

Optimal Policies for Recovering the Value of Consumer Returns

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This paper characterizes the class of Pareto optimal returns policies between a manufacturer and a retailer who receives consumer returns. The manufacturer may take a costly *hidden action* that reduces the expected number of products returned by consumers, which when realized is *hidden information* known only to the retailer. When faced with consumer returns, the retailer must decide whether to send the product back to the manufacturer, who harvests a low salvage value, or to engage in costly refurbishment that permits the returned product to be resold to consumers. We find that the optimal returns policies may be implemented through the payment by the manufacturer of a full refund to the retailer of the wholesale price for any returns, as well as a bonus paid to the retailer that is decreasing in the number of returns to the manufacturer.

Keywords: consumer returns, returns policy, preponement, hidden action, hidden information

1. Introduction

There is a surprising variety in the policies adopted by manufacturers to deal with the products returned to their retailers by consumers. Some manufacturers, such as Johnson & Johnson, have a strict no-returns policy in which the retailer alone deals with the disposition of any consumer returns. In contrast, Dell and HP not only accept consumer returns from retailers, but also provide compensation to the retailers for these returns. Dell refunds the full wholesale price to the retailer for any returns and, for any number of returns below a prespecified cap, pays a bonus that is decreasing in the number of returns. HP also provides a full refund to retailers for returns but, in addition, sets aside a returns allowance, the amount of which is determined by a specified discount from the wholesale price on all sales, in a “holding account”. For each return to the manufacturer, HP deducts a constant fee from the account, the balance of which (either positive or negative) is paid to the retailer on a quarterly basis.

Finally, manufacturers selling their products through an internet retailer such as Amazon.com generally fulfill their sales orders and accept all returns directly from the consumers. When a consumer wants to return his product, the Amazon “Online Returns Center” creates a return request that is forwarded to the manufacturer. In this case, the consumer is refunded directly by

the manufacturer and the retailer acts simply as an intermediary between the manufacturer and the consumer. By providing a model of optimal returns policies, this paper provides a rationale for why, in practice, manufacturers adopt different returns policies.

The use of returns policies by manufacturers to alleviate overstock problems by retailers facing random demand has been extensively studied and is well-understood.¹ It has become increasingly apparent, however, that many manufacturer returns policies are motivated less by inventory management concerns than by the need to deal with the returns of products by consumers to retailers, particularly when the products involved have a short life cycle or are time-sensitive in nature.² In such a setting, timely disposition of the returned products becomes paramount, and providing incentives for retailers to refurbish and resell the product, rather than returning it to the manufacturer who harvests a low salvage value from the return, becomes the overriding concern. This is the topic of our paper.

We consider an environment in which a manufacturer sells a product to a retailer, which is then resold to consumers in a competitive market at a fixed, and known, price. The consumer sales generate a number of returns to the retailer, which is a random variable, and the retailer may engage in costly “refurbishment” to re-sell a returned product to consumers, or it may return the product to the manufacturer. We assume that the manufacturer may take a costly, but hidden, action that reduces the probability of product returns, and that the actual number of returns is hidden information known only to the retailer. We characterize the class of Pareto optimal returns policies in this environment, each of which may be implemented by the use of a full refund of the purchase price to the retailer of any products returned to the manufacturer, coupled with a bonus paid to the retailer that is decreasing in the number of products actually returned.³

¹The most famous article in this regard is that of Pasternack (1985) who, in the context of the single period inventory (“newsvendor”) problem with random demand, demonstrates that an appropriately designed “buy-back” contract can allow the manufacturer in a decentralized supply chain setting to achieve the vertically integrated (“first-best”) outcome. More recently, Arya and Mittendorf (2004) derive an optimal returns policy in a setting in which the retailer has private information about consumers’ valuation of the product, and they demonstrate that returns policies may serve as a useful tool for eliciting the retailer’s private information. In a similar vein, Taylor and Xiao (2009) examine the role of rebates and returns policies in providing the incentive for retailers to obtain private information on consumers’ demand through costly forecasting.

²A good example is the case of consumer electronics in which Lawton (2008) notes that “consumers bring back to the store 11% to 20% of all electronic goods they purchase, with the highest return rates for wireless phones, GPS units, MP3 players, and wireless networking gear”. The reasons noted for the return by the consumers were “no trouble found”(68%), “buyer’s remorse”(27%), and product defect (5%). Fueled by the adoption of liberal returns policies at most major retailers, consumers have responded by returning products for just about any reason.

³Our approach is similar to that employed by Crocker and Slemrod (2007) who characterize a Pareto optimal contract in an earnings management setting with both a hidden action and hidden information. That work, in turn, draws on the seminal work on hidden actions by Holmstrom (1979) as well as the most recent analysis of costly state falsification as a problem of hidden information by Crocker and Morgan (1998). In each of these cases, the characterization of the

The optimal returns policy reflects a trade-off between providing the manufacturer with the incentive to take the costly action that reduces the number of expected returns, on the one hand, and the incentives retailers face to return the product to the manufacturer rather than to refurbish, on the other. At one extreme, a pure sales contract that entailed no payment to the retailer for returns to the manufacturer would provide the retailer with the incentive to engage in the economically efficient level of refurbishment, but such a contract would also provide the manufacturer with no incentive to take the costly action, leading to an excessive number of consumer returns. Alternatively, compensating the retailer for returns incentivizes the manufacturer to invest in reducing the number of returns from consumers, but such a policy also gives the retailer the incentive to send back too many returns to the manufacturer. The optimal returns policy involves a balancing of these competing efficiency effects.

Our paper builds on what has become a substantial literature on the problem of consumer returns and the appropriate design of reverse supply chains. Blackburn et al. (2004) report that a significant portion of the residual value of the returned products is eroded because of delays in the reverse supply chain. They suggest a strategy of *preponement* in which products with a high marginal value of time should have a responsive reverse chain involving an early disposition decision, in terms of testing, sorting and remanufacturing, of returns. Similarly, Guide et al. (2006) show that when the return rate and value decay of returns are both low, centralized evaluation is profitable, but when both are high it is profitable to increase the responsiveness of the reverse chain by placing the evaluation facility as early as possible, even at the retailer's end.⁴ Finally, Ferguson et al. (2006) are concerned with the management of "false failure" returns by consumers, which is consistent with the problem we examine. They report that many companies, especially in the electronics industry, face a low percentage of returns with real functional or cosmetic defects, and that the majority of returns occur for other reasons including installation difficulties, product performance incompatible with consumer preferences, and buyer's remorse. In order to provide retailers with the incentive to deal appropriately with the consumer returns, the authors recommend the implementation of a target rebate contract that pays the retailer a specific amount per unit of false failure returns below a target level.⁵ Our contribution is to derive formally the Pareto

optimal contract is accomplished without any *a priori* restrictions on the functional form of the agreement.

⁴While both of these articles advocate a responsive reverse supply chain, neither considers the monetary incentives that would need to be provided to the retailer to realize this design. In other words, they do not examine optimal returns policies.

⁵Indeed, the contract suggested by Ferguson et al. (2006) can be viewed as a step-function approximation of the

optimal returns policies in a reverse supply chain setting in which early disposition of consumer returns is important.

The paper proceeds as follows. In section 2 we describe the environment and the model, and in section 3 we characterize the (first-best) Pareto optimal returns in an environment without hidden information or actions. In section 4 we characterize the (second-best) Pareto optimal returns policy when manufacturers take a hidden action and the actual number of returns is hidden information possessed by the retailer. Section 5 provides a discussion of the results, and in section 6 we derive closed-form solutions to the optimal returns policy for a specific example. A final section contains concluding remarks.

2. The Model

Our setting consists of a risk-neutral manufacturer selling, through a risk-neutral retailer, a product to the end consumer in a market characterized by consumer returns. For simplicity and without loss of generality we select units to normalize this sale quantity to one. The products are first sold by the manufacturer to the retailer at the per unit wholesale price w which is determined below, then by the retailer to the end consumer in a competitive market at the exogenously determined per unit selling price p .⁶ As commonly seen in practice, once the product is purchased by the consumer, the retailer's returns policy allows the return of the product to the store for a full refund of the selling price, which is typically referred to as "no-question, money-back guarantee" and it is broadly applied by most major retailers in the United States. Once the products are returned, the retailer must decide whether to send them back to the manufacturer, or to expend resources to refurbish and resell the products to the consumers.

The number of returns by consumers to the retailer is assumed to be a random variable, x , distributed on the interval $[\underline{x}, \bar{x}]$ according to the distribution $F(x | a)$ where a is an action taken by the manufacturer that affects the probability distribution of returns. The action a is known only by the manufacturer, and is therefore a *hidden action*. We assume that F is a concave⁷ function of the action a and that higher values of the action a shift the distribution of the number of returns

optimal bonus we derive, which is decreasing in the number of returns to the manufacturer.

⁶Note that we are distinguishing our approach from the overstock literature by assuming that the retailer can always sell all that she wishes in the competitive market at the competitive price of p . As a result, the retailer will never experience an overstock problem in the forward supply chain, which permits us to focus exclusively on the appropriate incentives, through an optimal returns policy, in the reverse supply chain.

⁷As we show below, the assumption of concavity for F will be required to satisfy the second order condition associated with the optimal choice of the action a by the manufacturer.

to the left in the sense of first order stochastic dominance, so that $F_a \geq 0$.⁸

One possibility would be to think of the manufacturer's action a as an investment that increases product quality, thereby reducing the potential for product failure and the associated return of the product to the retailer. However, as noted earlier, the majority of consumer returns in practice appear to occur for reasons not directly related to product failure (Ferguson et al. 2006). These *false failure* returns may reflect either a mismatch of product attributes with consumer needs and tastes, or perhaps a difficulty in product installation and use. To mitigate this problem, some manufacturers have focused on providing the consumer with easy and rapidly accessible information about product functionality. For example, Vizio Inc., a TV maker, has enclosed in its instruction booklet a one-page guide that helps the consumer to quickly set up the basic configuration of the product. Other manufacturers have taken a number of actions to ameliorate the effects of the technical complexity of their product in order to solve issues related to its hookup, use, or operation. For example, Philips in 2000 embarked on a program called "Initial Experience Predictor", the specific objective of which was to predict and thus improve the ease of use of Philips products. Since 2000, Philips has reduced returns by more than 500,000 units and saved more than \$ 100 million dollars per year (Sciarrotta 2003). In a similar vein, disk-drive maker Seagate Technology did away with installation CDs in Fall 2007 when it launched a consumer line of digital storage products called OneTouch in which the installation software came preloaded onto the device. Many companies have also increased service support with web and call center enhancements and launched advertising campaigns that encourage the customer to contact the manufacturer before returning the product to the retail store. For instance, in 2007 Sharp Corp. launched an added help service for customers who purchased high-end Aquos TVs. Still active, the service allows members to obtain free telephone and Internet advice, including how to set up the equipment, with an option for Saturday in-home service (Lawton 2008).

Finally, HP provides several examples of hidden actions that manufacturers may take to reduce the number of returns to the retail store. In one case, HP experienced very high return rates for its all-in-one printer (a printer with fax and copying capabilities) because consumers expected that the machine was capable of color faxing when instead it was not. Consumers' expectations in this regard arose because of a picture on the front of the printer package that showed a color page coming out of the machine. When HP changed the picture on the packaging to a black and white

⁸Note that the support for the random variable x does not change with a , which implies that $F_a(x) = F_a(\bar{x}) = 0$.

page, the return rates of the printer reduced significantly. Another step to reduce the number of returns involved the inclusion with HP printers of a CD that demonstrated all of the basic installation steps required to set up and use the printer. If consumers were still facing issues with the product, they could resort to a toll-free hot line provided by the manufacturer instead of returning the product (Ferguson et al. 2006, p. 378).

We assume that the value of returns, x , when realized, is privately observed by the retailer, and therefore is *hidden information*. Thus, the manufacturer cannot observe the realization, x , of returns to the retail store, while the retailer is not aware of the manufacturer's action, a , affecting the distribution of consumer returns. What the manufacturer actually observes is the number of products, y , that the retailer chooses to send back to the manufacturer. After returning y to the manufacturer, the retailer refurbishes and resells the remaining $(x - y)$ products at the same selling price as the new ones.⁹ Refurbishment is costly, however, and so the retailer incurs the convex refurbishment cost $c(x - y)$. A contract consists of a wholesale price, w , and a refund to the retailer, $r(y)$, the latter contingent on the amount of returns y sent by the retailer back to the manufacturer.¹⁰

The retailer's profit function is given by

$$\Pi_R \equiv (1 - y)p - w + r(y) - c(x - y), \quad (1)$$

where $c(x - y)$ represents the cost incurred by the retailer to resell the refurbished products. We assume that $c(0) = c'(0) = 0$, $c' > 0$, and $c'' > 0$, so that the cost incurred by the retailer is increasing and convex in the amount of products resold.

There are several different interpretations of $c(x - y)$ which are consistent with our model. The first is that it may reflect a formal refurbishment cost as a consequence of resources expended by the retailer to bring the returned product back to an *as new* condition and to resell it at the price p . For example, Sears Holdings Corp. categorizes returns into those that are *serviceable* and *not serviceable*, and the retailer takes responsibility for refurbishing and reselling serviceable items such as TVs and DVD players. In addition to the correction of repairable defects, refurbishment may entail the costly inspection and testing of the consumer returns to determine suitability for resale. An interesting case is provided by Motorola who in the interests of sustainability eliminated the

⁹The majority of returned products have no functional or cosmetic defect and, after visual inspection and repackaging, can be resold as new products (Guide et al. 2006, p. 1202).

¹⁰In the analysis below, we demonstrate that the role of w is to extract as much profit as possible for the manufacturer from the channel, while r determines the efficiency of the channel.

plastic packaging for its cable set-up box. An unintended side effect was that the retailer could no longer determine easily whether the product had been used, and so as a result the returns now required costly inspection and testing prior to resale.

A second interpretation applies in the case of false failure returns having no functional problems. Such returns nonetheless must be restocked, and may also require repackaging, to be resold at the as-new price p . Indeed, it is a common practice in the electronics industry for the manufacturer to provide the retailer with repackaging supplies to expedite resale (Stock et al. 2006). Moreover, consumer support programs adopted by some retailers avoid returns by effectively reselling the product to the original purchaser: “After-sales support by the retailer may also reduce the number of false failure returns from customers who have trouble configuring the new product so that it performs as expected.” (Ferguson et al. 2006, p. 378).¹¹

Finally, one could also think of $c(x - y)$ as the discount from the as-new price of p required to resell the product returned by the consumer. One often sees “opened box” products selling in retail establishments at substantial discounts simply to move the item off the floor. For example, when HP products are returned by consumers to Staples, the retailer places the products back into saleable inventory, if the products are unopened; otherwise it tests, wipes disks and re-sells the products as open box at a discounted rate.¹² In this and similar cases, the convexity of c may reflect simple bottlenecks in the refurbishment, inspecting or restocking technologies. Alternatively, it could be that returned products arrive at the retail store in different quality conditions, after which the retailer sorts the returns with respect to their quality and expends resources on the easiest-to-refurbish (and, hence, less costly) returns first. Similarly, the discount from the new price required to resell “opened box” products may be increasing and convex in the quality of the returned item, with those having only the seal broken in the box requiring only a small discount while those having obviously been used requiring a much larger mark down.

The manufacturer’s profit function is given by

$$\Pi_M \equiv w - r(y) - h(a) + sy, \quad (2)$$

where $h(a)$ represents the cost incurred by the manufacturer in exerting the action a , and s is the exogenously-determined residual value of any product returned to the manufacturer, where

¹¹Interestingly, the Geek Squad support plan of Best Buy that offers (for an additional fee) in-home technical service to those consumers who purchased a product and are not sure of how to install, configure, or use the product, was effective in reducing returns of home-theater systems by 10% and of PCs by 40% (Lawton 2008).

¹²Personal communication with Deborah Brooks, Senior Manager Supplier Relationship for Staples (10/24/2012).

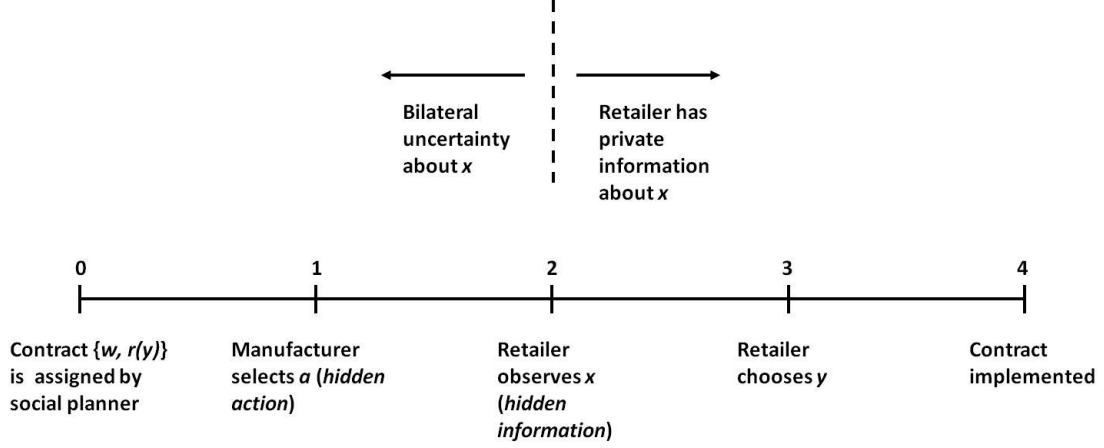


Figure 1: Sequence of events.

$p > s \geq 0$.¹³ We assume that h is strictly increasing and convex, and that $h(0) = h'(0) = 0$.

We now turn to the informational structure of the model, as illustrated by the sequence of events reported in Figure 1. At time 0, the contract $\{w, r(y)\}$ is assigned by a social planner, a process we describe in more detail below. At time 1, the manufacturer takes the hidden action a . At time 2, the retailer privately observes the realization of the number of returns x at her store, so that x constitutes hidden information. Next, at time 3, the retailer selects the number, y , of returned products to send back to the manufacturer, and resells the remaining $(x - y)$ refurbished products at the selling price of p . Finally, at time 4, the contract is implemented and the manufacturer is paid w for the products sold to the retailer, and the retailer receives the refund for returns, $r(y)$, based on her previously selected value of y .

3. First-Best Pareto Optimal Contracts

Before proceeding, we characterize as a benchmark for comparison an optimal contract were the number of consumer returns, x , and the manufacturer's action, a , publicly observable. In this setting, we may think of a contract being composed of a wholesale price, w , a stipulated manufacturer's action, a , and a returns policy, $\{r(x), y(x)\}$ that specifies for each level of consumer returns a payment to the retailer and a number of returns that should be sent back to the manufac-

¹³Our assumption that the manufacturer engages in the salvage activity is without loss of generality, as the results of the Theorem below hold even if the salvage is done by the retailer. The only difference is the interpretation of $r(y)$ in the two scenarios. When the retailer salvages, $r(y)$ represents the payment to the retailer for the y products that are sent to salvage instead of being refurbished and resold.

turer.¹⁴ The contracts we characterize are termed “first-best” because there are no informational constraints (regarding the observability of x and a) facing the manufacturer and retailer, in contrast to the scenario examined in section 4.

Our approach to characterizing a Pareto optimal contract is to employ the notion of the social planner, which is the standard tool of normative analysis in economics.¹⁵ The social planner is assumed to be omniscient, in the sense that it knows every agent’s preferences, as well as omnipotent, having the ability (at time 0 in Figure 1) to dictatorially assign contracts to the agents in the economy.¹⁶ It is also assumed that the social planner is guided by the Pareto criterion, so that the planner would not assign a contract that was Pareto dominated by another. As shown by Samuelson (1954), the solution to the social planner’s problem can be characterized by a straightforward constrained optimization problem, which in our environment may be written as maximizing the expected profit of the manufacturer

$$\max_{a, w, r(x), y(x)} \int_{\underline{x}}^{\bar{x}} \Pi_M(r(x), y(x), a, w) f(x|a) dx$$

subject to an expected profit constraint of the retailer

$$\int_{\underline{x}}^{\bar{x}} \Pi_R(r(x), y(x), a, w) f(x|a) dx \geq \bar{\Pi}_R,$$

where f is the density function associated with the distribution F .¹⁷

A solution to this maximization problem characterizes the Pareto optimal contract for a particular level of retailer expected profit, and the full range of Pareto optimal contracts is obtained

¹⁴Note that, for a given $\{r(x), y(x)\}$ we can construct the returns policy $r(y)$ by inverting $y(x)$ to obtain $x(y)$ and substituting the result into $r(x)$.

¹⁵The fundamental difference between normative (efficiency) and positive (equilibrium) analysis can be easily demonstrated with reference to the “Edgeworth box” exchange economy, which is a staple of undergraduate microeconomics courses. When characterizing the class of Pareto optimal allocations, the exercise performed is to examine the problem faced by a fictitious social planner that has the power to assign to the agents any allocation in the box, but is constrained by the resource constraints of the economy, that is, by the dimensions of the box. The planner is assumed to be omniscient, in the sense that she knows the preferences of the agents, and she is guided by the Pareto criterion. In this setting, the social planner would always assign an allocation on the contract curve (defined as the locus of the tangencies of the agents’ indifference curves) so that there would be no unexploited gains from trade.

In contrast, an equilibrium analysis would proceed by examining the problem faced by a fictitious Walresian auctioneer whose only power is to announce prices, after which the agents announce the trades that they would be willing to make at those prices. The process stops when the auctioneer arrives at prices that when announced result in trades that match, thereby clearing the market. As it turns out, this also results in an allocation that is on the contract curve. This confluence of the efficiency and equilibrium results forms the basis for the fundamental welfare theorems of economics (see Tresch 1981, p. 9).

¹⁶See Tresch (1981), p. 18.

¹⁷We could also write the optimization problem as one of maximizing the expected profit of the retailer subject to an expected profit constraint of the manufacturer. The solution would be equivalent to that characterized by Proposition 1, with the exception that (iii) would then reflect the binding participation constraint of the manufacturer.

by varying $\bar{\Pi}_R$. In the analysis that follows, we will in the interests of simplicity set $\bar{\Pi}_R = 0$, and we will refer to this as a participation constraint.

PROPOSITION 1. *A first-best Pareto optimal contract solves the necessary conditions*

$$\begin{aligned} (i) \quad & c'(x - y(x)) = p - s; \\ (ii) \quad & \int_{\underline{x}}^{\bar{x}} [h'f + (p - s)y(x)f_a] dx = 0; \text{ and} \\ (iii) \quad & \int_{\underline{x}}^{\bar{x}} \Pi_R f dx = 0. \end{aligned} \tag{3}$$

Proof. The characterization of $r(x)$ and $y(x)$ involves functional optimization with an isoperimetric constraint, which is examined in Kamien and Schwartz (1991, section 16) and Takayama (1991, p. 651). The Hamiltonian expression may be written as

$$H = \Pi_M f + \lambda \Pi_R f$$

where λ is an undetermined (Lagrange) multiplier. The first order necessary conditions for a solution are $H_y = H_r = 0$, where

$$\begin{aligned} H_y &= sf + \lambda [-p + c'(x - y)] f; \text{ and} \\ H_r &= -f + \lambda f. \end{aligned} \tag{4}$$

The second condition implies $\lambda = 1$, which implies part (iii) of the proposition and, upon substitution into the first condition, yields part (i).

The optimal value of a is determined by the point-wise maximization

$$\max_a \int_{\underline{x}}^{\bar{x}} \Pi_M f dx + \lambda \int_{\underline{x}}^{\bar{x}} \Pi_R f dx$$

which, since $\lambda = 1$, reduces to

$$\max_a \int_{\underline{x}}^{\bar{x}} (\Pi_M + \Pi_R) f dx$$

so that the choice of manufacturer action maximizes expected total profit. The first order condition for this maximization may be written as

$$\int_{\underline{x}}^{\bar{x}} \left[\left(\frac{d\Pi_M}{da} + \frac{d\Pi_R}{da} \right) f + (\Pi_M + \Pi_R) f_a \right] dx = 0.$$

Simplifying this expression, while noting that $\int_{\underline{x}}^{\bar{x}} f_a dx = 0$ and that $c(x - y)$ is a constant by condition (i), yields condition (ii). \square

The first condition of Proposition 1 characterizes the first-best number of consumer returns that the retailer should forward to the manufacturer, and condition (ii) characterizes the first-best

action that should be taken by the manufacturer to reduce consumer returns, which is also in this case the action that maximizes the total expected profits of the supply chain. The final condition characterizes the optimal payments, w and $r(x)$.¹⁸

4. Second-Best Pareto Optimal Contracts

We now turn to the characterization of Pareto optimal contracts when the social planner faces an environment in which the action taken by the manufacturer, a , is a hidden action the value of which is known only to the manufacturer, and the realization of consumer returns, x , is hidden information known only to the retailer. Since the social planner is constrained by the same informational asymmetries that face the agents in the economy, the contracts assigned by the social planner cannot depend directly on a and x , which are not publicly observable. Accordingly, in this setting the social planner faces constraints that were not present in the first-best analysis above, and so the Pareto optimal contracts characterized in this section are necessarily second-best.¹⁹

We begin by considering the effect on the social planner's problem of the retailer's hidden information regarding the actual number of consumer returns, x . In contrast to the first-best benchmark where the social planner could observe x and assign y accordingly to Proposition 1(i), in this section the number of returns to the manufacturer is necessarily chosen by the retailer who possesses private information on the actual number of consumer returns.

When presented with the returns policy, $r(y)$, the retailer must decide which level of returns maximizes her profit. With reference to Figure 2, the retailer selects the level of returns at which the retailer's indifference curve in (r, y) space, labeled as $\bar{\Pi}_R(x)$, is tangent to the refund function

¹⁸Any w and $r(x)$ that satisfies (iii) will solve the optimization problem. To see this, note that a pointwise optimization to determine w yields the first order condition $\lambda = 1$, just as did the first order condition for r . The reason for this indeterminacy is that, in the first-best setting, the only role played by both r and w is to extract profit from the retailer to ensure (iii), so having both tools is redundant. When we move to the second-best setting, however, the role of r changes substantially, as it will have an incentive effect that influences the retailer's decision regarding the number of consumer returns to send back to the manufacturer.

¹⁹This is, for example, the approach adopted by Crocker and Snow (1986, p. 322) in characterizing Pareto optimal contracts in an insurance market in which customers have hidden information regarding their probabilities of suffering an insurable loss. A similar approach is used in Stiglitz's examination (in Auerbach and Feldstein 1987, p. 996) of optimal tax policies when workers possess hidden information regarding their productivities. This point is also emphasized in Laffont (1986): "When the relevant information for allocating resources is decentralized, it is important to take into account the incentives that economic agents have to reveal their private information. Indeed, it would not be legitimate to criticise an allocation of resources that could be improved upon by a (social) planner having complete information without constraining him to use mechanisms capable of extracting the information that he does not possess" (p. 146). Finally, the seminal analysis of Myerson (1979) that develops the revelation principle justifying the use of the "truth-telling" constraint (5) also uses the approach of the social planner, which is referred to as the "arbitrator": "In this paper, we will consider the problem of an arbitrator trying to select a collective choice for a group of individuals when he does not have complete information about their preferences and endowments." (p. 61).

$r(y)$.²⁰ Since the retailer's indifference curve depends on the actual level of consumer returns, x , which is privately known by the retailer, we know that, given $r(y)$, a retailer having consumer returns of x will select the level of returns $y(x)$. In this fashion, the social planner may use a returns policy to influence the number of returns sent back to the manufacturer.

In this environment with hidden information, the standard solution technique is to apply the Revelation Principle (Myerson, 1979). The approach is as follows. We begin by decomposing the contract $r(y)$ into its constituent parts represented by the allocation $\{r(x), y(x)\}$, where we are recognizing that the refund and returns selected by the retailer depend on that retailers' level of consumer returns, x , which we shall refer to as retailer "type". By the Revelation Principle, there is no loss of generality in restricting our search for an efficient contract to those resulting from the application of a "Direct Revelation Mechanism" in which each retailer announces her type to be \hat{x} , and receives from the social planner the allocation $\{r(\hat{x}), y(\hat{x})\}$ that satisfies the condition

$$\Pi_R(r(x), y(x), w | x) \geq \Pi_R(r(\hat{x}), y(\hat{x}), w | x), \forall x, \hat{x} \in [\underline{x}, \bar{x}]. \quad (5)$$

Equation (5), which is often referred to as the "truth-telling" condition, guarantees that the retailer who is privately informed of the realization of returns, x , would always weakly prefer the contract $\{r(x), y(x), w\}$ to the contract $\{r(x'), y(x'), w\}$ for every $x' \neq x$. In other words, the contract chosen by the social planner provides the incentive for the privately-informed retailer to truthfully reveal her type, so that a retailer of type x receives the allocation $\{r(x), y(x)\}$. Once the efficient allocations are characterized, we can recover the refund policy of interest, $r(y)$, by inverting $y(x)$ and substituting the result into $r(x)$. The truth-telling condition (5) guarantees that, when faced with the returns policy $r(y)$, the type x retailer selects the level of manufacturer returns $y(x)$ (and receives the associated refund $r(x)$) as depicted in Figure 2.

We may write the profit of the x -type retailer who reports \hat{x} and receives the allocation $\{r(\hat{x}), y(\hat{x})\}$ as

$$\Pi_R(r(\hat{x}), y(\hat{x}), w | x) = (p - w) - py(\hat{x}) + r(\hat{x}) - c(x - y(\hat{x}))$$

and condition (5) requires that this be maximized at $\hat{x} = x$. The first order condition for the profit maximizing choice of \hat{x} is given by

$$\frac{d\Pi_R}{d\hat{x}} = y'(\hat{x}) [c'(x - y(\hat{x})) - p] + r'(\hat{x}) = 0 \quad (6)$$

²⁰From (1) we know that the equation of an x -type retailer's indifference curve associated with the profit level $\bar{\Pi}_R$ is given by $r = (y - 1)p + w + c(x - y) + \bar{\Pi}_R$.

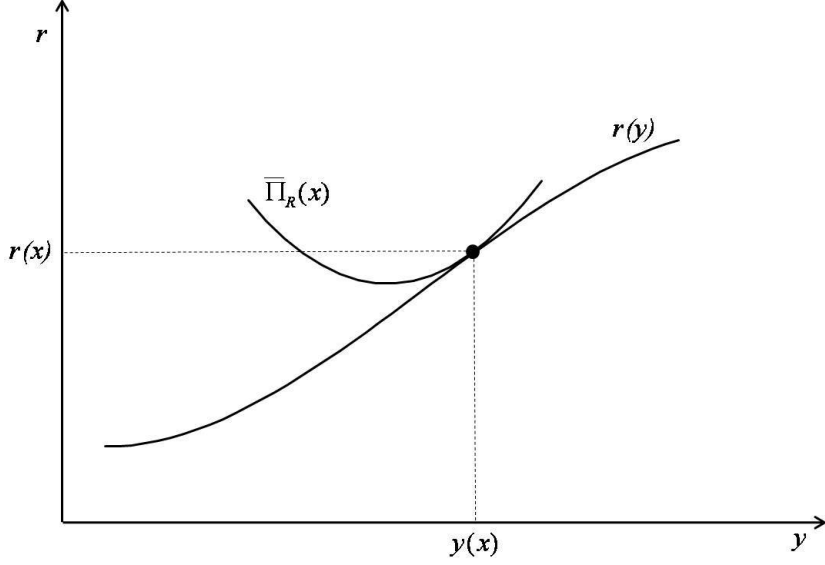


Figure 2: Optimal allocation consisting of a decision, $y(x)$, and a refund, $r(x)$, implemented by the indirect mechanism, $r(y)$.

at $\hat{x} = x$. As long as (6) is satisfied, we know that the retailer truthfully reports her type, so we may write her profit as $\Pi_R(r(x), y(x), w | x) = (p - w) - py(x) + r(x) - c(x - y(x))$. Taking the total derivative of Π_R with respect to x and substituting from (6) yields

$$\frac{d\Pi_R}{dx} = -c'(x - y), \quad (7)$$

which reflects the information rents that must be paid to induce the retailer to report her type truthfully in the direct revelation mechanism. Put differently, any returns policy selected by the social planner must satisfy the incentive compatibility constraint (7) in order to ensure that the truth-telling condition (5) required by the retailer's hidden information is satisfied.

The second order condition associated with (6) may be expressed as

$$\frac{\partial}{\partial x} \left(\frac{\frac{\partial \Pi_R}{\partial y}}{\frac{\partial \Pi_R}{\partial r}} \right) \frac{dy}{dx} = c''(x - y)y'(x) \geq 0, \quad (8)$$

which, given the convexity of $c(x - y)$, implies that $y(x)$ must be monotonically increasing.²¹ As a result, an incentive compatible contract will induce the retailer to send a higher number of products back to the manufacturer as the number of returns she receives by the consumers increases.

²¹Fudenberg and Tirole (1991), p. 258. Note that the monotonicity of $y(x)$ guarantees its invertibility.

A (second-best) Pareto optimal-contract is characterized by a solution to the problem that maximizes the expected profits of the manufacturer

$$\max_{r(x), y(x), a, w} \int_{\underline{x}}^{\bar{x}} \Pi_M(r(x), y(x), a, w) f(x|a) dx, \quad (9)$$

where f is the density function associated with the distribution F , subject to the incentive compatibility constraint (7), a participation constraint for the retailer, and a delegation constraint reflecting the optimal choice of the hidden action a by the manufacturer.²²

Notice that the contract is selected before the retailer observes the realization of x ; hence, the participation constraint has to grant the retailer an *ex ante* profit greater or equal than her reservation profit, which we assume here, without loss of generality, to be zero. Therefore, the participation constraint is given by

$$\int_{\underline{x}}^{\bar{x}} \Pi_R(r(x), y(x), w) f(x|a) dx \geq 0. \quad (10)$$

Because the manufacturer selects the hidden action, a , without observing the realization of x , he will choose an action to maximize his expected profits

$$\max_a \int_{\underline{x}}^{\bar{x}} \Pi_M(r(x), y(x), a, w) f(x|a) dx. \quad (11)$$

The first order condition associated with the maximization problem (11) yields

$$\int_{\underline{x}}^{\bar{x}} [\Pi_M f_a - h'(a) f] dx = 0, \quad (12)$$

which equates the expected marginal cost of taking the action with its expected marginal benefit, the latter consisting of the increase in the manufacturer's profits as the actual returns are reduced through the investment a . Equation (12) is the *delegation constraint*, reflecting the fact that the social planner is forced to delegate the choice of a to the manufacturer because it is a hidden action. The second order condition associated with the maximization problem (11) requires $\int_{\underline{x}}^{\bar{x}} [sy(x) - r(x)] f_{aa} dx - h''(a) \leq 0$. We will return to this issue below.

In order to set up the optimization problem, we follow the approach of Guesnerie and Laffont (1984) and begin by performing a change of variables. Solving the retailer's profit function for the

²²The solution to this constrained optimization problem, which is characterized in the Theorem below, is equivalent to that resulting from a problem that maximizes the expected profit of the retailer subject to a participation constraint of the manufacturer, with the exception that condition (iii) of the Theorem would then reflect the binding participation constraint of the manufacturer.

refund yields $r(x) = \Pi_R(x) - (1 - y(x))p + w + c(x - y(x))$, which upon substitution into the manufacturer's profit yields

$$\Pi_M = (1 - y(x))p - \Pi_R(x) - c(x - y(x)) - h(a) + sy(x). \quad (13)$$

This substitution permits one to solve the maximization problem (9) subject to constraints (7), (10), and (12), by writing the Hamiltonian as

$$H = \Pi_M f + \phi(x) \frac{d\Pi_R}{dx} + \mu [\Pi_M f_a - h'f] + \lambda \Pi_R f, \quad (14)$$

where y is the control variable, $\Pi_R(x)$ is the state variable, μ and λ are the Lagrange multipliers associated with constraints (12) and (10), respectively, and $\phi(x)$ is the costate variable for the equation of motion (7).

THEOREM. *A solution $\{\Pi_R(x), y(x), \phi(x), \mu, w, a, \lambda\}$ to the optimal control problem solves the following necessary conditions:*

- (i) $(-p + s + c')(f + \mu f_a) + \phi c'' = 0;$
- (ii) $\phi(x) = \mu F_a;$
- (iii) $\int_{\underline{x}}^{\bar{x}} \Pi_R(r(x), y(x), w) f(x|a) dx = 0;$
- (iv) $\int_{\underline{x}}^{\bar{x}} (yp + c - sy) f_a dx + \mu \int_{\underline{x}}^{\bar{x}} (\Pi_R + yp + c - sy) f_{aa} dx + h' + \mu h'' = 0;$
- (v) $\int_{\underline{x}}^{\bar{x}} [\Pi_R + yp + c(x - y) - sy] f_a dx + h' = 0;$
- (vi) $\frac{d\Pi_R}{dx} = -c'(x - y);$ and
- (vii) $\lambda = 1.$

Proof. Substituting expression (13) and the equation of motion (7), the Hamiltonian in (14) results in

$$\begin{aligned} H = & [(1 - y(x))p - \Pi_R - c(x - y(x)) - h(a) + sy] f - \phi(x) c'(x - y(x)) \\ & + \mu [(1 - y(x))p - \Pi_R - c(x - y(x)) - h(a) + sy] f_a - h'(a) f + \lambda \Pi_R f. \end{aligned} \quad (15)$$

The Pontryagin necessary conditions for a maximum require that $\frac{d\phi}{dx} = -\frac{\partial H}{\partial \Pi_R}$ and $\frac{\partial H}{\partial y} = 0$, so that we obtain, respectively

$$\frac{d\phi(x)}{dx} = (1 - \lambda)f + \mu f_a, \text{ and} \quad (16)$$

$$[-p + c'(x - y(x)) + s] (f + \mu f_a) + \phi(x) c''(x - y(x)) = 0. \quad (17)$$

The first order condition associated with the optimal choice of w is

$$\int_{\underline{x}}^{\bar{x}} \left[\frac{\partial \Pi_M}{\partial w} (f + \mu f_a) + \lambda \frac{\partial \Pi_R}{\partial w} f \right] dx = 0, \quad (18)$$

which, after simplification and noting that $\int_{\underline{x}}^{\bar{x}} f_a dx = 0$, yields $\lambda = 1$. As a consequence of the retailer's binding participation constraint (10), the Pontryagin condition (16) reduces to $\frac{d\phi(x)}{dx} = \mu f_a$. Integrating this last expression, in conjunction with the transversality condition, $\phi(\underline{x}) = 0$, implies that $\phi(x) = \mu F_a$. Finally, the first order condition associated with the optimal choice of a is given by

$$\int_{\underline{x}}^{\bar{x}} \left[\frac{\partial \Pi_M}{\partial a} f + (\Pi_M + \lambda \Pi_R) f_a + \mu \left[\left(\frac{\partial \Pi_M}{\partial a} - h' \right) f_a + \Pi_M f_{aa} - h'' f \right] \right] dx = 0, \quad (19)$$

which after some computation yields condition (iv).

Finally, applying again $\int_{\underline{x}}^{\bar{x}} f_a dx = 0$, condition (v) is the result of constraint (12), whereas condition (vi) is the equation of motion given by (7). \square

Conditions (i) and (ii) of the Theorem characterize the optimal number of returns sent by the retailer to the manufacturer, $y(x)$; (iii) represents the binding ex-ante participation constraint of the retailer, which characterizes the optimal wholesale price, w ; (iv) represents the optimal choice of action, a ; (v) is the delegation constraint; and (vi) is the equation of motion for the state variable Π_R , which determines the marginal information rent received by the retailer that is required in order to satisfy the incentive ("truth-telling") constraint. Finally, (vii) implies that the objective of problem (14) reduces to the maximization of the sum of expected manufacturer's and retailer's profits. Put differently, every Pareto optimal contract is a solution to the problem of maximizing total expected profits subject to the delegation (12) and the incentive (7) constraints. The Pareto optimal contracts differ only in the distribution of profits between the manufacturer and the retailer.

Now, we may recover the refund function $r(x)$. The equation of motion (vi) governing the path of the retailer profit state variable implies that

$$\Pi_R(x) = - \int_{\bar{x}}^x c'(t - y(t)) dt + \text{constant}. \quad (20)$$

Since the total surplus is divided between the manufacturer and the retailer, one may write

$$(1 - y)p + sy - c - h = \Pi_M(x) + \Pi_R(x),$$

which, upon substitution of (2) and (20) yields

$$r(x) = py(x) + c(x - y(x)) - \int_{\bar{x}}^x c'(t - y(t))dt + \text{constant}, \quad (21)$$

where the term $(w - p)$ has been included in the constant. We have some flexibility in selecting a constant to normalize this expression. In doing so, we note that we may decompose the refund function as

$$r(x) = wy(x) + B(x), \quad (22)$$

where $wy(x)$ is a full refund from the manufacturer to the retailer for returns, and $B(x)$ is a bonus paid to the retailer. We will normalize payoffs so that the bonus associated with the highest possible level of consumer returns, \bar{x} , is zero, so that $r(\bar{x}) = wy(\bar{x})$. This leads to the following result.

PROPOSITION 2. *The optimal refund is given by*

$$r(x) = py(x) + c(x - y(x)) - \int_{\bar{x}}^x c'(t - y(t))dt - (p - w)y(\bar{x}) - c(\bar{x} - y(\bar{x})). \quad (23)$$

Finally, turning to the second order condition for the maximization problem (11) that governs the choice of the action a , integrating by parts and noting that $F_{aa}(\bar{x}) = F_{aa}(\underline{x}) = 0$ yields

$$\int_{\underline{x}}^{\bar{x}} [sy'(x) - r'(x)] F_{aa}dx + h''(a) \geq 0.$$

From (1) we know that the refund is given by $r(x) = py(x) + w - p + c(x - y(x)) + \Pi_R(x)$. Differentiating $r(x)$ in conjunction with the equation of motion (7) yields $r'(x) = y'(x)(p - c'(x - y))$, so that we may write the second order condition as

$$\int_{\underline{x}}^{\bar{x}} [(s - p + c'(x - y))y'(x)] F_{aa}dx + h''(a) \geq 0.$$

Since F is assumed to be a concave function of a and $y' > 0$ by (8), this second order condition holds as long as the term in brackets is negative, so that $c' < p - s$, which implies that the retailer sends too many returns back to the manufacturer.

5. Discussion

For a given level of consumer returns, x , the first-best Pareto optimal number of products that the retailer should send back to the manufacturer is characterized by part (i) of Proposition 1.

From part (i) of the Theorem, we know that the second-best Pareto optimal level of returns in our environment with a hidden action and hidden information is given by

$$c'(x - y(x)) = p - s - \frac{\phi c''}{f + \mu f_a}.$$

By part (ii) of the Theorem, we know that ϕ equals zero at \underline{x} and \bar{x} , resulting in the first-best level of returns, but otherwise the number of returns to the manufacturer is distinctly second-best.

The optimal returns policy reflects a tension between the hidden action and hidden information aspects of the environment. To see this, first consider the extreme case in which the hidden action is irrelevant, so that $F_a = 0$. This implies $\phi = 0$ for every x , so that $y(x)$ is first-best. The optimal returns policy in this setting is given by the following proposition.

PROPOSITION 3. *In a setting with only hidden information and no hidden action, an optimal returns policy is given by*

$$r(y) = sy.$$

Proof. From conditions (i) and (ii) of the Theorem, the function $y(x)$ is defined by the condition $c'(x - y) - p + s = 0$, and an application of the implicit function rule yields $y'(x) = 1$. Total differentiation of (1) with respect to x yields

$$\frac{d\Pi_R(x)}{dx} = -py' + r'(y)y' - c'(x - y)(1 - y'). \quad (24)$$

Substituting this result into condition (vi) of the Theorem, and recalling that $y'(x) = 1$, we obtain

$$-p + r'(y) - c'(x - y) = 0 \quad (25)$$

which implies that $r'(y) = s$. Normalizing the returns policy so that the retailer receives a payment of zero when there are no returns to the manufacturer yields the desired result. \square

Proposition 3 characterizes the optimal returns policy when the manufacturer's action does not influence the number of consumer returns, which makes the retailer internalize the salvage value of any returns to the manufacturer. In this case, the optimal returns policy is to pay the retailer a refund reflecting the salvage value of the returns to the manufacturer, which in the case of a zero salvage value reduces to an *outright sale contract* with no payment to the retailer for returns.²³ The case of Johnson & Johnson mentioned earlier represents an example of products

²³Note that the wholesale price, w , is still determined by the ex ante zero profit condition for the retailer, which is part (iii) of the Theorem.

(such as shampoo) in which the manufacturer has no relevant actions to control the flow of consumer returns to the retail store. As the salvage value of products returned to Johnson & Johnson can be reasonably assumed to be zero, Proposition 3 explains why this manufacturer enforces the returns policy with its retailers to a zero refund policy.²⁴

Consider now the other extreme in which there is a relevant hidden action ($F_a > 0$), but no hidden information. Recall that the truth-telling constraint occasioned by the hidden information resulted in a constraint on the profit path of the retailer represented by the equation of motion (vi) in the Theorem.²⁵ But, if x is publicly observable, there is no such constraint on the profit path of the retailer, so that the costate variable ϕ is uniformly zero and the number of returns to the manufacturer is first-best.

PROPOSITION 4. *In a setting without hidden information and only a hidden action, the manufacturer requires that the retailer send back the first-best number of consumer returns, and a corresponding optimal returns policy is given by*

$$r(y) = py.$$

Proof. Since $\phi(x) = 0$, from part (i) of the Theorem we know that $y(x)$ is first-best. Since the manufacturer's choice of a satisfies (12), upon substitution of Π_M from (12) we obtain

$$\int_{\underline{x}}^{\bar{x}} [[r(y) - sy] f_a + h' f] dx = 0. \quad (26)$$

Setting $r(y) = py$ reduces equation (26) to condition (ii) of Proposition 1, thus yielding a first-best choice of a . \square

To draw out the implications of Proposition 4, let $w = p - k$, where k is a constant to be determined, and let $r(y) = wy$. Substituting into (1) and (2) yields

$$\begin{aligned} \Pi_R &= k - c(x - y); \text{ and} \\ \Pi_M &= p - py + sy - k - h(a). \end{aligned}$$

Recalling that y is first-best in this setting, it follows from Proposition 1 that the number of products refurbished by the retailer, $x - y$, is constant. Thus, if we set $k = c(x - y)$, we effectively

²⁴An interesting exception in this policy is provided for products that are nationally discontinued, in which case Johnson & Johnson takes back the products from the retailer and gives full credit for them. Since the decision to discontinue a product is the choice of the manufacturer, this policy is consistent with our results and causes the manufacturer to internalize the effects of its decision.

²⁵Put differently, (vi) characterizes the information rents that must be paid to the retailer in order that information is truthfully revealed in the direct revelation mechanism.

have a *consignment contract* in which the manufacturer pays the retailer a fixed amount to place the product on the shelf and manage the consumer returns, while the manufacturer receives all of the revenues from sales to consumers as well as bears the full cost of any consumer returns. This is the scenario faced by manufacturers who sell their products through the Amazon web portal. The manufacturer in this setting receives all returns directly from consumers, the retailer has no private information and a consignment contract is optimal.

To summarize, in the case of no hidden action (Proposition 3), a pure sale contract in which the retailer has no recourse for sending returns back to the manufacturer would be optimal (in the case of zero salvage value), whereas in the case of no hidden information (Proposition 4) a pure consignment contract in which the retailer never takes title to the product and forwards all consumer returns to the manufacturer would be optimal.

In a more general setting, the second-best nature of returns, y , reflects an efficiency trade-off between the hidden action and hidden information aspects of the problem, which can be seen most clearly in the case of zero salvage value ($s = 0$). In this case, a pure sale contract with no credit for returns to the manufacturer ($r(y) = 0$) gives the retailer the incentive to send the first-best level of returns back to the manufacturer, but this contract also gives the manufacturer no incentive to take the costly hidden action which leads to an inefficiently high level of consumer returns, x . Alternatively, the payment of a refund to retailers for returns ($r(y) > 0$) incentivizes the manufacturer to take the costly action, a , that reduces the expected number of consumer returns, but this payment also distorts the retailer's return incentives. The (second-best) efficient contract reflects a balancing of these competing efficiency concerns.

The returns policies of Dell and HP are consistent with this general case, as both exhibit the decomposition (22) associated with an optimal policy in the presence of hidden information and a hidden action. Both provide a full refund of the wholesale price to the retailer, as well as a bonus schedule that is decreasing in the number of returns to the manufacturer. In the case of Dell, the decreasing bonus is formally part of the policy, while HP achieves the same result by debiting the returns allowance account for the products returned by the retailer.

6. An Example

A closed-form solution for the manufacturer's optimal returns policy can be derived only for explicit forms of the distribution F and of the costs c and h . In this section we characterize a

Pareto optimal returns policy for a specific example. In particular, let the number of returns x vary in the interval $[0.1, 0.2]$, and let the distribution of x , selling price, and cost functions have the values reported in Table 1.

<i>Symbol</i>	<i>Value</i>
p	0.1
$F(x a)$	$\frac{(x-0.1)(x-0.1+a)}{a+0.1}$
$F_a(x a)$	$-\frac{2(10x-1)(5x-1)}{(10a+1)^2}$
$c(x - y)$	$\frac{(x-y)^2}{2}$
$h(a)$	$\frac{a^3}{3}$

Table 1: Parameter, distribution and cost functions.

Note that the support of x does not vary with a since $F_a(0.1 | a) = F_a(0.2 | a) = 0$. Also, it is straightforward to show that $F_{aa} < 0$, so that the second order condition for the choice of a is satisfied as long as $y(x)$ is greater than the first-best value, which we will demonstrate below. Since $F_a(x | a) \geq 0 \forall x \in [0.1, 0.2]$, it follows that higher values of the manufacturer's investment, a , decreases the probability of products being returned to the retailer.

By applying the Theorem to this specific example we find the optimal values of a , μ and w for different values of s as reported in Table 2. It is apparent from the values of a that it is efficient

s	a	μ	w
0	0.01104440075	0.05579087873	0.09809168503
0.01	0.01072397905	0.05177719273	0.09875799453
0.02	0.01037599011	0.04761738306	0.09932694264
0.03	0.00999378945	0.04328944719	0.09979533069
0.04	0.00956790174	0.03876483044	0.10015985860
0.05	0.00908430261	0.03400257203	0.10041715670
0.06	0.00852032256	0.02894307643	0.10056382360
0.07	0.00783557272	0.02349141426	0.10059653700
0.08	0.00694574301	0.01747357856	0.10051234760

Table 2: Optimal values of a , μ , and w for different values of s .

for the manufacturer to invest less intensively in reducing returns from consumers for higher values of the salvage value. A similar effect of an increasing salvage value on the manufacturer's investment is reflected by the Lagrangian multiplier, μ , which reflects the shadow cost of the delegation constraint associated with the selection of the optimal a by the manufacturer. The decreasing values of μ for higher s correspond to the lower impact that the optimal investment,

a , has on the expected profits of the manufacturer as the salvage value increases. The last column of Table 2 shows the optimal wholesale price. As established by the Theorem, the only role of the wholesale price is to extract all the surplus from the retailer and reduce her expected profits to zero. In particular, notice that for $s \geq 0.04$, the wholesale price becomes higher than the selling price of 0.1. As a consequence, the retailer incurs a loss when selling to the consumer, but she balances this loss with the profit earned from the refund received when sending the products back to the manufacturer.

In Figure 3 we report, for different values of s , the number of returns, $y(x)$, associated with the optimal returns policy. We contrast the optimal $y(x)$ in a decentralized system with those that would result in a (first-best) vertically integrated setting and find that, except for values of x at the boundary of the support, $y(x)$ is greater than first-best. The distortion, Γ , resulting from the hidden action of the manufacturer and the hidden information of the retailer is non-negative for all x . Notice that, as required by the second order condition (8), $y(x)$ is monotonically increasing in x .

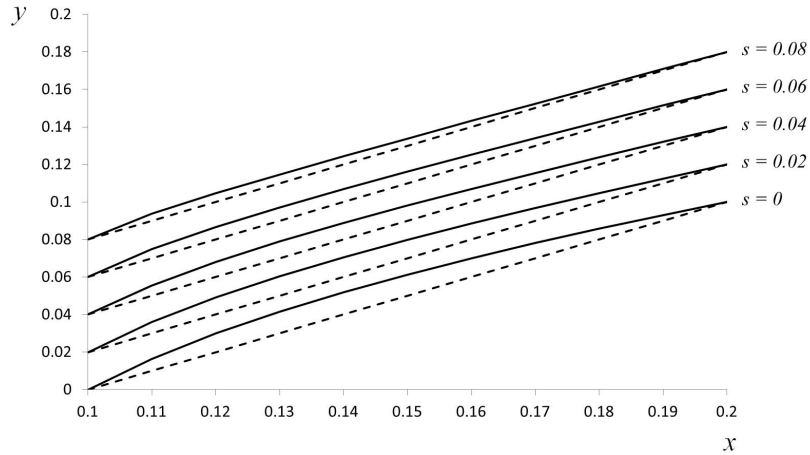


Figure 3: Optimal number of returns to the manufacturer, $y(x)$, in a first-best (dashed line) and a second-best (solid line) contract, for different values of the salvage value, s .

The manufacturer's optimal refund, $r(x)$, for different values of the salvage value, s , is reported in Figure 4. The refund is increasing in x and is higher for higher values of s , so that the manufacturer adopts a more generous pay-back to the retailer for the returns to his plant when he can extract more value from them through the higher salvage value. The monotonicity of $r(x)$ could be mistakenly interpreted as an increasing reward to the retailer for returning products. However, $r(x)$ can be decomposed, as noted by (22), into a refund of the wholesale price, wy , and

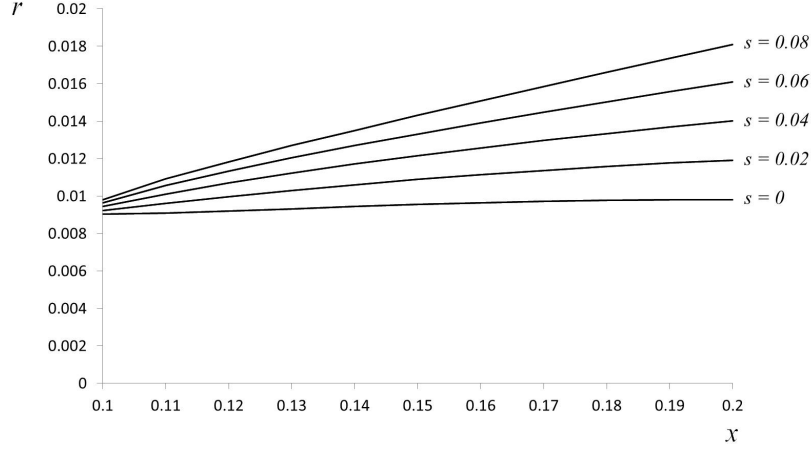


Figure 4: Optimal manufacturer returns policy, $r(x)$, for different values of the salvage value, s .

a bonus meant to induce the retailer to refurbish and then resell the returned products. Figure 5 depicts this bonus for different values of s and shows that it is indeed decreasing in x . Furthermore, for higher values of s , the bonus is lower, which reflects the manufacturer's tendency to give a lower incentive to the retailer for reselling the returned product when the manufacturer can recover value through a higher salvage value.

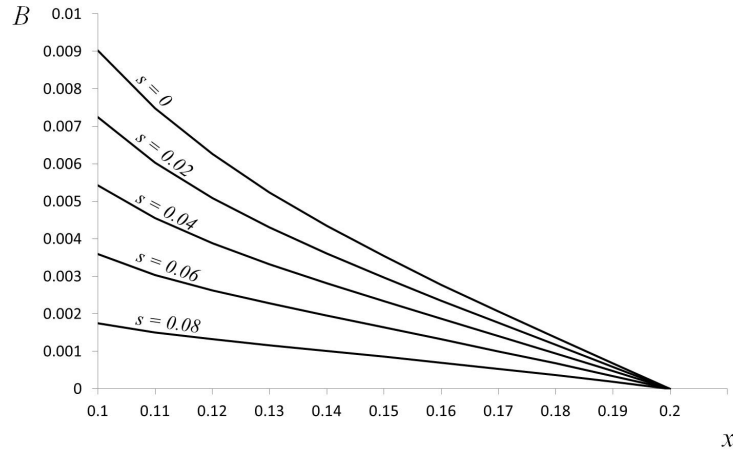


Figure 5: Optimal manufacturer bonus, $B(x)$, for different values of the salvage value, s .

Finally, having reported the efficient allocations, $y(x)$ and $r(x)$, we turn back to the main goal of this article, which is to characterize the optimal returns policy, $r(y)$. To derive the returns policy as a function of y , we first invert the function $y(x)$ ²⁶, and then substitute the resulting expression into the function $r(x)$. In Figure 6 we report the optimal returns policy as a function of y for the

²⁶The monotonicity of $y(x)$ guarantees the existence of the inverse function. See also note 21.

case of $s = 0$.

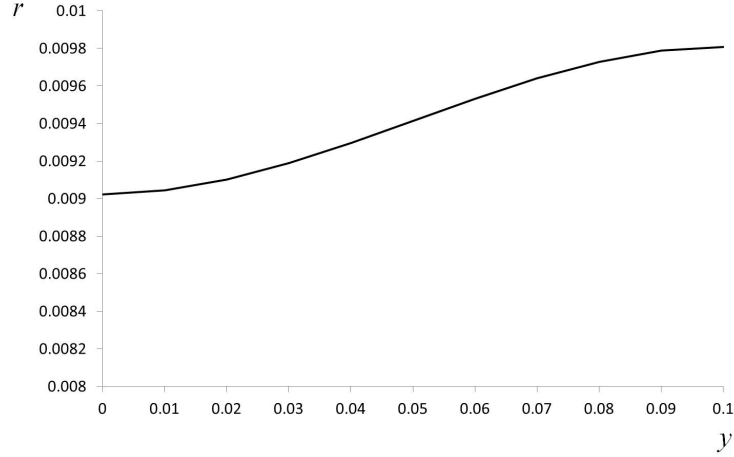


Figure 6: Optimal manufacturer returns policy, $r(y)$, for $s = 0$.

7. Concluding Comments

While previous research has focused on the design of manufacturer's returns policies as a tool to alleviate the overstock problem that occurs in a decentralized supply chain when retailers face an uncertain demand, this paper is concerned with returns of a different nature. As a result of the liberal returns policies generally adopted by retailers, consumers often return products with no quality or performance issues, and the key to value recovery is timely processing and resale by the retailer. An effective returns policy must provide the retailers with the incentive to refurbish and resell the returned products, when appropriate, rather than sending the returns back to the manufacturer who harvests a low salvage value. This paper has characterized such policies, the characteristics of which have been shown to be consistent with many of the returns policies observed in practice.

Before concluding, we would like to address two issues in order to put this work in context: (i) The relationship of our model to the "newsvendor" overstock literature; and (ii) our use of the social planner to characterize Pareto optimal returns policies.

First, in the traditional newsvendor model, which is extensively reviewed by Cachon (2003), retailers may experience an overstock when their inventory of a product exceeds the amount demanded by the market. These excess inventories are then liquidated at a salvage value that is

generally assumed to be the same for either the retailer or the manufacturer.²⁷ Since the primary goal in this literature is to design contracts that provide retailers facing potentially costly overstocks with the incentive to order the optimal amount of product, the disposition of salvaged products is of secondary interest. Indeed, there is no mention in this newsvendor literature about the incentives provided to salvage either more or less, as these unsold products are generally assumed to be “at the end of their lifecycle” (Ferguson et al, 2006, p. 376) and the overstocks are, by default, salvaged in their entirety by either the manufacturer or the retailer.

The case of consumer returns, however, is substantially different since the retailer has the choice of either refurbishing the returns for resale or sending them back to the manufacturer for salvage. In this setting, incentives are relevant because the early disposition of consumer returns at the retail level is a critical determinant of the amount of value harvested in the reverse supply chain. Refurbishment and resale are often preferred to potentially lengthy delays generated by returns to the manufacturer that can erode a substantial portion of the products residual value. The motivation for our approach is provided by Guide et al (2006, p. 1208): “With preponement, additional work is required at the retailer to handle and repackage the returns. Without any capacity adjustment from the existing configuration, the processing rate at the retailer with preponement is evidently lower than in the existing configuration; thus a capacity increase may be warranted. The retailer may need to hire and train workers to perform this task and maintain extra packaging material at the stores. To gain retailer cooperation, the manufacturer may need to offer incentives.” It is precisely these incentives that are the topic of this paper.

Second, our approach has been to characterize the class of Pareto optimal contracts in an environment where the manufacturer may take a hidden action that reduces the expected number of consumer returns which, when realized, is hidden information known only to the retailer. We show that all Pareto optimal returns policies may be implemented through the use of a full refund of the purchase price to retailers for any products returned to the manufacturer, coupled with a bonus paid to the retailer that is decreasing in the number of returns sent back to the manufacturer. Moreover, as the salvage value received by the manufacturer for returned products increases, the bonus paid to the retailer is reduced, resulting in more returns to the manufacturer.

We do not attempt to model the precise bargaining process through which the manufacturer

²⁷“The qualitative insights from the analysis do not depend on whether it is optimal for the retailer or the supplier to salvage left over inventory. (The supply chain contracting literature generally avoids this issue by assuming the net salvage value of a unit is the same at either firm.)” (Cachon 2003, p. 234).

and retailer arrive at a specific returns policy. Indeed, the equilibria of such games, particularly in informationally constrained environments such as the one we consider, are notoriously sensitive to the sequence of moves and the relative bargaining power of the two parties which, in practice, is likely to vary on a case-by-case basis.²⁸ In contrast, given the informational structure of the model, the social planner's problem that we consider is well-defined and the class of Pareto optimal policies characterized represents the best outcomes that could be achieved by the equilibrium of any bargaining process. If the parties were to adopt a bargaining process that resulted in a contract that was not Pareto optimal, then both could be made better off by moving to a process that did. Put differently, while our approach cannot predict the equilibrium returns policy adopted in specific settings, we do know that the equilibrium should be contained in the class of Pareto optimal policies and therefore exhibit the properties that we characterize. Thus, if we observe in practice returns policies that are consistent with the characteristics of Pareto optimal policies, we may conclude with some confidence that the parties have done the best that they could under the circumstances, even if we do not know the precise path by which they reached agreement. In other words, the characteristics associated with the Pareto optimal returns policies may be viewed as "best practices" for managing consumer returns.

Our primary managerial insight is that, in the presence of hidden action and hidden information, the optimal returns policy in a decentralized supply chain cannot achieve the level of efficiency achievable by a centralized supply chain, as neither the action taken by the manufacturer to reduce returns nor the number of returns to the manufacturer by the retailer are first-best. Nonetheless, we find the design of a returns policy is an important determinant of a manufacturer's ability to increase the responsiveness of the reverse supply chain.

References

- Auerbach, A.J., M.S. Feldstein. 1987. *Handbook of public economics, volume II*. North-Holland, Amsterdam.
- Arya, A., B. Mittendorf. 2004. Using returns policies to elicit retailer information. *RAND J. Econom.* **35**(3) 617–630.
- Blackburn, J. D., V. D. R. Guide, Jr., G. C. Souza, L. N. Van Wassenhove. 2004. Reverse supply chains for commercial returns. *California Management Review*, **46**(2), 6–22.
- Cachon, G. 2003. Supply chain coordination with contracts, Ch. 6. A. G. de Kok, S. C. Graves, eds. *Handbooks in Operations Research & Management Science*. Vol. 11. Elsevier B. V., New York, 229–339.

²⁸This ambiguity is also addressed in Cachon (2003): "The contract that is actually adopted at the end of the negotiation process depends on the firms' relative bargaining power.... These choices matter when one wants to predict with precision the particular outcome of a negotiation process...." (p. 234).

- Crocker, K. J., J. Morgan. 1998. Is honesty the best policy? Curtailing insurance fraud through optimal incentive contracts. *Journal of Political Economy*. **106**(2) 355–375.
- Crocker, K. J., J. Slemrod. 2007. The economics of earnings manipulation and managerial compensation. *RAND J. Econom.* **38**(3) 698–713.
- Crocker, K. J., A. Snow. 1986. The Efficiency Effects of Categorical Discrimination in the Insurance Market. *Journal of Political Economy* **94**(2) 321–344.
- Ferguson, M., V. D. R. Guide Jr., G. Souza. 2006. Supply Chain Coordination for false failure returns. *Manufacturing & Service Operations Management* **8**(4), 376–393.
- Fudenberg, D., J. Tirole. 1991. *Game Theory*. MIT Press, Cambridge, MA.
- Guesnerie, R., Laffont, J. J. 1984. A complete solution to a class of principal-agent problems with an application to the control of a self-managed firm. *Journal of Public Economics*. **25**(3), 329–369.
- Guide, V. D. R., G. C. Souza, L. N. Van Wassenhove, J. D. Blackburn. 2006. Time value of commercial product returns. *Management Science*, **52**(8), 1200–1214.
- Holmstrom, B. 1979. Moral Hazard and Observability. *Bell Journal of Economics*, **10**(1), 74–91.
- Kamien, M. I., N. L., Schwartz. 1991. *Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management*. 2nd ed. Elsevier Science Publishing Co., New York.
- Laffont, J.J.. 1989. *The Economics of Uncertainty and Information*. MIT Press, Cambridge.
- Lawton, C. 2008. The War on Returns. *Wall Street Jour.* May 8. Page D1.
- Myerson, R.B. 1979. Incentive compatibility and the bargaining problem. *Econometrica*, **53**(47), 61–73.
- Pasternack, B. 1985. Optimal pricing and returns policies for perishable commodities. *Marketing Science* **4**(2), 166–176.
- Samuelson, P. A. 1954. A Pure Theory of Public Expenditure. *Review of Economics and Statistics*. **36**(4), 387–389.
- Sciarrotta, T. 2003. How Philips reduced returns. *Supply Chain Management Review*. **7**(6), 32–38.
- Stock, J., T. Speh, H. Shear. 2006. Managing product returns for competitive advantage. *Sloan Management Review*, **48**(1), 57–62.
- Takayama, A. 1991. *Mathematical Economics*. Cambridge University, Press, Cambridge, U.K.
- Taylor, T. A., W. Xiao. 2009. Incentives for retailer forecasting: rebates vs. returns. *Management Science*, **55**(10), 1654–1669.
- Tresch, R. W. 1981. *Public Finance: A Normative Theory*. Business Publications, Plano, TX.