THE KOREAN ECONOMIC REVIEW
Volume 22, Number 2, Winter 2006

RETURN POLICY AS A SIGNALING DEVICE IN HORIZONTALLY DIFFERENTIATED PRODUCTS

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We consider a market for horizontally differentiated product in which the information about the location of the product is asymmetric between a monopolist and buyers. The vertical characteristic of the product (i.e., quality) is assumed to be common knowledge. Product differentiation is modeled a la Hotelling. Three types of sellers are assumed: A and C at two endpoints and B at the center. We analyze two signaling games, one with price being a signaling device and another with return policy. We show that return policy is a more efficient signaling device than price. When return policy can be adopted, (a) for most parameter values, there exists a separating equilibrium in which only seller B uses the return policy; (b) A pooling equilibrium in which all sellers use the return policy also exists; (c) Whenever return policy is adopted by some seller, it improves social welfare.

JEL Classification: C72, D82
Keywords: Return policy, Signaling, Horizontal Differentiation

I. INTRODUCTION

Rational consumers will decide to purchase a good only when they expect to get value exceeding the price. The value from the consumption depends on the characteristics of the good and the consumer's preference. In many cases, consumers are required to make the decision before they

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Received for publication: Sep. 19, 2006.   Revision accepted: Nov. 20, 2006.

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collect enough information about the product characteristics. For example, many people make decisions just on the basis of the information from online shopping malls, printed catalogs, or home-shopping TV channels. In these cases, consumers do not have a chance to examine the product physically prior to decision making. If the goods are search good, the characteristics of the good can be discerned when consumers examine the good physically after receipt. If the goods are experience good, consumers can identify the characteristics of the good only after using the good for some period of time. In either case, some consumers will realize that the product is different from what they expected. Then they will regret their purchase decisions. Because of this risk, consumers are reluctant to purchase the good. In order to reduce the consumers' risk, some sellers promise to the buyers that they can return the good if they don't like it.

Sellers offer different return policies. Some sellers promise full refund without any restrictions. And some sellers offer a limited version of return policy. And others do not promise any refund at all. There can be many reasons why the sellers choose different return policies. If the product is horizontally differentiated product, the seller's optimal choice about the return policy may depend on the characteristics of the product. If the seller's product is 'moderate' in the sense that many consumers like it, the seller may want to use the return policy. But if the seller's product is 'extreme' in the sense that only a small number of consumers like it, the seller may not want to use the return policy, for it is too costly. In other words, the return policy can be used as a signaling device for the characteristic of the product.

Since Akerlof (1970) shows that asymmetry of information about the quality of the good can lead to market failure, there is a great deal of literature showing that sellers can signal the quality of the good, so that they solve the adverse selection problem. Various signal devices such as pricing, advertising, warranties and money-back guarantee have been examined.[1] The previous literature focused only on the *vertical* characteristic, i.e., quality, of the good. In the real world, however, there is much uncertainty about the *horizontal* characteristics as well.

[1] Price and advertising in Milgrom and Robert (1986); warranties in Spence (1977), Grossman (1981), Gal-Or (1989) and Lutz (1989); money-back guarantee in Moorthy and Srinivasan (1995).

Regarding the horizontal characteristics, sellers may not have any incentive to lie about them and thus they make efforts to provide precise information about these by using advertising and sales persons' assistance. However, there can be some dimensions of characteristics that cannot be well explained to buyers. In case of online sales, for example, pictures and written explanations cannot fully provide the information about the horizontal characteristics of a good. When the information about some horizontal characteristics is asymmetric, the market may not fully realize the gains from trade. This market failure occurs through buyers' wrong decisions. There are two types of errors in their decisions.

Type I error: Some buyers decide not to buy the good which they should purchase.

Type II error: Some buyers end up buying the good which they should not purchase.

In this asymmetric information situation, if only some types of sellers use the return policy, it can signal the information about product characteristic, so that buyers have more precise information before they have to make a decision. As a result, both Type I and Type II errors can be reduced. In this case, return policy plays the role of 'signaling'. And if all types of sellers use the return policy, then buyers can return the good whenever they dislike it, so Type II error is reduced. And since return is always possible, buyers do not need to hesitate to buy, so Type I error is also reduced. In this case, return policy plays the role of 'insurance'. Thus the market efficiency can be improved as the return policy is introduced.

Return policy in this paper should be distinguished from warranties or money back guarantees in previous literature. The latter requires the buyer to present the evidence of the defect. But under our return policy, buyers are not responsible for proving the defection of the good. Whenever they are not fully satisfied with the good, they can request a refund. In the real world, we can frequently observe buyers returning goods even when there is no defect. This shows that horizontal differentiation is closely related with return policy.

In this paper, we consider a market for a horizontally differentiated product in which the information about the location of the product is asymmetric between a monopolist and potential buyers. The quality – i.e., vertical characteristic – of the good is assumed to be common knowledge. We model the product differentiation by using a Hotelling's linear city model. Three types of sellers are assumed: A and C at two endpoints and B at the center of the unit interval. We analyze two signaling games. In the first game, price is used as a signaling device. For this game we characterize a unique separating equilibrium and a unique pooling equilibrium. In the second game, return policy can be used as a signaling device. For this game we characterize a unique separating equilibrium and two pooling equilibriums. We use perfect Bayesian equilibrium for equilibrium notion.

We show that return policy is a more efficient signaling device than price. For the second signaling game, we will show that (a) for most parameter values, there exists a separating equilibrium in which only seller B uses the return policy; (b) A pooling equilibrium in which all sellers use the return policy also exists; (c) Whenever return policy is adopted by some seller, it improves social welfare.

Che (1996) is one of a few literatures on consumer return policies while there are many works that study the manufacturers' return policies toward retailers such as Pasternack (1985), Marvel and Peck (1994) and Arya and Mittendorf (2004). Like our paper, Che (1996) is also motivated by the understanding that return policies can have different rationale from that of warranties. He focused on the "experience goods" nature of many products. Consumers do not know their preferences for the good at the time of purchase, but come to understand their preferences after purchase. There is no information asymmetry; consumers have full information about the characteristic of the good. It is assumed that consumers are risk averse and the seller is risk neutral. It is shown that the seller can increase the profit by adopting the return policy when consumers are highly risk averse or retail costs are high. In other words, the return policy can play the role of 'insurance' by optimally transferring consumers' risk to the seller. In contrast, our model is based on the understanding that buyers can make *ex post* loss because of incomplete information about the horizontal characteristic of the good, not because of uncertainty about their own preferences. In this situation, the return policy can play the role of 'signaling device'.

Moorthy and Srinivasan (1995) addressed the signaling of return policy. They showed that return policy (they call it 'money-back guarantee') can signal quality when products are vertically differentiated. They compared the signaling performance of (1) price and (2) price with return policy. They showed that under certain conditions price alone cannot signal the quality, and under certain conditions return policy can improve the signaling performance of price. In their model, there is no equilibrium in which both types use the return policy; only a high quality seller uses the return policy. This implies that the only role of the return policy is 'signaling'. In our model, however, there exists a pooling equilibrium as well, in which all sellers use the return policy. This implies that a return policy can play the role of 'insurance' as well. In our model, even seller A can get the benefit from return policy since it protects buyers from the risk of ending up purchasing goods B or C. In contrast, a low quality seller cannot get any benefit from return policy unless it increases the chance that consumers confuse him with high quality sellers.

This paper is organized as follows. In section II, we present the model and analyze the first signaling game. In section III, we define the second signaling game and characterize a separating and two pooling equilibriums. Here we compare the efficiency of price and return policy as a signaling device. In section IV, we compare the welfare levels for different equilibriums. In section V, we provide summary and concluding remarks.

II. THE MODEL

Consider a monopolist, whose location in a linear product space can be one of three positions, $A = 1$, $B = 1/2$ and $C = 1$. In this paper, we consider the situation where the location is not a choice variable; it is already determined from the beginning. The monopolist knows his own location. We assume the constant returns to scale technology, so that the unit cost is given by c. There is a continuum of buyers. The most preferred product characteristics of potential buyers are uniformly distributed along the unit interval $[0,1]$. Each buyer purchases at most one unit of the good. When a buyer consumes the good, he enjoys the utility of $U = 1 - d - p$, where d denotes the distance between the product's location and the buyer's location, and p is the price of the good.

2.1 Full Information

For a benchmark case, suppose that the seller's location is known to buyers. If the seller is type A and he charges the price p, the buyers in $[0, 1-p]$ will purchase the good.[2] The seller's profit function is given by $\pi = (p-c)(1-p)$. The optimal price is $p = \frac{1+c}{2}$, and the buyers in $[0, \frac{1-c}{2}]$ purchase the good. And the maximum profit is $\pi = \frac{(1-c)^2}{4}$. If the seller is type B, the buyers in $[p-\frac{1}{2}, \frac{3}{2}-p]$ purchase the good. The seller's profit function is given by $\pi = 2(p-c)(1-p)$. The optimal price is $p = \frac{1+c}{2}$, and the buyers in $[\frac{c}{2}, 1-\frac{c}{2}]$ purchase the good. And the maximum profit is $\pi = \frac{(1-c)^2}{2}$. By symmetry, type C seller charges the same price and earns the same profit as type A seller.

Proposition 1

When the seller's type is fully known to consumers, the optimal price and profit for each type of seller are given by:

Seller A and C: $p = \frac{1+c}{2}$, $\pi = \frac{(1-c)^2}{4}$

Seller B: $p = \frac{1+c}{2}$, $\pi = \frac{(1-c)^2}{2}$

From Proposition 1, when full product information is disseminated all sellers charge the same price, but seller B earns twice as much as other types of sellers. Since seller B is located at the center and other sellers are located at end points, seller B has an advantage - shorter average distance

[2] Since the maximum utility that the consumer can get is 1, we will restrict the range of price to $0 \le p \le 1$.

between the product and potential buyers. This location advantage is the source of the higher profit.

2.2 Asymmetric Information

Now we consider an asymmetric information case, where buyers do not know the location of the product until they purchase the product. We assume that prior to the purchase, buyers believe that the product is one of three types with equal probability, $1/3$. In this situation, the price may signal the type of the seller. To analyze this possibility, we will define a signaling game $G(c)$. The order of the moves is as follows. First, the Nature determines the type of the product. Each type is chosen with probability $1/3$. The Nature's choice is known to the seller, but not to the buyers. Second, the seller chooses the price level. Third, the buyers decide whether to purchase or not. Once buyers purchase the product, the type of the product is revealed. For this signaling game, we will analyze perfect Bayesian equilibrium (PBE)[3] But we will restrict our analysis to symmetric equilibrium, where sellers A and C behave in the same manner. We think that this can be justified since they are in symmetric situations.

The following theorem shows that there exists a unique separating equilibrium[4].

Proposition 2

The following constitutes a unique separating Perfect Bayesian equilibrium for a signaling game $G(c)$.

Seller's strategy:

A. If he is a type A or C, the price and profit are given by:

a. If $c \le \frac{1}{2}$, then $p = \frac{1}{2}$, and $\pi = \frac{1}{2} - c$

b. If $c > \frac{1}{2}$, then $p = c$, and $\pi = 0$

B. If he is a type B,

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[3] For a good review of perfect Bayesian equilibrium, see Ch. 4 of Gibbons (1992).

[4] To be more precise, this equilibrium is a partially separating equilibrium, since sellers A and C use the same strategies. But for simplicity, we will simply call it separating equilibrium.

a. If $c \leq \frac{1}{2}$, then $p = \frac{1}{2} + c$, and $\pi = \frac{1}{2} - c$

b. If $c > \frac{1}{2}$, then $p = 1$, and $\pi = 0$

Buyers' belief:

A. If $c \leq \frac{1}{2}$, buyers believe that the good is a type B if $p \geq \frac{1}{2} + c$ while the good is A or C with equal probability if $p < \frac{1}{2} + c$.

B. If $c > \frac{1}{2}$, buyers believe that the good is a type B if $p \geq 1$ while the good is A or C with equal probability if $p < 1$.

Buyers' strategy:

A. If $c \leq \frac{1}{2}$,

a. If $p \geq \frac{1}{2} + c$, the buyers in $[p - \frac{1}{2}, \frac{3}{2} - p]$ purchase.

b. If $\frac{1}{2} < p < \frac{1}{2} + c$, no buyers purchase.

c. If $p \leq \frac{1}{2}$, all buyers purchase.

B. If $c > \frac{1}{2}$,

a. If $p \geq 1$, the buyers in $[p - \frac{1}{2}, \frac{3}{2} - p]$ purchase.

b. If $\frac{1}{2} < p < 1$, no buyers purchase.

c. If $p \leq \frac{1}{2}$, all buyers purchase.

Proof. See Appendix.

We can find that seller B charges higher than seller A, but makes the same profit. The seller may want to lower price to raise profit. But if he does so, seller A has an incentive to mimic seller B, so that separation cannot occur. When the price is used as a signal, in any separating equilibrium, profits should be the same for all types.

In addition to the separating equilibrium, there is a pooling equilibrium too. The following theorem shows that there exists a unique pooling equilibrium.

Proposition 3

The following constitutes a unique pooling Perfect Bayesian equilibrium for a signaling game $G(c)$.

Seller's strategy: All sellers charge the same price and make the same profits.

A. If $c \le \frac{1}{3}$, $p = \frac{1}{2}$, and $\pi = \frac{1}{2} - c$

B. If $\frac{1}{3} < c \le \frac{2}{3}$, $p = \frac{1}{3} + \frac{c}{2}$, and $\pi = \frac{(2-3c)^2}{6}$

C. If $c > \frac{2}{3}$, $p = c$, and $\pi = 0$

Proof. Since the proof is very similar to that of Proposition 6, it is omitted.

2.3 The Signaling Game

When the type of the good is not known to buyers, buyers face high risk, so they are reluctant to purchase the good. In response to this, sellers may want to lower the price allowing profit to become smaller. However sellers can respond in a different way. They can reduce the risk for buyers by using the return policy. From now on, we assume that sellers can use the return policy. Under this policy, buyers can return the good whenever they are not satisfied with the characteristics of the good. Thus buyers do not need to prove that the product has a defect. The return policy differs from warranty. Under the warranty, buyers can get a refund only when they can prove that the good is defective. In the real world, the refund rates can be very different. But for simplicity, we assume that if the seller decides to use the return policy, the seller should refund the full price upon the buyer's request. The return process incurs the cost of r to the seller. And to the buyer, there is no return cost. We also assume that the seller's return cost is smaller than the production cost: $0 \le r \le c$.[5] Now we can define a signaling game $G(c,r)$. The order of the moves is as follows. First, the Nature determines the type of the product. Each type is chosen with probability $1/3$. The Nature's choice is known to the seller, but not to the buyers. Second, the seller chooses the price level and whether he will use the return policy. Third, the buyers decide whether to purchase or not. Once buyers purchase the product, the type of the product is revealed. If unsatisfied, buyers can return the product.

III. EQUILIBRIUM

In this section, we will analyze perfect Bayesian equilibrium (PBE) for our signaling game. But we will restrict our analysis to symmetric equilibrium, where sellers A and C behave in the same manner. We think that this can be justified since they are in the symmetric situations.

First, we characterize a separating equilibrium where only seller B uses the return policy.

Proposition 4

The following constitutes a separating perfect Bayesian equilibrium for a signaling game $G(c,r)$ if the parameter values satisfy one of these conditions.

(1) $c \le \frac{2\sqrt{2}-1}{4} = 0.4571$ or $c > \frac{3}{4}$

(2) $0.4571 < c \le \frac{1}{2}$ and $r \ge c^2 + \frac{c}{2} - \frac{7}{16}$

(3) $\frac{1}{2} < c \le \frac{3}{4}$ and $r \ge (\frac{3}{4} - c)^2$

Seller's strategy:

A. If he is a type A or C, he does not use the return policy <NR>. And the price and profit are given by:

a. If $c \le \frac{1}{2}$, then $p = \frac{1}{2}$, and $\pi = \frac{1}{2} - c$

[5] If $r > c$, the seller would be better off let the buyer keep the product for free.

b. If $c > \frac{1}{2}$, then $p = c$, and $\pi = 0$

B. If he is a type B, he uses the return policy <R>. And the seller charges $p = \frac{1+c}{2}$ and the profit is $\pi = \frac{(1-c)^2}{2}$.

Buyers' belief:

A. If the seller does not use the return policy, buyers believe that the good is a type A or C with equal probability.

B. If the seller uses the return policy, buyers believe that the good is a type B.

Buyers' strategy:

A. If the seller does not use the return policy,

a. If $p \le \frac{1}{2}$, all buyers purchase.

b. If $p > \frac{1}{2}$, no buyers purchase.

B. If the seller uses the return policy,

a. If $p \le \frac{1}{2}$, all buyers purchase.

b. If $p > \frac{1}{2}$, the buyers in $[p - \frac{1}{2}, \frac{3}{2} - p]$ purchase.

Proof. See Appendix.

Notice that even though seller B uses the return policy, return does not actually occur in this equilibrium since the type of the good is fully revealed if seller's type is B. And we can also notice that seller B can make the same profit as in the full information case. Seller A can make larger profit than in the full information case if the production cost is sufficiently small, i.e., $c < \sqrt{2} - 1 = 0.4142$[6].

In Proposition 2, we showed that price alone can signal the type of the seller. But we can show that return policy is more efficient singling device than price. The following theorem shows that social welfare is

[6] See Table 1.

larger when return policy is used as a signaling device. For expositional convenience, let's denote the separating equilibrium with return policy by SE and the separating equilibrium without return policy by SE^0.

[Table 1] Comparison of Profits

c	Full Info	SE	Full & SE	PE1	PE2	
	A	A	B	A = B	A-	B-
0.0000	0.2500	0.5000	0.5000	N/A	N/A	N/A
0.0500	0.2256	0.4500	0.4513	N/A	N/A	N/A
0.1000	0.2025	0.4000	0.4050	N/A	N/A	N/A
0.1500	0.1806	0.3500	0.3613	N/A	N/A	N/A
0.1835	0.1667	0.3165	0.3333	N/A	N/A	N/A
0.2000	0.1600	0.3000	0.3200	N/A	N/A	N/A
0.2500	0.1406	0.2500	0.2813	N/A	N/A	N/A
0.3000	0.1225	0.2000	0.2450	N/A	N/A	N/A
0.3333	0.1111	0.1667	0.2222	0.1667	N/A	N/A
0.3500	0.1056	0.1500	0.2113	0.1504	N/A	N/A
0.4000	0.0900	0.1000	0.1800	0.1067	N/A	N/A
0.4142	0.0858	0.0858	0.1716	0.0956	0.0858	0.1716
0.4200	0.0841	0.0800	0.1682	0.0913	0.0800	0.1670
0.4300	0.0812	0.0700	0.1625	0.0840	0.0700	0.1591
0.4367	0.0793	0.0633	0.1587	0.0793	0.0633	0.1537
0.4500	0.0756	0.0500	0.1513	0.0704	0.0500	0.1432
0.4571	0.0737	0.0429	0.1474	0.0659	0.0429	0.1376
0.4867	0.0659	0.0133	0.1317	0.0486	0.0133	0.1141
0.5000	0.0625	0.0000	0.1250	0.0417	0.0000	0.1036
0.5500	0.0506	0.0000	0.1013	0.0204	0.0000	0.0829
0.6000	0.0400	0.0000	0.0800	0.0067	0.0000	0.0648
0.6500	0.0306	0.0000	0.0613	0.0004	0.0000	0.0490
0.6667	0.0278	0.0000	0.0556	0.0000	0.0000	0.0443
0.7000	0.0225	0.0000	0.0450	0.0000	0.0000	0.0357
0.7500	0.0156	0.0000	0.0313	0.0000	0.0000	0.0245
0.8000	0.0100	0.0000	0.0200	0.0000	0.0000	0.0155
0.8500	0.0056	0.0000	0.0113	0.0000	0.0000	0.0087
0.9000	0.0025	0.0000	0.0050	0.0000	0.0000	0.0038
0.9500	0.0006	0.0000	0.0013	0.0000	0.0000	0.0009
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Theorem 1

Return policy is a more efficient signaling device than price.

A. If the good is type B, profit and consumer surplus are larger in SE.
B. If the good is type A, profit and consumer surplus are the same in SE^0 and SE.

Proof. This can be easily verified from Table 2.

While the cost of using the return policy is higher for seller A, there is no cost of following other seller's price. Thus in the case of price signaling all types of sellers should make the same profit. Because of this, seller B's equilibrium profit should be lowered to that of seller A. In the case of return policy signaling, however, there is no constraint like this. Therefore, seller B can make the maximum profit that can be earned in the case of full information. For this reason, return policy is more efficient.

Now we can show that the equilibrium presented in Proposition 4 is a unique separating equilibrium.

Proposition 5

There is no separating equilibrium where types A and C use the return policy and type B does not. In other words, the following cannot be a Perfect Bayesian equilibrium for a signaling game $G(c,r)$.

Seller's strategy:

A. If he is a type A or C, he uses the return policy. And the seller charges $p=\frac{1+c+r}{2}$, and the profit is $\pi=\frac{(1-c-r)^2}{4}$.

B. If he is a type B, he does not use the return policy. And the seller charges $p=\frac{1+c}{2}$, and the profit is $\pi=\frac{(1-c)^2}{2}$.

Proof. See Appendix.

Now we will characterize a pooling equilibrium where no seller uses the return policy.

Proposition 6

The following constitutes a pooling Perfect Bayesian equilibrium for a signaling game $G(c,r)$ for the following parameter values.

(1) $\frac{1}{3} < c \le \frac{1}{2}$, and
$$\frac{1}{2}(4c-1) - \frac{(3c-1)\sqrt{6}}{3} \le r \le \frac{1}{2}(4c-1) + \frac{(3c-1)\sqrt{6}}{3}$$

(2) $\frac{1}{2} < c \le \frac{2}{3}$, and $\frac{\sqrt{6}-1}{c} - (\frac{2\sqrt{6}}{3} - 1) \le r \le \frac{1}{2}(4c-1) + \frac{(3c-1)\sqrt{6}}{3}$

(3) $\frac{2}{3} < c \le 1$, and $\frac{1}{3} \le r \le \frac{1}{2}(4c-1) + \frac{\sqrt{144c-81}}{6}$

Seller's strategy: Regardless of the type, sellers do not use the return policy. And the seller's equilibrium price and profit are given by:

A. If $c \le \frac{1}{3}$, $p = \frac{1}{2}$, and $\pi = \frac{1}{2} - c$

B. If $\frac{1}{3} < c \le \frac{2}{3}$, $p = \frac{1}{3} + \frac{c}{2}$, and $\pi = \frac{(2-3c)^2}{6}$

C. If $c > \frac{2}{3}$, $p = c$, and $\pi = 0$

Buyers' belief:

A. If the seller does not use the return policy, buyers believe that the good is a type A or C or B with equal probability.

B. If the seller uses the return policy, buyers believe that the good is a type A or C with equal probability.

Buyers' strategy:

A. If the seller does not use the return policy,

a. If $p \le \frac{1}{2}$, all buyers purchase.

b. If $\frac{1}{2} < p < \frac{2}{3}$, the buyers in $[3p - \frac{3}{2}, \frac{5}{2} - 3p]$ purchase.

c. If $p \geq \frac{2}{3}$, no buyers purchase.

B. If the seller uses the return policy,

a. If $p \leq \frac{1}{2}$, all buyers purchase.

b. If $p > \frac{1}{2}$, the buyers in $[0, 1-p]$ and $[p, 1]$ purchase.

Proof. See Appendix.

In this equilibrium, the buyers have different beliefs on-the-equilibrium and off-the-equilibrium path. There exists another pooling equilibrium in which off-the-equilibrium path belief is the same as on-the-equilibrium path belief. Since this type of pooling equilibrium is not much different from the current one except the range of parameter values, we will not describe it in more detail.

Now we analyze a pooling equilibrium where every type of sellers uses the return policy.

[Table 2] Comparison of Price, Output and Welfare (1)

<table>
<tr><th></th><th></th><th>Full Info.</th><th>SE^0</th><th>SE</th><th>PE1</th><th>PE2</th></tr>
<tr><td rowspan="2">p</td><td>A</td><td rowspan="2">$\frac{1+c}{2}$</td><td colspan="2">$\frac{1}{2}$ if $c \leq \frac{1}{2}$
c if $c > \frac{1}{2}$</td><td rowspan="2">$\frac{1}{3}+\frac{c}{2}$ if $\frac{1}{3} < c \leq \frac{2}{3}$
c if $c > \frac{2}{3}$</td><td rowspan="2">$\frac{1+c-r}{2}$</td></tr>
<tr><td>B</td><td>$\frac{1}{2}+c$
1</td><td>$\frac{1+c}{2}$</td></tr>
<tr><td rowspan="2">q[7]</td><td>A</td><td>$[0, \frac{1-c}{2}]$</td><td colspan="2">$[0,1]$
ϕ</td><td rowspan="2">$[\frac{(3c-1)}{2}, \frac{3(1-c)}{2}]$
ϕ</td><td>$[0, \frac{1-c+r}{2}]$</td></tr>
<tr><td>B</td><td>$[\frac{c}{2}, 1-\frac{c}{2}]$</td><td>$[c, 1-c]$
ϕ</td><td>$[\frac{c}{2}, 1-\frac{c}{2}]$</td><td>$[\frac{c-r}{2}, 1-\frac{c-r}{2}]$</td></tr>
</table>

7 q denotes the set of potential buyers who finally purchase.

[Table 2] Comparison of Price, Output and Welfare (2)

		Full Info.	SE^0	SE	PE1	PE2
π	A	$\frac{(1-c)^2}{4}$	$\frac{1}{2}-c$ 0	$\frac{1}{2}-c$ 0	$\frac{(2-3c)^2}{6}$ 0	$\frac{(1-c)^2-2r(1+c)+r^2}{4}$
	B	$\frac{(1-c)^2}{2}$		$\frac{(1-c)^2}{2}$		$\frac{(1-c)^2-rc}{2}$
CS	A	$\frac{(1-c)^2}{8}$ [8]	0		$\frac{1}{3}-\frac{3}{2}c+\frac{3}{2}c^2 \le 0$ [9] 0	$\frac{1}{8}(1-c+r)^2$ [10]
	B	$\frac{(1-c)^2}{4}$ [11]	$\frac{(1-2c)^2}{4}$ [12] 0	$\frac{(1-c)^2}{4}$	$\frac{1}{3}-\frac{c}{2}-\frac{3}{4}c^2$ [13] 0	$\frac{1}{4}(1+c^2-2cr+r^2)$ [14]
SW	A	$\frac{3(1-c)^2}{8}$	$\frac{1}{2}-c$ 0		$1-\frac{7}{2}c+3c^2$ 0	$\frac{1}{8}(3-6c+3c^2-2r-6rc+3r^2)$
	B	$\frac{3(1-c)^2}{4}$	$\frac{(3-2c)(1-2c)}{4}$ 0	$\frac{3(1-c)^2}{4}$	$1-\frac{5}{2}c+\frac{3}{4}c^2$ 0	$\frac{1}{4}(3+3c^2-4cr+r^2-4c)$

Proposition 7

The following constitutes a pooling perfect Bayesian equilibrium for a signaling game $G(c,r)$ for the following range of parameter values.

(1) $\sqrt{2}-1=0.4142<c\le\frac{1}{2}$ and $r\le c-(\sqrt{2}-1)$

(2) $c>\frac{1}{2}$ and $r\le(1+c)-2\sqrt{c}$

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[8] $CS=\int_0^{\frac{1-c}{2}}(-t+\frac{1-c}{2})dt=\frac{(1-c)^2}{8}$

[9] $CS=\int_{(3c-1)/2}^{3(1-c)/2}(\frac{2}{3}-t-\frac{c}{2})dt=\frac{1}{3}-\frac{3}{2}c+\frac{3}{2}c^2$

[10] $CS=2\int_{(c-r)/2}^{1/2}(t-\frac{c-r}{2})dt=\frac{1}{4}(1+c^2-2cr+r^2)$

[11] $CS=2\int_{c/2}^{1/2}(t-\frac{c}{2})dt=\frac{(1-c)^2}{4}$

[12] $CS=2\int_{c}^{1/2}(t-c)dt=\frac{(1-2c)^2}{4}$

[13] $CS=2\int_{(3c-1)/2}^{1/2}(t+\frac{1}{6}-\frac{c}{2})dt=\frac{1}{3}-\frac{c}{2}-\frac{3}{4}c^2$

[14] $CS=\int_0^{(1-c+r)/2}(\frac{1-c+r}{2}-t)dt=\frac{1}{8}(1-c+r)^2$

Seller's strategy: Regardless of the type, the seller uses the return policy. And the seller charges $p = \frac{1+c-r}{2}$. And the profit is given by

A. If the type is A or C, $\pi = \frac{1}{4}\{(1-c)^2 - 2r(1+c) + r^2\}$.

B. If the type is B, $\pi = \frac{1}{2}\{(1-c)^2 - rc\}$.

Buyers' belief[15]:

A. If the seller uses the return policy, buyers believe that the good is a type A or C or B with equal probability.

B. If the seller does not use the return policy, buyers believe that the good is a type A or C with equal probability.

Buyers' strategy:

A. If the seller uses the return policy, for any price $p \le 1$, all buyers purchase. After purchase,

  a. If it is type A, the buyers in $[1-p, 1]$ return.

  b. If it is type B, the buyers in $[0, p-\frac{1}{2}]$ and $[\frac{3}{2}-p, 1]$ return.

B. If the seller does not use the return policy,

  a. If $p \le \frac{1}{2}$, all buyers purchase.

  b. If $p > \frac{1}{2}$, no buyers purchase.

Proof. See Appendix.

We have found a separating equilibrium (SE) and two pooling equilibriums (PE1, PE2); in PE1, nobody uses the return policy, but in PE2, everybody does. Comparing the ranges of parameter values for different equilibriums, we can derive the following relationships.

Theorem 2

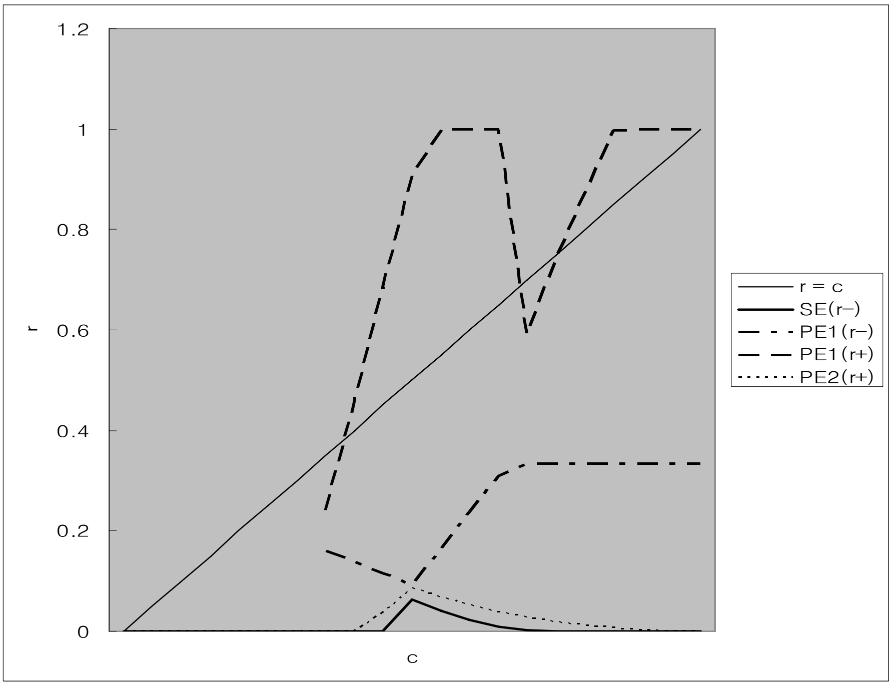
The space of parameter values (c, r) can be divided into four areas.

[15] There exists another pooling equilibrium in which off-the-equilibrium path belief is the same as on-the-equilibrium path belief.

A. Area 1: PE1 and SE exist together.
B. Area 2: SE is a unique equilibrium.
C. Area 3: SE and PE2 exist together.
D. Area 4: PE2 is a unique equilibrium.

Figure 1 illustrates the division of parameter space. We can see that Area 1 and 2 are much larger than Area 3 and 4. For comparison, optimal prices and profits are summarized in Table 2.

[Figure 1] Division of Parameter Space[16]



IV. WELFARE ANALYSIS

As stated in Theorem 1, there can be multiple equilibriums. In this section, we compare the welfare levels for different equilibriums.

[16] Area 1: The area above PE1(r-) and below PE1(r+) and r=c line.
Area 2: The area above PE2(r+) and below PE1(r-) and r=c line.
Area 3: The area above SE(r-) and below PE2(r+)
Area 4: The area below SE(r-)

Theorem 3

When the parameters (c, r) are in Area 1, social welfare is larger in SE than in PE1. Therefore, SE is socially superior to PE1.

A. If the good is type B,

a. Profit is always larger in SE.

b. Consumer surplus and social welfare are larger in SE.

B. If the good is type A or C,

a. Profit is always larger in PE1.

b. Consumer surplus and social welfare are larger in SE.

More detail about the welfare comparison is summarized in Table 3. In SE, seller B can signal the type of good by using the return policy. Since the uncertainty is completely eliminated, seller B can charge a higher price and make a larger profit. In PE1, seller A gets some benefit because consumers cannot distinguish him from seller B. Many buyers lose because of this uncertainty, and aggregate consumer surplus is negative. But in SE, seller A should lower the price since buyers no longer confuse him with seller B, and total consumer surplus becomes zero.

Theorem 4

When the parameters (c, r) are in Area 3, social welfare is larger in PE2 than in SE. Therefore, PE2 is socially superior to SE.

A. If the good is type B,

a. Profit is always larger in SE.

b. Consumer surplus and social welfare are larger in PE2.

B. If the good is type A or C,

a. Profit is larger or at least the same in PE2.

b. Consumer surplus and social welfare are larger in PE2.

More detail about the welfare comparison is summarized in Table 3. In PE2, seller B should lower the price since now the type of the good is not revealed through the return policy. Although the sales increase as the price falls, the profit decreases. But the consumers will be better off because more consumers are served with lower price. In PE2, seller A will raise the price since buyers face no risk due to full refund. Buyers are better off even with higher price because the risk is now completely eliminated.

Theorem 3 and Theorem 4 imply that whenever return policy is adopted by some seller, it will improve social welfare even though it may hurt other sellers.

[Table 3] Welfare Comparison

A	SE – PE1	PE2 – SE
π	$-\frac{1}{6}+c-\frac{3}{2}c^2<0$ if $c<\frac{1}{2}$ $-\frac{(2-3c)^2}{6}<0$ if $\frac{1}{2}<c\le\frac{2}{3}$ 0 if $c>\frac{2}{3}$	$\frac{1}{4}(-1+2c+c^2-2r-2rc+r^2)\ge 0$ if $c\le\frac{1}{2}$ $\frac{1}{4}\{(1-c)^2-2r(1+c)+r^2\}\ge 0$ if $c>\frac{1}{2}$
CS	$-\frac{1}{3}+\frac{3}{2}c-\frac{3}{2}c^2\ge 0$ if $\frac{1}{3}<c\le\frac{2}{3}$ 0 if $c>\frac{2}{3}$	$\frac{1}{8}(1-c+r)^2>0$
SW	$-\frac{1}{2}+\frac{5}{2}c-3c^2>0$ if $c<\frac{1}{2}$ $-1+\frac{7}{2}c-3c^2>0$ if $\frac{1}{2}<c\le\frac{2}{3}$ 0 if $c>\frac{2}{3}$	$\frac{1}{8}(-1+2c+3c^2-2r-6rc+3r^2)>0$ $\frac{1}{8}(3-6c+3c^2-2r-6rc+3r^2)>0$
B	SE - PE1	PE2 – SE
π	$-\frac{1}{6}+c-c^2>0$ if $\frac{1}{3}<c\le\frac{2}{3}$ $\frac{1}{2}(1-c)^2>0$ if $c>\frac{2}{3}$	$-\frac{rc}{2}<0$
CS	$c^2-\frac{1}{12}>0$ $\frac{(1-c)^2}{4}>0$	$\frac{1}{4}(-2cr+r^2+2c)>0$
SW	$c-\frac{1}{4}>0$ $\frac{3(1-c)^2}{4}>0$	$\frac{1}{4}(-4cr+r^2+2c)>0$

V. SUMMARY AND CONCLUDING REMARKS

We have found that price or return policy can be used as a signaling device when the horizontal characteristic of the good is private information. However, we have shown that a return policy is a more efficient signaling device in the sense that social welfare is larger with return policy signaling.

For the return policy signaling game, we have characterized a unique separating equilibrium and two pooling equilibriums. In the separating equilibrium, only the seller of ‘moderate’ product uses the return policy. Sellers of ‘extreme’ products do not offer return policy. Since using the return policy signals a good’s exact type, buyers have complete information prior to their purchase decisions. So the seller of ‘moderate’ products does not need to give the refund actually, even though he promised to do so.

There are two pooling equilibrium, one (PE1) with none using the return policy and another (PE2) all. Depending on the parameter values, the signaling game has a unique equilibrium or two equilibriums. When both SE and PE1 are equilibriums, we found that SE is socially superior. And when both SE and PE2 are equilibriums, we found that PE2 is socially superior. It follows that whenever return policy is adopted by some seller, it will improve social welfare even though it may hurt other sellers.

The main contribution of this paper is to show that a return policy can signal the horizontal characteristics of the product. As the proportion of online sales increases, the asymmetry of information about horizontal characteristics becomes more important. In this paper, we have analyzed a very simple case in which there are only three types of products and the return policy promises full refund. If there are more than three types of products, however, return policies with different refund rates can be used by sellers for signaling.

In this paper, sellers are allowed to use only one signaling device, price or return policy. However, it might be interesting to study what happens if sellers use both the return policy and the price as signaling devices. This will be left for a future research agenda.

Appendix

Proof of Proposition 2

It is very straightforward to show that the strategies and beliefs above constitute a perfect Bayesian equilibrium. We only show the uniqueness of the separating equilibrium. In any separating equilibrium types of sellers are revealed. When seller A's type is partially revealed (i.e., buyers believe that the type is A or C with equal probability), his optimal price and profit are as follows. If $c \le \frac{1}{2}$, $p = \frac{1}{2}$ and $\pi = \frac{1}{2} - c$. If $c > \frac{1}{2}$, $p = c$ and $\pi = 0$. When seller B's type is revealed, his optimal price and profit is as follows. $p = \frac{1+c}{2}$ and $\pi = \frac{(1-c)^2}{2}$. If each type of seller charges his own optimal price, it cannot be equilibrium. In this situation, seller B makes larger profit than seller A, so that seller A wants to mimic seller B simply by charging seller B's price. In order to eliminate this deviation incentive, seller B's equilibrium profit should be lowered to $\pi = \frac{1}{2} - c$ if $c \le \frac{1}{2}$ (or $\pi = 0$ if $c > \frac{1}{2}$). This can be obtained when the price is raised to $p = \frac{1}{2} + c$ ($p = 1$, respectively). For a seller to be regarded as a type B, the price should not be lower than $p = \frac{1}{2} + c$ ($p = 1$, respectively). If the price is lower than this, the seller should be regarded as type A or C with equal probability. Under this belief, seller A or C can make the maximum profit since the optimal price $p = \frac{1}{2}$ (or $p = c$, respectively) is lower than this critical value $p = \frac{1}{2} + c$ (or $p = 1$). This proves the uniqueness.

Proof of Proposition 4

First, we will show that seller A has no incentive to be regarded as type B. If seller A uses the return policy, buyers believe that the seller's type is B. Buyers' demand depends on the value of p as follows.

If $p \le \frac{1}{2}$, all buyers purchase.

If $p > \frac{1}{2}$, the buyers in $[p - \frac{1}{2}, \frac{3}{2} - p]$ purchase.

But after the seller's type is revealed, some buyers may return:

If $p \le \frac{1}{2}$, the buyers in $[1 - p, 1]$ will return. Thus the net quantity sold equals to $1 - p$ and the returned quantity equals to p.

If $\frac{1}{2} < p \le \frac{3}{4}$, the buyers in $[1 - p, \frac{3}{2} - p]$ will return. Thus the net quantity sold equals to $\frac{3}{2} - 2p$ and the returned quantity equals to $\frac{1}{2}$.

If $\frac{3}{4} < p \le 1$, the buyers in $[p - \frac{1}{2}, \frac{3}{2} - p]$ will return. Thus the net quantity sold equals to 0 and the returned quantity equals to $2(1 - p)$.

Thus the profit function is given by:

If $p \le \frac{1}{2}$, $\pi = (p - c)(1 - p) - rp$.

If $\frac{1}{2} < p \le \frac{3}{4}$, $\pi = (p - c)(\frac{3}{2} - 2p) - \frac{r}{2}$.

If $\frac{3}{4} < p \le 1$, $\pi = -2r(1 - p) < 0$

The profit maximizing price and the maximum profit are given by:

If $c \le \frac{1}{4}$, $p = \frac{1}{2}$ and $\pi = \frac{1}{2}(\frac{1}{2} - c - r)$

If $\frac{1}{4} < c \le \frac{3}{4}$, $p = \frac{3 + 4c}{8}$ and $\pi = \frac{1}{2}\{(\frac{3}{4} - c)^2 - r\}$

We examine the condition under which seller A has no incentive to deviate.

If $c \le \frac{1}{4}$, the deviating profit $\frac{1}{2}(\frac{1}{2} - c - r)$ should be smaller than or equal to $\frac{1}{2}(1 - 2c)$. For this we need $r \ge c - \frac{1}{2}$, which is always satisfied.

If $\frac{1}{4} < c \le \frac{1}{2}$, the deviating profit $\frac{1}{2}\{(\frac{3}{4} - c)^2 - r\}$ should be smaller than or equal to $\frac{1}{2}(1-2c)$. For this we need $c \le \frac{2\sqrt{2}-1}{4}$ or $\frac{2\sqrt{2}-1}{4} < c \le \frac{1}{2}$ and $r \ge c^2 + \frac{c}{2} - \frac{7}{16}$.

If $\frac{1}{2} < c \le \frac{3}{4}$, the deviating profit $\frac{1}{2}\{(\frac{3}{4} - c)^2 - r\}$ should be smaller than or equal to 0. For this we need $r \ge (\frac{3}{4} - c)^2$.

If $c > \frac{3}{4}$, profit always equals to 0 regardless of deviation. So there is no restriction on the value of r.

Now we have only to show that seller B has no incentive to be regarded as type A.

If a seller does not use the return policy, buyers believe that the seller's type is A or C. Then the buyers will purchase only when the price is lower than or equal to $\frac{1}{2}$, and then all the buyers will purchase. Thus the optimal price for the seller is $\frac{1}{2}$, and the profit is $\frac{1}{2} - c$, which is smaller than $\frac{(1-c)^2}{2}$ for all c.

Proof of Proposition 5

First, we will show that if seller A uses the return policy, his optimal price is $p = \frac{1+c+r}{2}$. If $p \le \frac{1}{2}$, the profit is given by $(p-c)(1-p) - rp$. The first-order condition yields $p = \frac{1+c-r}{2}$, which is larger than $\frac{1}{2}$ by the assumption of $r \le c$. Thus profit maximizing price should be $p = \frac{1}{2}$, and the profit becomes $\frac{1}{4}(1-2c-2r)$. If $p > \frac{1}{2}$, the profit is given by $(p-c)(1-p) - r(1-p) = (p-c-r)(1-p)$. The first-order condition yields $p = \frac{1+c+r}{2}$, and the profit becomes $\frac{1}{4}(1-c-r)^2$, which is larger than $\frac{1}{4}(1-2c-2r)$. Thus seller A's optimal price is $p = \frac{1+c+r}{2}$.

Now we will show that given the belief, seller A has an incentive to stop using the return policy. If seller A does not use the return policy, buyers believe that the seller's type is B. When the price is p, the buyers in $[p-\frac{1}{2}, \frac{3}{2}-p]$ will purchase. And even after the seller's type is revealed, the buyers cannot return. Thus the profit is given by $(p-c)(2-2p)$. The profit maximizing price is $p = \frac{1+c}{2}$, and the resulting profit is $\frac{(1-c)^2}{2}$, which is larger than $\frac{(1-c-r)^2}{4}$. Thus he will deviate.

Proof of Proposition 6

First, let us check seller A's incentive to deviate. Seller A may want to deviate to <R>, and charge $p = \frac{1+c+r}{2}$ and earn the profit of $\frac{(1-c-r)^2}{4}$.

When $c > \frac{2}{3}$, this will be smaller than the equilibrium payoff if $r > \frac{1}{3}$.

When $\frac{3-\sqrt{6}}{3} = 0.1835 < c \leq \frac{9-\sqrt{6}}{15} = 0.4367$, this will be always smaller than the equilibrium profit.

When $0.4367 < c \leq \frac{2}{3}$, the deviating profit will be smaller than the equilibrium profit if $r > (\sqrt{6}-1)c - (\frac{2\sqrt{6}}{3}-1)$.

When $c \leq 0.1835$, the deviating profit will be smaller than the equilibrium profit if $r > (1-\frac{\sqrt{6}}{3}) - c$.

Now let us check seller B's incentive to deviate. Suppose that the seller deviates to <R>. If he charges $p \le \frac{1}{2}$, all buyers purchase and none of them return. The resulting profit is $\frac{1}{2} - c$. If he charges $p > \frac{1}{2}$, the buyers in $[0, 1-p]$ and $[p, 1]$ purchase and after the type is revealed, the buyers in $[0, p-\frac{1}{2}]$ and $[\frac{3}{2} - p, 1]$ will return. The profit function is given by $(3-4p)(p-c) - r(2p-1)$. The profit maximizing price is $p = \frac{4c+3-2r}{8}$, and the resulting profit is $\frac{1}{16}\{4r^2 + 4r(1-4c) + 16c^2 - 24c + 9\}$.

Now we want to derive the condition under which seller B will not deviate.

When $c \le \frac{1}{3}$, the deviating profit should be smaller than $\frac{1}{6}$, but this is impossible; by charging $p = \frac{1}{2}$, the seller can make profit $\pi = \frac{1}{2} - c > \frac{1}{6}$.

When $\frac{1}{3} < c \le \frac{2}{3}$, the deviating profit is smaller than $\frac{(2-3c)^2}{6}$ if $\frac{1}{2}(4c-1) - \frac{(3c-1)\sqrt{6}}{3} < r \le \frac{1}{2}(4c-1) + \frac{(3c-1)\sqrt{6}}{3}$.

When $c > \frac{2}{3}$, the deviating profit is smaller than 0 if $\frac{1}{2}(4c-1) - \frac{\sqrt{144c-81}}{6} < r \le \frac{1}{2}(4c-1) + \frac{\sqrt{144c-81}}{6}$.

Thus the range in which neither type of seller wants to deviate is as follows.

(1) $\frac{1}{3} < c \le \frac{1}{2}$, and

$$\frac{1}{2}(4c-1)-\frac{(3c-1)\sqrt{6}}{3}<r\le\frac{1}{2}(4c-1)+\frac{(3c-1)\sqrt{6}}{3}$$

(2) $\frac{1}{2}<c\le\frac{2}{3}$, and $\frac{\sqrt{6}-1}{c}-(\frac{2\sqrt{6}}{3}-1)<r\le\frac{1}{2}(4c-1)+\frac{(3c-1)\sqrt{6}}{3}$

(3) $\frac{2}{3}<c\le 1$, and $\frac{1}{3}<r\le\frac{1}{2}(4c-1)+\frac{\sqrt{144c-81}}{6}$

Proof of Proposition 7

Given the buyers' belief, the deviating profit will not depend of the type of the seller. Since A's equilibrium profit is smaller than B's, it suffices to show that the seller A has no incentive to deviate to <NR>. Let us check seller A's incentive to deviate.

When $c\le\frac{1}{2}$, the deviating profit is $\frac{1}{2}-c$, which will be smaller than the equilibrium profit if $r\le c-(\sqrt{2}-1)$, which is positive only when $c>\sqrt{2}-1$.

When $c>\frac{1}{2}$, the deviating profit is 0, which will be smaller than the equilibrium profit if $r\le(1+c)-2\sqrt{c}$, which is positive as long as $c<1$.

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