14 Warranties

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1. Introduction
A good can be defined by the set of its properties. Some of the properties are observable before purchase. According to Nelson (1970), we call these attributes search properties. Other characteristics cannot be observed. We call these characteristics experience properties, when their true quality is only revealed some time after the purchase (for example, functionality, duration). Otherwise they have to be classified according to Darby and Karny (1973) as credence properties (for example, therapeutic influence).¹

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.² Commonly, the guarantee expires after a certain time period after the purchase, and therefore only those experience properties are covered which may reveal themselves within the warranty period. Apparently, the warranty is not a panacea against bad products.

What is a warranty? The warranty is a promise by the seller to take contractually specified measures in case the performance of the purchased item is bad. Such measures³ are typically money-back warranties,⁴ price reductions,⁵ subsequent-improvement,⁶ or replacement warranties.⁷ 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 be the result of either of two different situations. The

¹ The economics of credence goods are investigated by Dulleck and Kerschbamer (2006).
³ For a comparison of the different measures, see Wehrt (1995a), Friehe and Tröger (2008).
⁶ See Wehrt (1995a).
⁷ See Mann and Wissink (1990), Gal-Or (1989).
first is when a deficiency in the technical development of the product has 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 that signals 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, will the supplier erroneously offer a warranty. These considerations may explain why the warranty literature focuses on the manufacturing flaw.

The present chapter is divided into two parts. Section A 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 Section B, 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, restricted in magnitude and duration.

A. WARRANTIES IN AN UNILATERAL CONTEXT

2. Warranties as a Device of Insurance

The simplest 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 $p$ cannot be influenced, either by the seller’s investment in the manufacturing process or by the consumer’s care-taking.

The seller offers the product at 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:

$$V = p - c - \pi * w$$

The consumer values a faultless item at $q$ ($\geq p$) monetary units. A defective item causes him a loss of $L$. The utility function $U$ is defined over the monetary income. It expresses the risk aversion of the consumer and therefore increases with decreasing rates: $U' > 0$, $U'' < 0$. Expected utility is:
Assuming a constant profit on the side of the suppliers makes the product price 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. Figure 14.1 offers an 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: \( c + \pi w \). 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

\[
EU = (1 - \pi) * U(q - p) + \pi * U(q - p - L + w)
\]

*Figure 14.1  Insurance against product defects*
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 $\pi^*(L - L')$. For such an offer, a risk-neutral consumer would bid for a price which is $\pi (L - L')$ monetary units smaller. He would therefore be indifferent with respect to the choice of either offer. Risk-averse consumers would fear, in addition to the pure monetary effect, 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. Consumers prefer a ‘full’ warranty, unrestricted in magnitude and duration.

3. Warranties as a Signal of Quality

Signalling literature can be traced back to Spence (1973), who wrote an article on ‘Job Market Signaling’. Grossman (1981, p. 479) argued ‘that when firms have tools available which they could 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. The type $S$ produces at small unit costs $c_S$ but has a large rate of defective units $\pi_S$, whereas type $H$ has higher unit costs $c_H$ but a smaller quota of defective items $\pi_H$. Let us assume that the customers know about the market average failure rate, but they are uninformed about the firm-specific quota. Let us suppose furthermore that there are enough potential suppliers of each type to satisfy the market demand within the whole market.

When offering the product without a warranty, firms of type $S$ would get the whole market demand at price $p = c_S$, 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. Like 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 extreme cases where misleading advertisements are hardly sanctioned by the law, advertising can be taken as a specific form of a warranty. Even without legal sanctions, if – in a long-term relationship – wrong advertising leads

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8 Noll (2004) compares warranties and advertisement as different measures to assure product quality.
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to the loss of former reputation, it works like a warranty (advertising then may signal quality).\(^9\)

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 their sold products are revealed,\(^10\) 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 \(S\) to use the warranty signal. Hence, they will do so and offer a full warranty which is preferred by most buyers anyway. Nevertheless, when they observe the supplementary warranty of competing high-quality suppliers, firms of type \(S\) 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 less than the original differences in unit costs of production?

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

\[
EU_i = U(q - p),
\]

where \(i = S, H\). If and only if \(p_H \leq p_S\), which means that \(c_H + \pi_H L \leq c_S + \pi_S L\), firms of type \(H\) will be able to serve the market. See Figure 14.2 for an illustration. The diagram includes the zero-profit lines of two representative firms of type \(S\) 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 \(S\) creates a competitive disadvantage: the additional warranty costs in comparison to high-quality suppliers exceed the original unit costs 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 overlapping systems of indifference curves. The system \(EU_H\) informs us about the expected utility of

\(^9\) For more information on this topic, see Milgrom and Roberts (1986), Kihlstrom and Riordan (1984), Schmalensee (1978), Nelson (1974).

\(^{10}\) Compare Bigelow et al. (1993), Noll (2004).
representative customers if they contract with firms of type $H$, the system $EUS$ informs about contracting with type $S$. The intersecting curves $EUS$ and $EUH$ 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 $EUS$ curve. Since such offers would cause losses, firms of type $S$ would refrain from doing so. Hence the tangency point $A$ characterizes a stable competitive equilibrium.

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 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 clientele. The outcome is Pareto optimal. It does not deviate from the outcome that would occur if firms had truthfully disclosed their failure rate and offered insurance against defective items (see Spence 1977, p. 570).

2. A monopolist serves the market. The monopolist would increase warranty coverage as long as the marginal buyer’s willingness to pay increases with this coverage (Grossman 1981, p. 475). Problems arise in cases where the individual losses differ: the social planner would look at inframarginal buyers to control warranty coverage, whereas the monopolist observes the marginal buyer’s 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. 1307–19) who emphasized the ‘Investment Theory of Warranty’. According to his interpretation, the 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 the manufacturer exerts to keep the failure rate optimal.

   As with the situations described in 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 exists 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 $\pi$. 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: $r(\pi) < \pi$. Let us assume further $p(w)$ denotes the competitive price which is charged, if a warranty of extent $w$ is combined with the product. 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:

$$\frac{U'(q - \overline{V} - c + (1 - \pi) \cdot w - L)}{U'(q - \overline{V} - c - \pi \cdot w)} = \frac{[1 - r(\pi)] / r(\pi)}{[1 - \pi] / \pi} > 1$$

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

Figure 14.3 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 $V_S = 0$ indicates the true quota of defective items of supplier $S$. However, consumers expect a failure rate that corresponds to the slope of zero-profit line $V_S = 0$. 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 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 $S$, because the true rate of defective items is higher than the customers expected. The minimum price firm $S$ would claim for a full warranty contract is determined by point $Q$. The representative consumer values this offer with expected utility $EU_S$ and concludes that there exists a more valuable contract (utility $EU_S$) without a warranty indicated by point $T$.

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 $S$, 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 firms $S$ determined by point $Q$. Consequently, it should be expected that firms of type $H$ serve the market. However, just as the customers underestimate the rate of defective items of firms $S$, the rate of defective items of firms $H$ is underestimated by a factor of 3 (see line $V_H$).

The current offer of firms $S$, selling the product without a warranty as indicated by point $T$, leads to utility $EU_S$. The full-warranty contract indicated by $Z$ creates the same utility. Moreover, $Z$ is also a point on the indifference curve $EU_H$. Therefore we have: $EU_S = EU_H$. 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 $X$ is less than $EU_S$. So, the offer $T$ is preferred to $X$.

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, can the market failure 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 the 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, by the intensity of use or by buyers’

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12 Emons (1989b).
care, then partial warranties would fit 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. I expect that a third alternative will solve the problem with lower social costs: if firms are allowed comparative advertising, 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. Warranties are always limited in duration. Mostly, the warranty periods cover only a part of the lifetime of the 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.

According 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 of warranties are typical for retailing and commercial uses. Often these exclusions are directed against aggressive use or 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 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

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13 Priest (1981); Kambhu (1982); Cooper and Ross (1985).
15 See Priest (1981, p. 1319) for a detailed empirical investigation of warranty contracts.
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 electronic adjustments on the part of the manufacturer, as well as responsible behaviour 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) and Emons (1988). All these models assume that warranty promises are enforceable. Clearly, if warranties could not be enforced (compare Bigelow et al. 1993; Noll 2004), 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 \( y \):

\[
d(x, y) = \pi(x, y) \ast L
\]

Furthermore, let \( \pi_x < 0, \pi_{xx} > 0, \pi_y < 0, \text{ and } \pi_{yy} > 0 \). The representative consumer is risk neutral. Let us assume that his willingness to pay for an intact item is \( q \). His utility is measured in money terms and equals his willingness to pay. Then the expected utility is:

\[
EU = q - \pi \ast (L - w) - y - p
\]

The seller’s profit is:

\[
V = p - x - \pi \ast w
\]

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

\[
- \pi_x(x, y) \ast L = 1 \text{ and } - \pi_y(x, y) \ast L = 1
\]

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

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

\[- \pi_x(x, y) * w = 1 \text{ and } - \pi_y(x, y) * (L - w) = 1\]

A comparison with the Pareto conditions reveals a degree of tension. Pareto-optimal quality investments by the manufacturer require a warranty level of \(w = L\), whereas Pareto-optimal care-taking by the consumers presupposes a level of \(w = 0\). Therefore, a joint surplus-maximizing allocation is impossible;\(^{16}\) a 'second-best' solution will be the outcome.

Let the functions \(x^*(y, w)\) and \(y^*(x, w)\) describe the 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 \([x^o(w), y^o(w)]\) denote the point of intersection of both functions. It represents the Nash equilibrium for the non-cooperative part of the game. When jointly arriving at a conclusion about the level of the warranty, both parties anticipate their reciprocal pattern of unobserved behaviour (Cooper and Ross 1985, p. 109). They consequently maximize their joint surplus under the restriction of the Nash equilibrium, described above:

\[
\max_w EU + V = q - \pi * L - x - y
\]

subject to \(x = x^o(w)\) and \(y = y^o(w)\).

The first-order condition requires:

\[
x^o'(w) * \left[ - \pi_x(x, y) * L - 1 \right] + y^o'(w) * \left[ - \pi_y(x, y) * L - 1 \right] = 0
\]

According to the first-order conditions of unobserved party behaviour, we have: \(- \pi_x(x, y) = 1/w\) and \(- \pi_y(x, y) = 1/(L - w)\), respectively. Therefore the first order condition is:

\[
x^o'(w) * \left( \frac{L}{w} - 1 \right) + y^o'(w) * \left( \frac{L}{L - w} - 1 \right) = 0
\]

On condition that \(x^o' > 0\) and \(y^o' < 0\), the outcome will always be a partial warranty which, on the one hand, is greater than zero, but, on the

\(^{16}\) See Cooper and Ross (1985, p. 107).
other hand, is less than one. Namely, if the degree of warranty coverage \( w/L \) converges to one, the first term of the above equation vanishes. The derivative is thus 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 for party behaviour, the conditions of \( x^{\sigma'} > 0 \) and \( y^{\sigma'} < 0 \) are not always fulfilled. Its validity depends on the magnitude and the sign of \( \pi_{xy} \) (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 legal rules can be designed 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 paying the warranty, loses the same amount the buyer gets. According to Kambhu (1982), no legal warranty rule exists which offers both parties 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, 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 from the set of a high and a low level of care, consumers will choose the low level. 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. Emons’s (1988) last result 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, buyers detect all possible shortcomings of the product. So it seems that the authors are really investigating 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 types 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 an incentive to make adequate quality investments.

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

Satisfied consumers reward 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 by price beforehand and if he kept the given warranty promise. A firm’s reputation in period $t$, then, is 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 consumers.

17 For further models of reputation with regard to product quality, see Ely and Välimäki (2003), MacLeod (2007), Hörner (2002).
A reputational equilibrium can be defined by four conditions (see 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: $(x_t, y_t) = R_t = (x_{t-1}, y_{t-1})$.
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 expected utility is:

$$EU_{qL} = q - \pi * (L - w) - y - p$$

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:

$$-\pi_y(x_{qL}, y_{qL}) * (L - w_{qL}) = 1$$

$$-\pi_x(x_{qL}, y_{qL}) * (L - w_{qL}) = p_x$$

$$\pi(x_{qL}, y_{qL}) = p_w$$

The optimal values of the three variables $y_{qL}$, $x_{qL}$, $w_{qL}$ do not vary with respect to the 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, customers will avoid him. Therefore that seller’s profit is

$$V_1 = p(x, w) - x_0,$$
where \( x_0 \) determines the costs of the minimum quality. If the firm keeps its reputation \( R_t \) permanently, it will earn profits during all subsequent periods. Using the interest rate \( r \), discounted future profits can be stated as:

\[
V_2 = \{ p(x, w) - \pi * w \} * (1 + r) / r.
\]

Defending the firm’s reputation requires profits \( V_2 \) to be at least as high as profits \( V_1 \). Therefore we have:

\[
p(x, w) \geq x + \pi * w + r \{ x + \pi * w - x_0 \}
\]

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:

\[
V_3 = x_0 - x - \pi * w + \{ p(x, w) - \pi * w \} / r.
\]

These profits are not allowed to exceed zero. It follows therefore that:

\[
p(x, w) \leq x + \pi * w + r \{ x + \pi * w - x_0 \}.
\]

If we compare the first condition above which prevents the seller from milking its reputation on the one hand and the second condition which assures that market entry is not profitable on the other hand, equality arises. The price function calculates the equilibrium prices 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 \( (1 + r) \pi \), 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 expected utility will only grow by a factor of \( \pi \) when switching to the other partial market. Consolidated with the price increase, the net effect is thus negative. Therefore, risk-neutral consumers will decide against the warranty.
With respect to this outcome, the first-order conditions of consumer behaviour will be simplified to:

\[- \pi_y(x_{qL}, y_{qL}) * L = 1\]

\[- \pi_x(x_{qL}, y_{qL}) * L = 1 + r\]

The important result therefore is: risk-neutral parties will approximately choose 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 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, the earliest learned experiences can be applied 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 applying the model to the real world, two additional effects have to be taken into account. On the one hand, consumers do not buy to order at the beginning of a new period, but at different points in time during a current period. Therefore learned experiences begin 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 until 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 in higher discount rates. Smaller deviations from the optimal quality investments can therefore be expected with regard to easily detectable 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 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 at 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.\(^{18}\)

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 chance to externalize failure costs to his buyers. Therefore buyers profit twice from an increase in the warranty coverage. First, 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 and Outlook
The purpose of this chapter is 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 as 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 firms’ rates of defective items. In this case, a 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

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\(^{18}\) Other explanations for this aspect are offered by Emons (1989b) and Cooper and Ross (1988).
and reality disappears. Certainly, specified partial warranties form the optimal 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.

Finally, we 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 lifts slightly and an additional step in the direction of the best of all worlds can be made.

However, within the European Community, EC Directive 1999/44, which aims at the harmonization of national warranty law amongst the member states, prescribes that all national legislations have to comply with a statutory minimum of warranty duration of two years. In addition, the EC Directive lays down the remedies which can be taken against the seller if the sold product is in a bad state and its sequence of application. After fruitless trials of subsequent performance – according to the choice of the buyer: subsequent delivery or subsequent improvement – or if the seller refuses, the buyer is allowed to rescind the sales contract or to claim a price reduction.19

Bibliography


Contract law and economics


