					
10%	1.57	3.59	4.75	5.68	4.45	10.13	1.60	3.62	4.52	5.52	4.32	9.84
20%	1.57	3.59	4.75	3.90	3.36	7.26	1.73	3.71	3.67	3.40	2.87	6.27
30%	1.57	3.59	4.75	2.72	2.63	5.35	1.90	3.82	2.89	2.15	1.90	4.05

	c = 2											
	(MCk, RI)						(MIk, RC)					
α	w^*	r^*	Q^*	Π_M	Π_R	Π_T	w^*	r^*	Q^*	Π_M	Π_R	Π_T
10%	3.17	4.33	1.08	0.78	0.51	1.28	2.91	4.23	1.33	0.66	0.78	1.45
20%	3.52	4.47	0.68	0.34	0.19	0.54	2.90	4.24	1.21	0.08	0.64	0.72
30%	4.04	4.67	0.27	0.08	0.03	0.11	2.88	4.25	1.10	-0.42	0.51	0.09
	(IR)						**(CR)**					
10%	2.92	4.23	1.43	0.74	0.77	1.50	3.15	4.33	1.01	0.71	0.53	1.24
20%	2.92	4.23	1.43	0.15	0.60	0.75	3.48	4.47	0.58	0.29	0.22	0.51
30%	2.92	4.23	1.43	-0.43	0.43	-0.01	3.95	4.65	0.22	0.06	0.05	0.11

Table 7.9. Performance of Strategic and Decentralized Symmetric Cases under Stochastic and Price-Dependent Demand for varying Shares of Reverse Logistic Costs among the Players

	v	v_r	(MC^k, RI) Π_M	%Δ	Π_R	Π_T	%Δ	(MI^k, RC) Π_M	%Δ	Π_R	Π_T	%Δ
b = -3	0.4	0.2	1.81	-5.4%	1.18	2.99	-23.5%	1.56	-1.9%	2.13	3.70	25.6%
k = 5	0.8	0.4	2.09	-12.5%	1.48	3.57	-25.2%	1.97	5.9%	2.61	4.58	30.7%
	1.2	0.6	2.53	-17.0%	2.05	4.57	-24.5%	2.60	12.3%	3.36	5.96	29.7%
b = -1.5	0.4	0.2	7.35	-4.7%	4.98	12.33	-9.8%	6.65	1.3%	6.45	13.10	9.1%
k = 10	0.8	0.4	7.90	-6.5%	5.54	13.44	-10.7%	7.36	3.5%	7.17	14.53	10.5%
	1.2	0.6	8.57	-8.1%	6.38	14.95	-9.7%	8.22	5.5%	7.98	16.20	9.4%
b = -6	0.4	0.2	0.08	-175.7%	0.04	0.13	-51.9%	-0.14	-	0.41	0.27	108.1%
k = 2.5	0.8	0.4	0.10	-564.8%	0.06	0.16	-69.5%	-0.11	-	0.62	0.51	202.0%
	1.2	0.6	0.15	-21.3%	0.14	0.30	-77.2%	0.04	-	1.28	1.32	271.8%

Table 7.10. Percent Differences of the Manufacturer's and Total Supply Chain Performance to the Cases of Decentralized Symmetric Behavior under Stochastic and Price-Dependent Demand and a Constant Return Rate for Positive Salvage Values in Different Markets

(MC^k, RI) is outperformed by (MI^k, RC) if salvage values are positive. Accordingly, the retailer benefits from the latter policy, whereas the manufacturer is better off under the former what is outlined in table 7.10.

Buy-Back Option

To complete the analysis for strategic options under stochastic and price-dependent demand we examine the buy-back option. Table 7.11 compares decentralizes symmetric and asymmetric settings with the strategic optimization policies in the base case settings under a buy-back contract. *Importantly, the relationship* $w^* = s^* + \frac{c}{2}$ *that we retrieved for the optimal wholesale and buy-back price does not hold under strategic decision making.* However, opposed to the coordinating effect of a buy-back contract under stochastic demand better coordination is not possible with the strategic optimization if demand is price-dependent as well. The decision variables of the players are (mainly) found in between the range of those of the symmetric setting. Thus, the performance of the players has to be in between the symmetric cases as well. *Moreover, strategic decision making is not available under a buy-back rebate in the base case settings.*

	Wholesale Contract		Buy-Back Contract			
	Symmetric		Symmetric		Strategic	
	(CR)	(IR)	(CR)	(IR)	(MC^k, RI)	(MI^k, RC)
w^*	2.50	2.18	3.34	3.00	3.25	3.07
s^*	-	-	2.84	2.50	2.44	2.74
r^*	4.07	3.90	4.32	4.13	4.28	4.16
Q^*	1.84	2.91	2.47	3.63	2.41	3.62
Π_M	1.411	1.585	1.857	1.769	1.837	1.615
Π_R	1.141	1.677	0.942	1.481	0.852	1.548
Π_T	2.552	3.262	2.799	3.250	2.689	3.163

Table 7.11. Percent Differences of the Manufacturer's and Total Supply Chain Performance to the Cases of Decentralized Symmetric Behavior under Stochastic and Price-Dependent Demand and a Constant Return Rate for Positive Salvage Values in Different Markets

Figures 7.4 and 7.5 show and compare the player's pay-offs they receive in the decentralized policies if the retailer ignores or includes returns throughout for varying values of β and l. We observe, that strategic decision making does not improve the manufacturers situation and, hence, the tactical option to selfishly increase her profits is not given. this extends the initial findings for buy-back contracts. However, setting (MC^k, RI) still shows minimal profits for the retailer. Moreover, the profits of the players in setting (IR) are (hardly) never outperformed.

The effect of positive salvage values on the availability of tactical options is similar to under a wholesale contract. The manufacturer can, except for smaller market sizes, not improve his performance by optimizing egoistically. Consequently, strategic options are not present. Intuitively, higher salvage values improve the performance of the supply chain, whereas coordination is also not reached. Table 7.12 presents the equilibrium values of the strategic policies for identical salvage values ($v = v_r$) and different market sizes and elasticities. Additionally the percent difference of the manufacturer's profits to the decentralized symmetric settings is shown. The results do extent the findings under buy-back contracts for stochastic and price-dependent demand and thus need no further investigation.

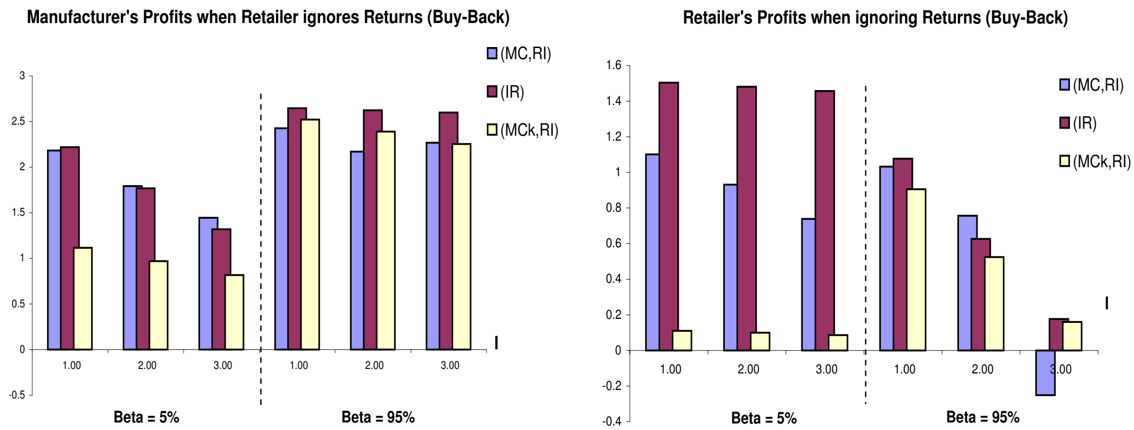

Figure 7.4. Manufacturer's and Retailer's Profits (Retailer ignores Returns in all Cases) under Different Optimization Strategies for Different β and l under a Buy-Back Contract and Stochastic and Price-Dependent Demand with a Constant Return Rate

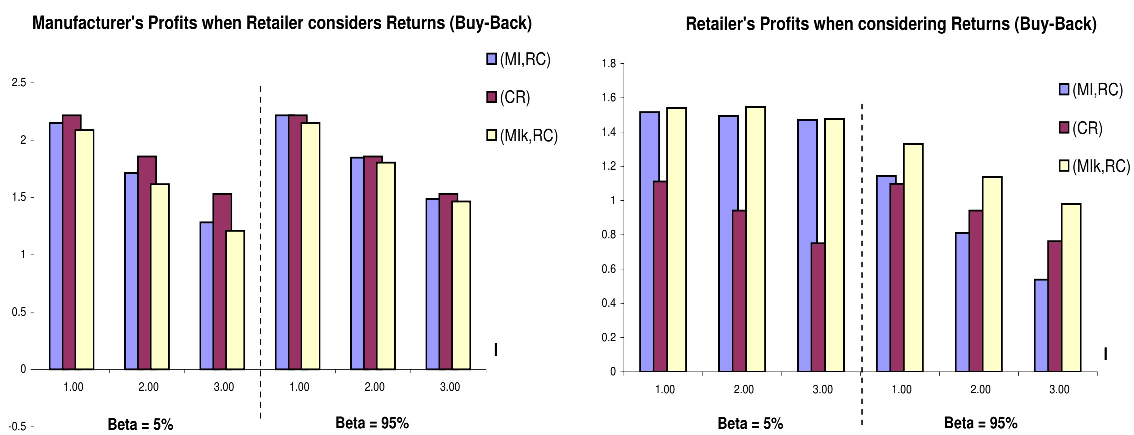

Figure 7.5. Manufacturer and Retailer Profits (Retailer considers Returns in all Cases) under Different Optimization Strategies for Different β and l under a Buy-Back Contract and Stochastic and Price-Dependent Demand with a Constant Return Rate

	v	v_r	(MC^k, RI) Π_M	$\%\Delta$	Π_R	Π_T	(MI^k, RC) Π_M	$\%\Delta$	Π_R	Π_T
b = -3	0.4	0.4	2.25	-3.8%	1.10	3.35	2.21	-4.1%	1.76	3.96
k = 5	0.8	0.8	3.11	-0.1%	1.50	4.61	3.02	-1.7%	2.13	5.16
	1.2	1.2	4.35	0.4%	2.15	6.50	4.28	-0.5%	2.60	6.88
b = -1.5	0.4	0.4	8.83	-2.1%	4.41	13.25	8.78	-0.9%	5.25	14.03
k = 10	0.8	0.8	10.14	-0.4%	5.10	15.24	10.04	-0.5%	5.81	15.85
	1.2	1.2	11.67	0.0%	5.81	17.48	11.59	-0.1%	6.33	17.91
b = -6	0.4	0.4	0.96	-	0.00	0.96	-0.07	-	0.34	0.27
k = 2.5	0.8	0.8	0.97	-	0.00	0.97	0.18	-4.2%	0.50	0.68
	1.2	1.2	0.98	3.1%	0.50	1.48	0.91	-5.0%	0.83	1.74

Table 7.12. Performance of the Strategic Cases with a Buy-Back Option under Stochastic and Price-Dependent Demand and a Constant Return Rate for Positive Salvage Values in Different Markets and Percent Differences of the Manufacturer's Profits to the respective Decentralized Symmetric Policies

The presented strategic options, however, require the supply chain members to have asymmetric information. Taking advantage of this information in order to improve own profits on the account of the other supply chain member is in general not a fair practice in a well-functioning relationship. The retailer or manufacturer might also notice the strategy option applied when comparing expected and received profits after the deal is made. This affects future deals as well, since the players should learn from their fault. Consequently the relationship between the supply chain players should be affected by strategic decision making.

7.3 Conclusions

For the considered demand and return models in this thesis, we have investigated the results of the computational study in terms of game theoretic implications and strategic options that arise out of asymmetric decision making. Finally, the most important findings in this chapter are summarized:

Results of the Game Theoretic Analysis

1. Applying game theory, we find the "prisoner's dilemma" since both players choose (CR) as their dominant strategy if demand is stochastic or stochastic and price-dependent. Rational acting players thus end up with the worst possible profits and consequently in a pareto-inefficient Nash-equilibrium. This holds true for both a wholesale and a buy-back contract.

2. The policy (CR) in which the players arrive, is either found by dominant strategies of both players (i.e. both consider returns independently of the other player's optimization process) or by the dominant strategy to consider returns of solely one player, whereas the other player rationally reacts with the non-dominant strategy to consider returns as well, since this gives him the better compared pay-offs.

3. The situation (CR) is either pareto-optimal or pareto-suboptimal depending on the demand and return model and the coordination scheme considered. In other words, switching the optimization policy either benefits both players or only one, with the other one being worse off.

4. Possible ways to overcome the prisoner's dilemma have to go beyond individual self-interest of the players. Communication, mutual trust or repeated deals can help to improve the performance in decentralized organized supply chains.

Results of Strategic Decision Making

1. Exploiting available information about the optimization process of the retailer, the manufacturer can improve her optimal profits by switching from policy (IR) to (MC^k, RI). Two reasons are crucial: Firstly, an increased wholesale price

widens her profit margin and, secondly, the optimal order quantity Q^{IR*} exceeds Q^{CR*}.

2. The increase in the manufacturer's profits is only marginally (about 2%), whereas the retailer faces a severe reduction of about 30% to 40%. As the manufacturer raises her profits on the back of the retailer's, he can react by changing its optimization policy as well, what ends up under the setting (CR) again. Consequences are as outlined in the game theoretic section.

3. Under stochastic demand, supply chain coordination is in some cases possible through strategic optimization of the manufacturer. Buy-back contracts for example, can lead to a coordination of the supply chain.

4. For stochastic and price-dependent demand and if a buy-back contract is given, strategic options are not available in general for the vendor.

5. Under stochastic and price-dependent demand and a price-sensitive return rate, the manufacturer does not perform better in the asymmetric policies, and thus, strategic options are not available.

CHAPTER 8

CONCLUSIONS AND EXTENSIONS

In this thesis we have studied the effect of asymmetric decision making on the coordination of a two echelon supply chain facing consumer returns. We first considered demand to be stochastic and then to be stochastic and price-dependent, whereas in both cases returns were a constant fraction of sales. To a large extent, we have been able to widen the findings of Ruiz Benítez (2007) [42] for symmetric optimization to the asymmetric settings, (MC, RI) and (MI, RC). Total profits of the asymmetric cases are (mostly) in between the ones of the decentralized symmetric policies, whereas the players can be either worse or better off. This is intuitive, since the asymmetric settings can be seen as a mix of the decentralized symmetric cases. We have shown that the relationship between the decision variables holds under asymmetric decision making. Declining wholesale prices set by the manufacturer induce higher order quantities of the retailer, and, in the case of stochastic and price-dependent demand, lower retail prices as well. Further, we found buy-back rebates to improve the coordination of asymmetrically optimized supply chains compared to a wholesale price-only contract. In the case of stochastic demand we noticed the severe shift in profits to the side of the manufacturer. However, regardless of whether the supply chain is provided with a wholesale or buy-back contract, better coordination than in the symmetric policies is not reached by optimizing asymmetrically.

Additionally, we studied stochastic and price-dependent demand with a price-dependent return rate. Observations for the decentralized symmetric and asymmetric settings are mainly similar to those under a constant return rate, whereas we found interesting cases where they are different. Most important, the centralized system that considers returns in the optimization process is no longer the coordinating solution. In fact, ignoring returns results in higher total profits. However, the strong influence of the retailer's pricing decision on return rates and, thus, on individual and system-wide profits became clear. Concerning total profits, we found that ignoring returns is the better choice under a price-only contract. Further, when considering returns, buy-back rebates do coordinate the supply chain, whereas ignoring returns has detrimental effects on the performance of the total system. The shift in profits to the manufacturer, however, is much less articulated than under a constant return rate.

For the asymmetric settings we also conducted a game theoretic analysis from which we gained interesting insights on the value of mutual cooperation and information sharing in decentralized organized supply chains. According to the prisoner's dilemma, without cooperation, rationally acting players end up considering returns which are least favorable for both. Further, strategic options have been studied through which the manufacturer can egoistically raise her profits by exploiting available information about the optimization process of the retailer. By doing so, supply chain coordination is also possible in the asymmetric cases, whereas an incentive scheme for the retailer is necessary in order not to lose his goodwill.

For possible extensions to this work, we can think of two directions. Firstly, asymmetric settings can be studied for different pricing schemes, for example price-postponement. Both possibilities, asymmetric optimization on purpose, that is strategic behavior, and the case of unintentional asymmetric behavior can be regarded. Especially, the former might gain interesting results in terms of supply chain coordination under consumer returns. Secondly, as for the case of price-dependent demand, analytical results seem impossible, variations in the demand and return function could further generalize retrieved results. Finally, a return model as presented by Su (2007)

[45] that bases on a stochastic consumer utility for the product should be interesting to study. In this model, consumers find their valuation of the product after purchasing the item, and will only return the product if the valuation is lower than the retail price.

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