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WARRANTIES

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Abstract

The objective of this chapter is to give the reader an overview of the approaches found in the warranty literature. The main question examined is whether the parties of a sales contract voluntarily specify an efficient warranty provision. The chapter starts with the investigation of unilateral cases in which only the seller influences the probability of a product breakdown. Then it switches to bilateral problems in a 'one-shot' relationship. Finally, it studies bilateral problems under repeated purchases. The outcome is that there is no need for legal intervention in this field.
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1. Introduction

A good can be defined by its properties. Some of the properties can be observed before the purchase. According to Nelson (1970) we call these attributes search properties. Other characteristics cannot be observed. We call such characteristics experience properties when their true quality is only revealed some time after the purchase (for example, functionability, duration). Otherwise they have to be classified according to Darby and Karny (1973) as credence properties (for example, therapeutic influence). Warranties control the quality of the experience characteristics of a good. However, if we take a look at what happens in reality, we discover that warranties are actually only offered for a subgroup of the set of experience characteristics (see Priest, 1981). Commonly, the guarantee expires after a certain time period after the purchase, and therefore only those experience properties are covered which reveal themselves within the warranty period. Apparently, the warranty is not a panacea against bad products.

What is a warranty? A warranty is a promise of the seller to take contractually specified measures in case the performance of the purchased item is bad. Such measures (for a comparison of the different measures; see Wehrt, 1995) are typically money-back warranties (see Mann and Wissink, 1988, 1990), price reductions (see Grossman, 1981; Cooper and Ross, 1985), and

subsequent-improvement (see Wehrt, 1995) or replacement warranties (see Mann and Wissink, 1990, Gal-Or, 1989). The warranty condition has to be met before the buyer gets warranty compensation. Normally the warranty condition states that the purchased unit has to become defective, that is the bought item breaks down, parts of it do not work normally or the item is in a bad condition. The defect may result from two different situations. The first is when a deficiency in the technical development of the product caused a constructional flaw. In this case the defect is inherent in every item of the product and the average quality of the good is bad. The second concerns shortcomings in the production process, which may cause a manufacturing flaw. In this case only a fraction of the items sold will become defective. If one looks at the warranty as an instrument to signal high product quality, it is obvious that the supplier of a product with a constructional flaw is not going to offer a warranty. Only in cases where the supplier was unaware of the constructional flaw before putting the product on the market, the supplier will erronously offer a warranty. These considerations may explain why the warranty literature focuses on manufacturing flaws.

The present article is divided into two parts. The first section addresses unilateral problems of moral hazard and adverse selection in a 'one-shot' relationship and, if need be, how they can be solved by warranties. In the second part bilateral problems are discussed. First we will discuss the problems in a 'one-shot' game. Afterwards we will introduce long-term relationships. The analyses will explain why warranties are often partial, and restricted in magnitude and duration.

A. Warranties in a Unilateral Context

2. Warranties as a Device of Insurance

The simpliest type of problem is the following: risk-averse consumers demand goods from risk-neutral sellers. A certain fraction of the sold items will become defective after a period of use. When signing the purchase contract, neither the consumers nor the sellers know which units will be critical, but the parties process symmetric information about the average probability of failure. This failure probability (cannot be influenced, either by the sellers' investment in the manufacturing process or by the consumers' care-taking.

The seller offers the product at a price p. He faces constant unit costs of production: $c > 0$. In case of a defect he has to compensate the consumer by means of a warranty payment: w ($0 \leq w \leq p$). His profits V can be expressed as:

$$V = p - c - \varrho w$$

The consumer values a faultless item with q ($\geq p$) monetary units. A defective item causes him a loss of F/l. The utility function U is defined over the monetary income. It expresses the risk aversion of the consumer and therefore increases with decreasing rates: $U' > 0$, $U'' < 0$. The expected utility is:

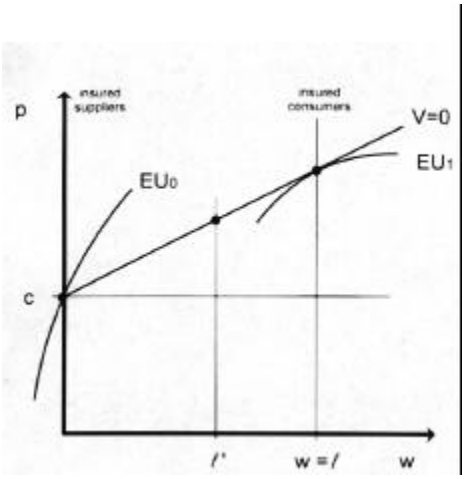
$$EU = (1 - \varrho)U(q - p) + \varrho U(q - p - F/l + w)$$

Assuming a constant profit on the side of the suppliers, the product price becomes dependent on the magnitude of the promised warranty: $p = p(w)$. A Pareto-optimal allocation requires marginal utility to be identical in situations both with and without a product defect. We therefore have: $w^* = l$.

This resource allocation will be achieved automatically in the long run in a competitive market, see Figure 1 for illustration. Every point of the diagram represents a price-warranty combination. Price-warranty combinations along the vertical axis insure the seller against product risks because no warranty compensation has to be paid at all, whereas the buyer will be fully insured if a combination from the vertical line $w = l$ is taken. Free market entry drives the product price down to unit cost level: $c + \varrho w$. The straight line $V = 0$ represents this zero-profit level. The slope of this zero-profit line depends on the failure probability of the product. It is steep if the probability of failure is high, and relatively flat if the probability is low. The tangency point between the indifference curve EU_1 and the zero-profit line represents the competitive equilibrium. This equilibrium is stable. A firm considering a smaller warranty level has to be aware that the consumers will look for lower prices in case of lower warranty levels. Reducing the warranty level from l to l' lowers the firm's cost and therefore the product price by $\varrho(l - l')$. For such an offer a risk-neutral consumer would bid for a price which is $\varrho(l - l')$ monetary units smaller. He would therefore be indifferent with respect to the choice of either offer. Risk-averse consumers would not only fear the pure monetary effect, but also the risk exposure which is caused by the now only partial warranty. Therefore they would refuse the new offer.

Our first result is: warranties protect risk-averse consumers against manufacturing flaws. The consumers prefer a 'full' warranty, unrestricted in magnitude and duration.

Figure 1 Insurance against product defects



3. Warranties as a Signal of Quality

Signalling literature can be traced back to Spence (1973) who wrote an article on 'Job Market Signalling'. Grossman (1981, p. 479) argued that 'when firms have tools available which they can use to convey information they will do so'. With warranties we have such a tool of information transfer. Assume there are two types of manufacturers. Type L produces at low unit costs c_L but has a large rate of defective units $(_L$, whereas type H has higher unit costs c_H but a smaller quota of defective items $(_H$. Let us assume that the customers know about the average market failure rate, but keep them uninformed about the firm-specific quota. Let us suppose furthermore that there are enough potential suppliers of each type to satisfy the demand within the whole market.

When offering the product without a warranty, firms of type L would get the whole market demand at price $p = c_L$, because the customers are not able to distinguish between these two types of firms. It is not useful for customers to buy at price $p = c_H$. By charging this price, low quality firms may pretend to sell items of high quality.

Firms of type H may start to advertise, in order to inform the consumers about the high quality of their products. Similarly to statements about price, as long as the right to make untrue statements is not sanctioned, advertising signals can be imitated by low quality suppliers (however, in a long-term relationship advertising may signal quality. For more information on this topic

(see Nelson, 1974; Schmalensee, 1978; Kihlstrom and Riordan, 1984; Milgrom and Roberts, 1986).

It is because of the legal system that warranty commitments become credible signals. Putting aside those cases in which a firm is dissolved before the defects of its sold products are revealed, the legal order enforces warranty claims. Therefore, a firm which promises a warranty has to be aware of the resulting warranty costs in the future. Since low-quality suppliers face higher defect rates, they have to expect higher warranty costs. It is therefore cheaper for firms of type H than for firms of type L to use the warranty signal. Hence, they will do so and offer a full warranty, which is preferred most by the buyers anyway. Nevertheless, when they observe the supplementary warranty of competing high-quality suppliers, firms of type L will also offer a warranty. The competitive outcome as to which type of producer finally succeeds in serving the market then depends on the answer to the question
: will the higher warranty costs of low quality firms be lower than the original differences in unit costs of production?

Referring to the model of the previous paragraph, we know that risk-averse consumers prefer being fully insured against the monetary loss of a product defect: $w = l$. They favour a full warranty when contracting with either type H or L firms. Their expected utility therefore equals:

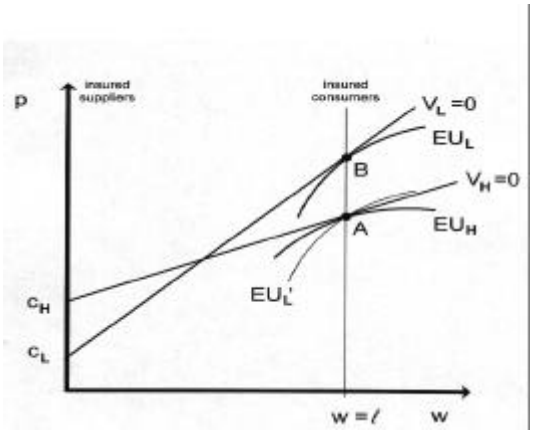
$$EU_i = U(q - p_i)$$

If and only if $p_H \leq p_L$, which means that $c_H + \varrho_H l \leq c_L + \varrho_L l$, firms of type H will be able to serve the market. Look at Figure 2 for an illustration. The diagram includes the zero-profit lines of two representative firms of type L and H. The point of intersection determines a specific partial warranty provision. Given this warranty provision, both firms face the same costs. Expanding the warranty further, the sharper warranty-cost increase for firms of type L creates a competitive disadvantage: the additional warranty costs in comparison to high-quality suppliers exceed the original unit cost difference. Therefore - according to this example - firms of type H offer their products at the cheapest price. The tangency point A between the zero-profit line V_H and the indifference curve EU_H represents market equilibrium.

Notice that the diagram contains two overlaying systems of indifference curves. The system EU_H informs us about the expected utility of representative customers if they contract with firms of type H, the system EU_L informs us about contracts with type L. The intersecting curves EU_L' and EU_H represent the same level of expected utility. Since they intersect at a full-warranty price, consumers do not care about the firm-specific defect rate. Under full warranty the same price leads to the same expected utility, irrespective of which type of firm will sell. To distort the equilibrium, low-quality firms therefore have to

make an offer in the south-eastern area of the EU_L' curve. Since such offers would cause losses, firms of type L refrain from doing so. Therefore the tangency point A characterizes a stable competitive equilibrium.

Figure 2 Signalling high quality



The outcome is Pareto-optimal. Since the consumers prefer to be insured, the tangency points A and B are the only candidates for a Pareto optimum condition under the restriction of zero profits. A dominates B because the expected utility of the representative consumer is higher with lower prices.

The assumptions of the original model can be altered in several respects:

1. The individual losses differ. Risk-averse consumers prefer a warranty coverage which compensates for their individual losses. Firms will then come up with offers varying in warranty coverage. Low-quality firms serve customers with small individual losses, whereas high-quality firms serve the more sensitive customers. The outcome is Pareto-optimal. It does not deviate from an outcome that would occur, if firms had truthfully disclosed their failure rate and offered an insurance against defective items (see Spence, 1977, p. 570).
2. A monopolist serves the market. The monopolist will increase warranty coverage as long as the marginal buyers' willingness to pay increases with this coverage (Grossman, 1981, p. 475). Problems arise in cases where the individual losses differ: the social planner will look at inframarginal buyers to control warranty coverage, whereas the monopolist observes the marginal buyers' willingness to pay (Spence, 1975).
3. The market structure is oligopolistic. Gal-Or (1989) showed that the informational content of warranties is limited, as multiple equilibria may exist.

4. Warranties as an Incentive to Invest in Quality

It was Priest (1981, pp. 1307-1319) who emphasized the 'Investment Theory of Warranty'. According to his interpretation a warranty is a device which controls the efforts taken by the manufacturer and the consumer to maintain a functioning product. The only relevant variable in a unilateral case - as discussed here - is the effort of the manufacturer to keep the failure rate optimal.

Similar to the situations in the previous paragraphs, the customers are interested in being fully insured against the loss caused by a potential product breakdown: $w = l$. The seller, who, by assumption, is also the manufacturer, thus internalizes the buyer's potential losses. The manufacturer therefore has to choose a level of quality investment x^* which minimizes unit costs of production plus expected losses:

$$c(x) + \pi(x) \cdot l$$

Assuming $c'(0) = 0$, $c' \geq 0$, $c'' > 0$, $\pi' < 0$, $\pi'' > 0$, there is an optimal positive level of quality investment. This level will be chosen by the manufacturer. His investment will thereby be guided by the following consideration: the effect of a quality investment is to reduce the defect rate. Evaluated in monetary terms, this effect has to be weighed against avoided losses. For any additional quality investment to be taken, the loss-reducing effect has to be larger than the costs of this investment.

5. Underestimated Failure Rates

Spence (1977, p. 563) already showed that no warranties will be offered in a competitive market where risk-neutral customers systematically underestimate the failure rate π. In case of risk-averse consumers only a partial warranty will be offered.

Let $r(\pi)$ be the failure rate which is perceived by the buyers: $r(\pi) < \pi$. Expected utility can then be expressed as:

$$EU = [1 - r(\pi) \cdot U(q - p(w)] + r(\pi) \cdot U[q - p(w) - l + w]$$

Maximization with respect to w then leads to the outcome:

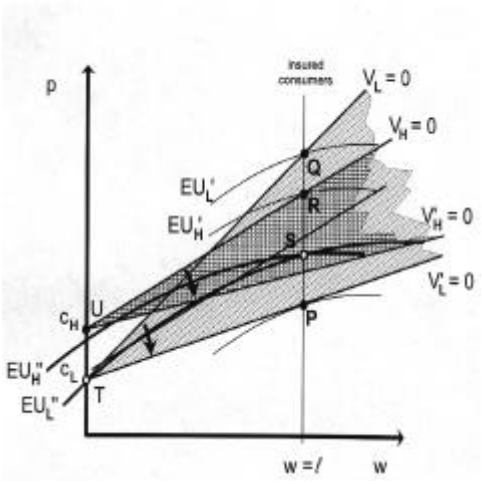
$$\frac{U'(q - \bar{V} - c + (1 - P) \cdot w - l)}{U'(q - \bar{V} - c - P \cdot w)} = \frac{[1 - r(P)]/r(P)}{[1 - P]/P} > 1$$

Hence the representative consumer prefers a partial warranty: $w^* < l$.

Figure 3 illustrates the special case in which the underestimation of the failure rates leads to the outcome that consumers are no longer interested in warranties. The slope of the zero-profit line $V_L = 0$ indicates the true quota of defective items of supplier L. However, consumers expect a failure rate that

corresponds to the slope of zero-profit line $V_L^{'} = 0$. They believe that the quota is one third of the true quota. Clearly, their system of indifference curves has to be constructed according to the wrongly assumed quota. The first-best choice of these consumers would be a price-warranty combination as is shown by point P with a full warranty. However, these customers have to realize that the desired contract is not offered in the market. Offering this contract would create losses for firm L, because the true rate of defective items is higher than the customers expected. The minimum price firm L would claim for a full warranty contract is determined by point Q. The representative consumer values this offer with expected utility $EU_L^{'}$ and concludes that there is a more valuable contract (utility $EU_L^{''}$) without a warranty indicated by point T.

Figure 3 Underestimated Failure Rates



Given this situation, we now assume that high-quality firms of type H are also in the market and sell the same product with a smaller rate of defective items. The corresponding system of indifference curves is characterized by the EU_H-lines. Compared with firms of type L the offer of the H type is of higher social value, because the full-warranty price of these firms determined by point R is less than the full-warranty price of firm L determined by point Q. Consequently, it is to be expected that firms of type H serve the market. However, just as the customers underestimate the rate of defective items of

firms L, the rate of defective items of firms H is underestimated by a factor of 3 (see line $V_H^{'} = 0$).

The current offer of firms L, selling the product without a warranty as indicated by point T, leads to utility $EU_L^{"}$. The full-warranty contract indicated by S creates the same utility. Moreover, S is also a point on the indifference curve $EU_H^{"}$. Therefore we have: $EU_L^{"} = EU_H^{"}$. The curve $EU_H^{"}$ intersects the ordinate at a price level which is less than c_H. Consequently, as c_H is the minimum price firms H have to charge for their goods without a warranty, the consumers expect that the utility of the offer characterized by point U is less than $EU_L^{"}$. So, offer T is preferred to U.

The awkward consequence of this example is that the consumers choose the wrong firms and the wrong warranty contracts. Therefore, we have to ask the question, whether the amount market failure can be corrected.

Basically there are three ways of legal interference. The most restrictive kind of intervention is to introduce a mandatory legal warranty over the typical lifetime of a product. However, this type of interference should only be applied in situations where the rate of failure is exclusively determined by the firm. If it is also influenced by inherent attributes of failure inclination on the side of the buyer (Wilson, 1977; Rothschild and Stiglitz, 1976), by the intensity of use (Emons, 1989a) or by buyers' care (Priest, 1981; Kambhu, 1982; Cooper and Ross, 1985) then partial warranties would be better. The second type of legal intervention is a disclosure rule which obliges the sellers to reveal the true failure rate before the purchase is made (Grossman, 1981). I expect that a third alternative will solve the problem with lower social costs: if firms are allowed comparative advertising, then the firm discriminated against will undertake the job to inform the buyers about the true quota of failure.

B. Warranties in a Bilateral Context

6. Warranties in a One-Shot Relationship

Observations in reality contradict the picture of long-lasting, fully compensating warranties (see Priest, 1981, p. 1319, for a detailed empirical investigation of warranty contracts). Warranties are always limited in duration. Mostly, the warranty periods cover only part of the lifetime of a product. Often the warranty periods are restricted to one year. Warranties which last for three or more years can rarely be found, although the lifetime of consumer durables often exceeds ten years.

With respect to the scope of warranties - German standard form contracts predominantly specify subsequent improvement or subsequent delivery - one often detects clauses which exclude the warranty with regard to certain uses or which make the validity of the warranty dependent on the buyer's intermediate input. Exclusions in warranties are typical for retailing and commercial uses. Often these exclusions are directed against aggressive use or the non-compliance with regular maintenance. Commonly, the operation of certain fragile parts falls under the warranty but the warranty coverage expires if attempts are made to open the product. On the other hand, parts housed deep within the product, inaccessible to the consumer's influence, are often protected by an extended warranty.

This short overview makes it clear that the organization of warranty contracts is essentially determined by the consumer's potential influence on parts of the product. However, the consumer's influence on the failure rate has not yet been investigated. Therefore, we have to extend the analysis to bilateral warranty problems, situations in which both parties, the manufacturer as well as the user, control the product's failure rate.

According to the investment theory of Priest (1981) every bilateral warranty problem is a mixture of different unilateral problems and hence can be reduced to its elementary ingredients. This view presupposes that it is a certain type of defect which points to the responsibility of, respectively, the seller or buyer. If this approach was correct, then the optimal warranty contract would have to stipulate a full warranty for those product risks which are under the control of the manufacturer and a full warranty exclusion for those risks which are under the control of the consumer. However, in addition to the elementary unilateral problems and their combinations, there is a real bilateral problem which cannot be decomposed. The optimal control of many of the product risks calls for a certain combination of seller's and buyer's care. Take for instance the case of a car engine. Its safe functioning requires the necessary mechanical and electronical adjustments on the part of the manufacturer as well as responsible behavior on the part of the driver. The breakdown probability increases if any of the parties fail to perform their duties.

The problem of bilateral investments is addressed in articles by Kambhu (1982), Cooper and Ross (1985), Mann and Wissink (1988), Emons (1988). All these models assume that warranty promises are enforceable. Clearly, if warranties could not be enforced, sellers would cheat on the warranty and the outcome would be minimum product quality. Therefore, I also assume an enforceable warranty. Let the damage function d be dependent on the manufacturer's quality investments x and the consumer's costs of care-taking y:

$$d(x, y) = \rho(x, y) \cdot l$$

Let furthermore: $\rho_x < 0$, $\rho_{xx} > 0$, $\rho_y < 0$, and $\rho_{yy} > 0$. The representative consumer is risk-neutral. Let us assume that his willingness to pay for an intact item is q and that his utility is measured in money terms and equals his willingness to pay. Then the expected utility is:

$$EU = q - \rho \cdot (l - w) - y - p$$

The seller's profit is:

$$V = p - x - \rho \cdot w$$

Maximization of the joint surplus with regard to x and y leads to the following first order conditions:

$$-\rho_x(x, y) \cdot l = 1 \quad \text{and} \quad -\rho_y(x, y) \cdot l = 1$$

Now we have to answer the question whether the parties will control their quality and maintenance as described with the first order conditions. Thereby we assume two steps of decisionmaking. During the first step the parties compete, when unobserved by the other party, and choose a certain level of investment. Afterwards they cooperate, when fixing a warranty compensation which maximizes the joint surplus.

For the first step the following first-order conditions are relevant:

$$-\rho_x(x, y) \cdot w = 1 \quad \text{and} \quad -\rho_y(x, y) \cdot (l - w) = 1$$

A comparison with the Pareto conditions reveals a degree of tension. Pareto optimal quality investments of the manufacturer require a warranty level of $w = l$, whereas Pareto optimal care-taking of the consumers presupposes a level of $w = 0$. Therefore, a joint surplus-maximizing allocation is impossible (compare Cooper and Ross, 1985, p. 107), and a 'second best' solution will be the outcome.

Let the functions $x^+(y, w)$ and $y^+(x, w)$ describe which level of investments a party will choose given the warranty promise w and the investment of the other party x or y, respectively. Let the pair $[x^\circ(w), y^\circ(w)]$ denote the point of intersection of both functions. It represents the *Nash equilibrium of the noncooperative part of the game*. When jointly arriving at a conclusion about the level of the warranty, both parties anticipate their reciprocal pattern of unobserved behavior (Cooper and Ross, 1985, p. 109). They consequently maximize their joint surplus under the restriction of the Nash equilibrium, described above:

$$\max_w \; EU + V = q - \rho \cdot l - x - y$$
$$\text{subject to}$$
$$x = x^\circ(w) \quad \text{and} \quad y = y^\circ(w)$$

The first-order condition requires:

$$xE'(w) \cdot [- (_x(x, y) \cdot l - 1] + yE'(w) \cdot [- (_y(x, y) \cdot l - 1] = 0$$

According to the first-order conditions of unobserved party behavior we have: $- (_x(x, y) = 1/w$ and $- (_y(x, y) = 1/(l - w)$, respectively. Therefore the first-order condition is:

$$x^{\circ\prime}(w)\left(\frac{l}{w}-1\right)+y^{\circ\prime}(w)\left(\frac{l}{l-w}-1\right)=0$$

On condition that $xE' > 0$ and $yE' < 0$ the outcome will always be a partial warranty which, on the one hand, is greater than zero, but, on the other hand, is less than l. If the degree of warranty coverage w/l converges to one, the first term of the above equation vanishes. The derivative is therefore negative. If the degree of coverage converges to zero, the second term disappears. Hence the derivative is positive. However, as is indicated by the equations of party behavior, the conditions of $xE' > 0$ and $yE' < 0$ are not always fulfilled. Its validity depends on the magnitude and the sign of $(_{xy}$ (complementary or substitutionary investments).

The outcome of the bilateral model is:

1. Parties who feel unobserved when carrying out their product investments normally agree to a partial warranty.
2. This voluntary agreement solves the bilateral problem in a suboptimal manner.

Kambhu (1982) raises the question whether or not it is possible to design legal rules which solve the problem of suboptimal incentives. He starts from the assumption that any warranty rule has to be 'balanced', which means that the seller, in making the warranty payment , loses the same amount of money as the buyer gets. According to Kambhu (1982) no legal warranty rule exists which offers both parties the Pareto-optimal incentives. This result becomes quite clear if one considers the restrictions under which the legislator has to develop the warranty rule. He has to accept that the legal consequence of the rule cannot depend on unobservable constituent facts.

Deviating from the above analyses, Emons (1988) examines the case of a voluntary warranty in which the quality investments of the manufacturer and the consumer's precautional measures do not continuously vary. He distinguishes two levels of *f* respectively, quality investments and care-taking. His conclusions are: if risk-averse consumers in a competitive market benefit from a full warranty more than from an incentive-compatible warranty, only a second-best solution is feasible, because the consumers will exert a low level of care. However, if the benefit of full insurance is lower and if the incentive-compatible warranty is extensive enough not to destroy the seller's

quality-assuring incentive, then the levels of quality and care will be optimal. The last result of Emons (1988) is crucially predetermined by the assumption of discontinuous variables. With continuous variables a full warranty coverage is necessary to assure the optimal quality investment of the seller. However, this coverage will eliminate the consumer's incentive to handle the good carefully.

Mann and Wissink (1988) discussed the case of a voluntary money-back warranty. The buyer is allowed to return the product within a period specified beforehand. The authors conclude that under extreme conditions the double-sided moral-hazard problem is solved by the first-best levels of care-taking. However, the assumptions of the model used are not realistic. On the one hand, the authors implicitly presuppose a very short period of exchange. This is assumed because buyers do not derive any benefit from the use of the product. On the other hand, the model presupposes that within this period the buyers detect all possible shortcomings of the product. So it seems that the authors really investigate the case of a search good.

7. Warranties in a Long-Term Relationship: The Model

The outcome of the above analysis is that in a one-shot relationship with enforceable warranties the first-best levels of parties' investments in quality and care-taking, respectively, cannot be achieved in general. This section now aims to examine the question whether the market outcome will improve if buyers purchase from sellers who have a good reputation. Deviating from the analysis of the last paragraph I assume unenforceable warranties. This assumption, which complicates the incentive problem, is used to show how reputation really works.

Consumer durables are the type of goods for which warranties are most important. Consumers remember the experiences they had with typical brands. These experiences are shared with other customers by word-of-mouth communication. Therefore, companies which have sold brands that customers disliked, may lose part of their reputation and therefore future sales. The mere possibility of future losses may give the seller the incentive to make adequate quality investments.

The following model (see Wehrt, 1995b) assumes a perfect competitive market. A multitude of sellers offer the same product with different warranty commitments in the market. However, the brands differ with respect to the unobservable quality investments and therefore varying failure probabilities. Consumers also influence the failure probabilities by their care investments.

Satisfied consumers award their sellers with a certain reputation. This reputation is earned, if during the previous period the seller at least delivered the quality he had signalled with the price beforehand and if he kept the given

warranty promise. A firm's reputation in period t is therefore a function of the quality-warranty package of the previous period: $R_t = (x_{t-1}, w_{t-1})$. The earned reputation allows the firm to ask a price in the next period which corresponds to its reputation: $p_t(R_t) = p_t(x_{t-1}, w_{t-1})$. Firms which have never earned a reputation or which have abused it are avoided by the consumers.
A reputational equilibrium can be defined by four conditions (compare Shapiro (1983)):

1. Every buyer chooses the quality-warranty package and the level of care-taking which maximizes his consumer surplus.
2. Buyers' expectations come true: a seller whom the buyers expect to meet a certain level of quality investments and to keep his warranty promise, performs in this way: $(x_t, w_t) = R_t = (x_{t-1}, w_{t-1})$.
3. In every partial market defined by a certain level of promised quality and warranty, supply equals demand.
4. Market entrance and market exit are not profitable.

The consumers are assumed to behave in a risk-neutral way. They can be distinguished by their willingness to pay q and the certain loss l that a breakdown of the purchased item causes. Thus the expected utility is:

$$EU_{ql} = q - \text{(illegible)}(l - w) - y - p \qquad \text{where } q \in [0, \infty),\ l \in [0, q]$$

According to the first equilibrium condition, a consumer of type ql maximizes his expected utility with respect to the variables y, x, w. Therefore, we have three marginal conditions:

$$-\text{(illegible)}_y(x_{ql}, y_{ql}) \cdot (l - w_{ql}) = 1$$

$$-\text{(illegible)}_x(x_{ql}, y_{ql}) \cdot (l - w_{ql}) = p_x$$

$$\text{(illegible)}(x_{ql}, y_{ql}) = p_w$$

The optimal values of the three variables y_{ql}, x_{ql}, w_{ql} do not vary with respect to a consumer's willingness to pay q, but as the appearance of the individual loss l in the first two conditions shows, they depend on l. Consumers with identical individual losses are members of the same class. They prefer a certain level of quality, warranty and own care-taking. Therefore, a firm with a certain reputation serves the consumers of a certain class.

The reputational equilibrium also requires that sellers have no incentive to abuse their reputation once it has been built up. A seller who exploits his reputation earns profits only during the next period. After that period the customers will avoid him. Therefore that seller's profit is

$$V_1 = p(x, w) - x_0,$$

where x_0 determines the cost of the minimum quality. If the firm keeps its reputation R_t permanently, it will earn profits during all the subsequent periods. Using the interest rate r, the discounted future profits can be stated as:

$$V_2 = \{p(x, w) - x - \text{(}w\} \text{ } (1 + r) / r$$

Defending the reputation requires profits V_2 to be at least as high as profits V_1. Therefore we have:

$$p(x, w) \geq x + \text{(}w + r \{x + \text{(}w - x_0\}$$

In the above, the term in the third position of the inequality stands for the quality premium the seller earns from complying with his reputation. On the other hand, according to equilibrium condition 4, the profitability of market entrance has to be prevented. A seller who enters the market will earn the following stream of profits:

$$V_3 = x_0 - x - \text{(}w + \{p(x, w) - x - \text{(}w\} / r$$

These profits are not allowed to exceed zero. Thus the above inequality has to hold with '$\leq$'. Hence, equality results. The price function calculates the equilibrium prices that sellers with different quality-warranty reputations will realize.

Under the restriction of this price function, customers are not interested in buying with a guarantee: $w = 0$. Inspection of the price function shows that if buyers consider purchasing from another partial market in which the offered guarantee is one monetary unit instead of no warranty, they have to be aware that the price will increase not only by factor $(1 + r)$ (, but that it will further increase, as sellers in this new partial market have to take into consideration that their customers are more careless because of the offered warranty. On the other hand, having chosen the optimal levels of quality and care-taking under the premise of no warranty, a consumer's net benefit is lower than the price increase, because the expected utility will only grow by a factor of (when switching to the other partial market. Consolidated with the price increase, the net effect is therefore negative. Therefore, risk-neutral consumers will decide against the warranty.

With respect to this outcome, the first-order conditions of consumer behavior will be simplified to:

$$- \text{(}_y(x_{ql}, y_{ql}) \text{ } l = 1$$

$$- \text{(}_x(x_{ql}, y_{ql}) \text{ } l = 1 + r$$

The important result therefore is: risk-neutral parties will approximately choose the first-best levels of quality investments and care-taking, if the discount rate

of future profits is small enough. So, even in a situation where warranties are not enforceable, there is a realistic chance that parties will choose the optimal quality and care investments.

8. Warranties in a Long-Term Relationship: Discussion

What are the main variables that influence the magnitude of the discount rate *r*? The interest rate *r* connects the periods of usefulness. It therefore represents a measure of the speed with which the information about the experience characteristics of the purchased goods spreads to the buyers. According to the model, agreements will only be contracted at the beginning of a period. Hence acquired experience can be applied no earlier than at the beginning of the next period. In this case the discount rate *r* - and therefore the quality premium - is indeed determined by the length of the period of usefulness.

When putting the model into reality, two additional effects have to be taken into account. On the one hand, consumers do not buy on command at the beginning of a new period, but at different points in time during a current period. Therefore acquired experience begins to spread to the buyers immediately after a product defect is detected. In this case it is not only the length of the period of usefulness that influences the discount rate *r*, but rather the length of time that passes before the defect is discovered. So those kinds of flaws which immediately reveal themselves after the purchase (for example, compatibility) lead to a small discount rate, whereas other types of flaws which appear after a long period of use (for example, durability) result into higher discount rates. Smaller deviations from the optimal quality investments can therefore be expected with regard to easily detected product failures, larger deviations with respect to hidden defects.

On the other hand, information needs time to spread to the consumers. A seller who has misrepresented his reputation will not lose his customers overnight, but in relation to the speed with which the information about the quality of his product diffuses. This aspect increases the interest rate *r*.

The model presupposes risk-neutral consumers. If the consumers are assumed to behave in a risk-averse way, then voluntary warranty contracts will be observable. Buyers of this type are ready to accept a mark-up that exceeds the expected monetary value of the warranty. Below a critical threshold of the discount rate *r*, they therefore prefer a warranty. However, the seller's quality premium which is necessary to let him comply with the given warranty promise, increases in proportion to how late the experience characteristics of the product will reveal themselves. Therefore, even risk-averse consumers are not interested in buying insurance against those defects which can only be detected in a late stage. These offers are too expensive. This aspect explains

why warranties are fully compensating but limited in duration, rather than partially compensating and unrestricted in duration (other explanations of this aspect are offered by Emons, 1989a; Cooper and Ross, 1988).

If the legal order enforces warranties, then the quality premium is no longer necessary to make the seller comply with the warranty promise. The sole function of the quality premium then is to assure the seller's quality investments. However, the enforced guarantee is also an instrument of quality assurance. For instance, in the case of a full warranty the seller has no opportunity to externalize failure costs to his buyers. Therefore buyers profit twice from an increase in the warranty coverage. Firstly, it offers more compensation in case of a defect. Secondly, it reduces the quality premium and possibly - if the monetary effect of the diminished quality premium exceeds the additional costs of the expanded warranty - makes the product cheaper. This effect explains the outcome of the altered model. In case of enforced guarantees and a positive discount rate r even risk-neutral consumers prefer positive warranty coverage (see Wehrt, 1995b, p. 172).

9. Conclusions

The purpose of this chapter was to give a brief overview of the approaches and the literature written in the field of product warranties. Starting with unilateral problems we discovered a contradiction between the types of warranty contracts we observe in reality (partial warranties) and the optimal design of such contracts which was derived from the analysis (full warranties). Hence, it could be that market failures explain the deviation between 'what is' and 'what should be'. An explanation was offered by considering the possibility that customers systematically underestimate the firms' rates of defective items. In such a case the wrongly assessed failure rate makes consumers erroneously decide against a full warranty.

Expanding the analysis to bilateral problems, we found out that the problem's optimal solution changes. The original gap between model and reality disappears. Certainly specified partial warranties form the optimal type of contract. However, we have to conclude that the optimality of this contract is due to the restrictions of unobservability. Its optimality is not due to a world in which either party is fully informed about how the other party handled the product. But even a legislator has to accept that he cannot get access to the best of all worlds.

We finally looked at repeated purchases. As the seller often sells the same product, consumers have a broader basis for drawing inferences about the seller's quality investments. Therefore, the veil of ignorance slightly lifts and an additional step into the direction of the best of all worlds can be made.

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