Double Moral Hazard: an Experiment on Warranties

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Abstract

The paper designs a two-stage experiment to analyze a market for durable goods with warranties. In such a market double moral hazard may arise as the seller can reduce (increase) the initial quality of the product sold, while the buyer can reduce (increase) the maintenance effort. In the first stage of the experiment we analyze the impact of the warranty on the equilibrium levels of the initial quality of the product and the effort of the buyer. In this respect, we show the suboptimality of the equilibria with warranty. In the second stage, we analyze the role of signaling and reputation in an intertemporal model. In this context the final quality of the product depends on whether quality and effort are complements or substitutes.

I. Introduction

The paper carries out an experimental analysis of the problem of double moral hazard arising in a context of asymmetric information. We focus on the seller-buyer relationship in the market for a durable good. The buyer does not know the "intrinsic" (initial) quality of the product at the time of purchase. By contrast, the seller does not know the true "identity" (characteristics) of the buyer. This asymmetric information determines a double moral hazard. Both producers and buyers take actions that influence the failure rate of the product, and both have an incentive to lower their inputs. Indeed, producers can reduce their costs by decreasing the initial quality of the product, while consumers can reduce their costs by reducing the maintenance effort. The analysis focuses on the incentive effects associated with the introduction of a warranty. This case is extremely interesting for the explanation of the double moral hazard phenomena and more generally for the behavior of economic actors in a context of asymmetric information. Indeed, asymmetric information characterizes most economic relationships. In fact, it is often the main motivation of these relationships.

The principal cases of double moral hazard are contractual arrangements involving profit (revenue) sharing, such as: franchising (see: Rubin, 1978), share cropping (see: Reid, 1977), licensing (see: Morasch, 1995), buyout agreement (see: Demsky, Sappington, 1991), wholesaler/retailer relationship (see: Romano, 1994), shopping centers/customers (see: Golosinski and West, 1995), incentive for workers inside the organization (see: Berkowitz and Kotowitz, 1993), money-back contracts (see: Mansoob and Murshed, 1994), commercial leasing and author/publisher contracts, and in the more general case of joint production.

The papers by Rubin (1978) and Reid (1977), for instance, refer, respectively, to franchising and share cropping analysis. Rubin (1978), building on previous work by Alchian and Demsetz (1972) and Jensen and Meckling (1976) on monitoring and control with the firm, proposes an explanation of franchising that is alternative to the capital market explanation. He shows that franchising is frequent when it is not physically possible for the franchiser to monitor the franchisee[1].
In his view, franchising is a form of solution to the monitoring and control problems.
Reid (1977) analyzes the landlords – share tenant relationships, arguing - in contrast to traditional theory - that sharecropping is an efficient contract[2].

The focus of this paper differs from that of the previous literature, as we consider the relationship between sellers and buyers of a warranted durable product. Section II briefly reviews the theory of double moral hazard. Sections III and IV describe the design and the result of our experimental analysis.

[1] The franchisor is a parent company that has developed some product or service for sale; the franchisee is a firm that is set up to market this product or service in a particular location.
[2] In the traditional theory, share-farmed lands yield less, for share tenants stint their effort.

II. The Theory of Double Moral Hazard

Double moral hazard may occur when two or more economic actors are engaged in a joint production, which is in the determination of a common outcome. We focus on the market for a durable good with warranty. In this environment the performance of the product is determined by the actions of the two agents (buyer and seller). Buyers take actions, which influence the performance of the product. The effects of warranties have four main dimensions. Indeed, warranties may act as (1) an incentive mechanism (for both sides of the market); (2) an optimal risk sharing; (3) a signaling of high quality product; and, finally, (4) a quality assuring mechanism. We review in turn these four dimensions.

1. Incentive mechanisms

The role of warranties as incentive mechanisms is studied by Cooper and Ross (1985), who developed a model in which the performance of a warranted durable product is jointly determined by the actions of consumers and producers. They discuss the effects of imperfect information, and the attendant double moral hazard, on the levels of effort exerted by consumers and on the quality offered by producers. Focusing on the second best non-cooperative solution, they show that the inefficiencies brought about by the double moral hazard crucially depend on whether the initial quality of the product and the effort devoted by the buyer are complements or substitutes.

Their analysis highlights three main characteristics of contracts with warranties. (i)Warranties represent a partial coverage for the failure of the product; (ii) warranties are generally offered by the producer and not by independent insurance companies; (iii) there is no explicit link between quality supplied and warranty offered.

Cooper and Ross focus on the non-cooperative solution, as the first-best cooperative solution is not feasible because of asymmetric information. The solution of the model is a contract between the seller and the buyer that defines both the price of the product and the warranty. Cooper and Ross assume that both producers and consumers are risk neutral. There is no certainty that the product will work after the purchase. The probability that the product will work is a function of the initial quality selected by the producer and of the maintenance effort exerted by the buyer after the purchase. Both inputs (quality and effort) have positive but decreasing marginal productivity. In the event of failure of the product, the warranty guarantees a compensation to the buyer. Expected total costs for producers are thus the sum of production costs and the expected payment of the warranty. The choice of maintenance effort and of initial quality affect both parties, directly through their respective cost functions and indirectly through the probability of product failure.

The full information cooperative solution is defined by the situation in which all elements of the contract (price, warranty, effort and quality) are determined cooperatively and thus jointly maximize the sum of the expected utility of consumers and the expected profits of producers. The cooperative solution is simply given by the combination of effort and initial quality that satisfies the equality between marginal costs and marginal benefits for both parties in the contract. It is worth noting that in general a cooperative solution is not necessarily unique and may even not exist.

When the determinants of the contract are not observable there is a problem of double moral hazard. As a cooperative solution is not feasible anymore, it is necessary to introduce agreements that serve as incentives to adopt “correct” behavior. This system of incentives is endogenously determined by the price and warranty. Cooper and Ross consider a two-stage game. In the first stage the level of prices and the value of the warranty are determined by a cooperative solution, while in the second, non-cooperative, stage prices and the warranty are taken as given and the players choose their supply of inputs in terms of effort and initial quality of the product. Because of the linearity of the problem, the equilibrium in the second stage of the game is independent of the level of prices, and only depends on the value of the warranty[3].

When the effort and the initial quality are determined non-cooperatively, the solution is given by the equilibrium reaction functions. For a given level of the warranty, buyers select the effort level that maximizes their expected utility, given their conjecture on the quality of the product. Similarly, the producer selects the level of quality that maximizes its benefits, for a given level of the warranty and his conjecture on the effort exerted by the consumer. The slopes of the reaction functions depend on the sign of the partial cross-derivatives of the probability of failure with respect to effort and quality. Therefore, the slopes depend crucially on the degree of complementarily or substitutability between effort and initial quality.

For a given level of the warranty, the model reproduces the results obtained by Kambhu (1982) and Mann and Wissink (1988)[4].
For a value of the warranty between zero and one (that is when the warranty is offered but its coverage is not complete), the second best solutions are inferior to the first best when quality and effort are complements (the partial cross derivative is positive), as both parties have incentives to lower their supply of inputs affecting the probability of product success or failure. The same result applies when the cross partial derivative is zero. By contrast, when quality and effort are substitutes results are ambiguous.

Our contribution in this paper is to verify empirically the relation between quality and effort in the presence of a warranty. Thus our empirical analysis tried to answer the question:

Q_1: are quality and effort complements or substitutes?

The analysis can be extended to an explicit dynamic setting, in which the level of quality is endogenously determined and the dynamics of the warranty can be explained. Indeed, to address key aspects of warranties, such as their duration and value, it is crucial to analyze a dynamic model, in which incentives are derived through an intertemporal optimization. In several cases the coverage of the warranty is strictly a function of time, as it falls from a constant level to zero at a given point in time. In some contracts, the warranty depreciates only gradually. In any scheme, a key question to be answered is why the duration of the warranty is partial? To answer to this question we examine next a few examples of multiperiod incentive problems.

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[3] It is thus possible to analyze the second stage of the game for an arbitrary couple of prices and warranty.
[4] The results by Cooper and Ross do not need the additional assumptions made by Kanbhu.

Cooper and Ross (1988) show that under certain conditions, a “two-period warranty” permits to achieve the first best solution. This is the first model that highlights the intertemporal effects of the presence of warranties. The authors emphasize the presence of an asymmetry between the care applied by the consumer and the quality controlled by the producer. Indeed, consumers decide about their maintenance effort during the whole life of the product, while producers choose the level of quality only at the moment of design and production of the good. This implies that the probability of success of the product essentially depends on the choice of effort. As a consequence of this asymmetry, the optimal warranty contract is given by a full-coverage warranty applied to a short time interval. In such a way the warranty maintains its function of positive signal of quality of the product at the time of purchase, while because of its short life, it is a deterrent for lowering the maintenance effort. The model is again a two-stage model, and the stages now represent two different periods. In the first period, the good is sold, and it will be repaired by the producer if it breaks down. The producer establishes the initial quality that will influence the performance of the product in both periods. Effort by the buyer is the other element affecting the performance of the product. The consumer picks two levels of effort, for period one and period two. The initial quality and effort enter separately in the probability function of success of the product. The assumption of separability (adopted as well in their first paper, Cooper and Ross, 1985) greatly simplifies the analysis of incentives. Indeed, separability allows them to solve separately the equations resulting from the joint maximization of the expected utility of consumers and expected benefits of producers. This implies the absence of strategic interaction between the two parties of the contract. Thus, they obtain a Nash equilibrium in dominant strategies. The contract specifies the price and the value of the warranty for the first and the second periods. It is shown that the first best solution cannot be implemented, in the presence of asymmetric information, if all three inputs, that is initial quality and effort levels in the two periods, are productive.

A warranty with decreasing coverage, ending before the death of the product, is an optimal solution. Therefore, only a differentiated structure of warranties is consistent with the solution of the incentive problem. In their example an optimal solution arises only when the level of warranty in the second period is zero.

However, as we will show below, their result does not appear very robust, as it hinges upon the concept of asymmetry, which is their only motivation for the study of incentives in an intertemporal setting. Furthermore, their assumption on separability appears inconsistent with empirical evidence, that suggests that the effort level is not independent of the intrinsic quality of the product.

The literature suggests other possible explanations for the life of warranties actually offered in the market. Emons (1989 a, and b) studies how a competitive market distributes warranty contracts when firms are not able to distinguish different types of consumers in terms of their maintenance effort. He shows that the problem of adverse selection determines a duration of the warranty that is shorter of the actual life of the products. As stated above, most warranty contracts imply a high coverage during a limited period. This structure is called “block warranty”[5].

[5] In the USA both the Mignuson-Moss Warranty and the Federal Trade Commission Act of 1978 establish that all consumer products with a price above 15 US$ should carry a written warranty.

Dybvig and Lutz (1993) develop a continuous time version of a dynamic model of warranties in the context of asymmetric information and double moral hazard. Within the set of multiple equilibria of the games they focus on the Nash equilibrium of the original game with elimination of strategies that are weakly dominated. Their main result relates to the optimality of the block warranty. Similarly to Cooper and Ross, they also indicate the asymmetry between the moral hazard for the consumer and for the producer, as the impact of the maintenance effort on the probability of failure of the product is cumulative. In sum, the contributions analyzed model the presence of the warranty as a mechanism to solve the problem of double moral hazard. The block warranty is optimal because by concentrating the coverage in the first period it maintains unaltered the incentives for producers (as the loss associated with low quality may be very high, given the short-lived but total coverage) and induces the incentives of consumers and the social incentives to coincide. The results of our empirical analysis confirm this conclusion.

We turn to a brief discussion of the possibility of implementing a first best solution in the presence of asymmetric information. It is very important to consider the role of incomplete information in the principal-agent relationship. In such a case it is interesting to verify the effects of an additional information. All forms of moral hazard arise because of the non-observability of actions and results.

In extremely simple situations it is possible to carry out an effective monitoring. In such cases, incorporating all information obtained in the contract, it is possible to reach the first best solution. However, information is usually very costly to obtain, and thus imperfect information is the rule. Nevertheless, empirically we can observe that imperfect information is used in the attempt to solve problems of moral hazard. As stated by Holmstrom (1992): “it is shown that any additional information about the agent’s action, however imperfect, can be used to improve the welfare of both the principal and the agent”[6]. These results explain the use of imperfect information in contracts (as described as well by Rogerson (1985), who shows that when a given public information can be used to infer, albeit imperfectly, the actions of one of the parties, it is optimal to use it when one designs and stipulates a contract). Kambhu (1982) discusses the problem of the observability, introducing two types of mechanisms: a balanced mechanism and an unbalanced mechanism[7]. He shows that it is possible to reach a solution “optimum optimorum” through an unbalanced mechanism. This type of mechanism is equivalent to a situation in which there is a third party who receives a compensation from the other two in exchange of a monitoring action (see: Macho and Castrillo (1991), for a similar view). Furthermore, Kambhu shows that in the class of unbalanced mechanisms it is possible to design an optimal contract that transforms the third agent in a voluntary participant and that produces payoffs higher than those for the case of balanced mechanism.

Mann and Wissink (1988) analyze cases of money-back contracts[8]. They develop a three-stage game. In the first (cooperative) stage players establish the price and a refund share; in the second stage (non-cooperative) players choose inputs in

[6] Homstrom presents a formulation that is similar to that in Mirlees (1974).

[7] In the balanced mechanism the price paid by the buyer equals the price obtained by the seller, while in the unbalanced mechanism the two prices differ.

[8] In which sellers promise to give back to consumers part of the price paid for the product when the product is restituted.

terms of quality and effort, while in the third and final stage consumers decide whether to return the product. This process allows to minimize the information necessary for the formulation of the contract and determines incentives in the presence of double moral hazard. The purchase price, the refund share and inputs are endogenously determined in the three-stage game and the presence of a third agent is not necessary. Finally, they show that only in the case of moderate uncertainty it is possible to establish a contract that determines incentives allowing to reach the first best solution.

The models analyzed above (Kambhu, and Macho and Castrillo) assumed that the performance of the product is observable without costs. This assumption seems to contradict the empirical evidence. If one assumes that performance is not perfectly observable or that there is a cost associated with observation, the above models are not valid.

Two additional important questions arise from the above analysis:

Q_2: Is it possible to design an optimal contract under DMH conditions?

Q_3: If it is possible, does this contract correspond to a block warranty?

2. Optimal risk sharing

Warranties may represent a form of insurance for risk averse consumers (as argued by Heal, 1977). The motivations for risk aversion may play a crucial role in the explanation of warranty contracts. The main point of the models discussed above was that the incentive effect rather than the insurance effect determines the warranty. For this reason they assume risk neutrality.

Uncertainty affects the demand function. Heal (1977) studies two distinct situations: one in which consumers and producers share the same information on the quality of the good, and another in which there is an asymmetric information, with an advantage for producers. The first situation refers to a market in which the quality is a random variable, whose probability distribution is known to both consumers and producers. Thus, the probability of failure is known but there is uncertainty on which of the products will actually fail. The second situation resembles the second-hand market, where the producers know perfectly the quality of the product (Akerlof, 1970).

When there is a warranty one can distinguish the incentive and the risk-sharing effects. Defining as optimal warranty the one that yields an optimal distribution of risk, a main result of Heal is tendency to excessive warranty offered by firms. Indeed, consumers are likely to be risk averse, while firms being large are likely to be risk neutral. According to Heal the optimum is achieved only after a redistribution of risk toward consumers, as firms tend to assume excessive risk. However, not all consumers are risk averse and those who are would ask a warranty with full coverage instead of the partial coverage offered by producers. The model by Heal, therefore, cannot explain a fundamental characteristic of warranties, namely the fact that they always offer partial coverage.

Thus two questions arise in this regard:

Q_4: Why does coverage fall over time?
Q_5: Why is the life of a warranty usually shorter than the expected life of the product covered?

3. Signaling mechanism

According to Emons (1989) firms that are not able to build reputation do not have incentives to produce high-quality product if there is no warranty. This is due to the fact that "lemons" can be produced at lower costs. Thus, Emons argue that warranties represent a deterrent for production of "lemons", as they penalize bad behavior on the part of producers. The main result of Emons is therefore that warranties are an incentive for producers to produce high-quality goods.

The literature on signals suggests that warranty and quality are positively related. For instance, Lutz (1989) show the existence of an equilibrium in which a warranty with limited coverage and a low price signal high quality. This type of equilibria is also found in our experimental analysis (experiment 1, section III), in which in a signaling game we find the presence of non intuitive equilibria. Empirical evidence seems inconsistent with the use of warranty as a signaling device.

Q_6: Is the warranty a good signal about quality?

Most warranties offer partial coverage and high-quality products are not always sold with warranties higher than those offered on low-quality goods. In Lutz (1989) a risk-neutral monopolist produces a good with exogenous and fixed quality and sells it to risk averse consumers. The probability of failure of the product depends on its quality and on the effort exerted by consumers. This effort cannot be observed by producers or by a third party, and thus the warranty offered cannot be related to effort. The results of the model confirm that the presence of a warranty does not imply a positive relation between warranty and quality.

4. Quality-assuring mechanism

Whenever consumers cannot evaluate the quality of products prior to their purchase, producers might find it convenient to reduce the quality of their products in order to get a short-term gain, before consumers have the chance to assess their "actual" quality.
The only way to keep this quality decrease under control is by introducing a price-based premium. In the frequent and realistic occurrence that the quality of products cannot be assessed prior to their purchase, it might be surmised that consumers will use the quality of the firm's just production to judge present quality.
In this situation, the choice to produce at different quality levels is made through a dynamic process. Past production quality is used as a signal to determine present quality.
In this sense, reputation-making can be considered a signaling process. Thus firms define their own quality standard; which we might call "reputational quality".

The price for high-quality, high-reputation products, is higher than the price for products of the same quality, but lesser reputation.This situation clearly is an instance of market failure and a negative social externality.
In the short term, the high-reputation firm can have extrabenefits from a decrease in the quality of its production that implies a reduction in production costs.
Thus, the opportunity cost of keeping a certain quality level, must be integrally offset by an increase in the product prices compared to its actual value.
The concept of warranty can be treated like the variable that in Shapiro's (1983) model represents the minimum quality (under which it is illegal to produce). Thus one can show that this concept is completely marginal within a quality-assuring mechanism.
But, reputation rather than warranty is the sole quality-assuring mechanism.

III. Experimental Analysis

Asymmetric information (regarding the quality of a good or service) determines market failures, in terms of adverse selection and moral hazard.

"Lemon market" outcomes, in which inefficiently low quality goods drive out high quality goods, are observed.

When the buyer doesn't know the real quality of the product prior to purchase, the price that he would be willing to pay will not exceed the average value of a unit offered for sale. Consequently the owner of high quality items may not wish to sell at a price that represents only the average values between his product and a low quality product.

This situation determines a market failure called adverse selection (Akerlof, 1970).

In principal agent problems, the agent's incentive to take advantage of his superior information is called moral hazard.

As stated by Davis and Holt (1993): "the laboratory is a natural place to investigate the effects of information asymmetries."

Lynch et al. (1986) modify the standard double auction by including the endogenous determination of quality. They analyze a double auction with quality uncertainty.

In their experiment, the sellers have to choose the product quality level before trading. The asymmetric information, in terms of quality unknown to the buyers, generated inefficiencies, in terms of lemon-market outcomes.

Revealing sellers' identities was not enough to avoid an inefficient outcome. Only truthful advertising resolved the effects of quality uncertainty, and moved this market to efficient equilibrium.

Holt and Sherman (1990) refer to posted offer trading institution, in order to study lemons-markets outcomes.

The problem of moral hazard in a principal-agent context amplified inefficient performance. In the Holt and Sherman (1990) experiment, the sellers decided both price and quality (in terms of gradations) before buyers shopped.

The efficient average-quality grade was observed only in a full-information context.

The papers by Nelson (1970) and Davis and Holt (1990) refer to the corrective capacity of reputation to solve market failures, determined by asymmetric information problems.

This capacity is essentially context specific, depending on the amount of interaction between agents.

One way to resolve moral hazard problems is to let agents invest in costly observable signals.

Miller and Plott (1985) test signaling behavior in a double auction market.

They verify an excessive amount of signaling in order to obtain a separating equilibrium between high and low quality.

In an environment characterized by an asymmetric information in terms of unknown quality to the buyer, a warranty can compound the moral hazard problem into a double moral hazard. The seller can reduce the intrinsic quality while the buyer reduces his maintenance effort and obtains the warranty benefit in case of product default.

The fact that in a two-agent setting both of them can influence the results is extremely interesting for the analysis of agents' behavior under reciprocal asymmetric information environment. The asymmetric information characterizes a large part of economic relationships. It verifies agency and delegation relationships when we are in the presence of knowledge and capability gaps (in problem solving).

Product warranties have not always been interpreted in a double moral hazard. At first we have a one way asymmetric information relationship between seller and buyer: if bad products cost comparatively less than good products there is the possibility that bad products drive out good products, Heal (1976). A similar presentation had been proposed by Kambhu (1982) and Laffont and Maskin (1987), with an ex ante informative advantage by the seller (and in the extreme case of seller's (absolute) monopoly power, which comes about when the quality is unverifiable by the customer); if "lemons" can be produced at a lower cost, they yield higher profits to the seller.

However in order to obtain a solution it is necessary to postulate the impossibility of ex post verifiability of the product by the customer; and in this way it is necessary to assume the irrelevance of reputation building. Both for reasons of individual reconstructing and for reasons related to the possibility that other agents' choices depend on other people's choices, that another explanation can be advanced.

The argument goes as follows on this ex post basis. If expectation on quality can be confirmed after buying, reputation is established (or increased), see Shapiro (1983).

The presence of warranty is one out of many possible signals, and in anyhow the pure existence of a warranty is not necessarily a good signal for reputation (see again Shapiro, 1983).

Let q_1 and q_2 represent the quality (ex ante unknown by the customer) of the product without and with warranty, respectively, and p_1 and p_2 the respective prices. If:

$$Dq = q_2 - q_1 < p_2 - p_1 = Dp \quad \text{(i)}$$

Then the warranty is not a proper signal to reputation.

In any case, a risk averse customer can chose the warranted product when risk aversion premium exactly compensates the disequality (i), i.e.:

$$r \cdot Dq = Dp \quad \text{(ii)}$$

where $r \geq 1$ is a measure of the customer's risk aversion.

So warranties can possibly insure a risk-averse consumer when (i) can be converted into equation (ii), see Heal (1977).

Let us now suppose that q is a variable for the producer, and by lowering the quality level of the product the possibility of product failure increases. Then, the cost for the producer for providing an additional unit of warranty will also increase. In this case we have a "single" moral hazard.

According to Spence (1977), a "sufficiently large" warranty will provide producers the incentive to supply high quality products.

With reference to the quality of goods, Gale and Rosenthal (1994) present a model for an "experience" good in which once a reputation was built by a firm with respect to a customer.

The decay process of reputation goes slower than the correspondent process of consumer fidelity. In this case once the reputation has been built it cannot be reversed by any customer's behavior if the cycle high quality/low price, high quality/high price, low quality/high price is ex ante planned by the firms. So, if all firms start producing high quality products they will start selling them at low price, then they will increase the price and finally they will decrease the quality maintaining the high price.

However the pure existence of a given ex ante level of warranty *w* constitutes an incentive device for the customers to adjust (by reducing it in case of full insurance) the care using the product, when this care cannot be ex post observed by the seller.
The presence of warranties with different lengths can be interpreted by the customers as signals related to different quality *q* (see Lutz, 1989); moreover the customers can also reduce the maintenance effort *c* when the disutility of choosing high effort is larger than the increase in probability of product failure after the warranty expiration. This is a very simple case of double moral hazard.
In this environment Cooper and Ross (1985) assume the presence of risk neutral consumers (for whom equation (ii) is never realized). In this case warranties do not serve risk-sharing purposes. Warranty is an incentive device to characterize the equilibrium choices of quality and care.
Emons (1989) proposes different warranties levels that do work (under particular conditions) as a quality assuring mechanism that must also be incentive compatible.
In a successive paper, Dybvig and Lutz (1993), after demonstrating that not only the level of the warranty protection but also its structure affects the buyers' and sellers' choice propose a block warranty as the best attainable solution.

In such a framework we have designed two experiments, in order to obtain reasonable answers to questions Q_1- Q_6:

Q_1: Are quality and effort complements or substitutes?
Q_2: Is it possible to design an optimal contract under DMH conditions?
Q_3: If it is possible, does this contract correspond to a block warranty?
Q_4: Why does coverage fall over time?
Q_5: Why is the life of a warranty usually shorter than the expected life of the product covered?
Q_6: Is the warranty a good signal about quality?

In particular we have designed the first experiment to find a solution to Q_6, and the second experiment to answer questions Q_1-Q_5.

EXPERIMENT 1 (procedure and design)

There is a tentative answer to question Q_6 that works as follows: let us suppose that we have several distinct sellers that provide goods of different qualities. In this case the firms offering high quality goods will also offer a more complete warranty, because of the lower probability of default for the high quality goods. The warranty will also be less costly if buyers cannot influence the quality of the product, thus it is considered exogenously given.

Under these particular conditions warranty must be considered from the point of view of a high quality firm as a cheaper signaling.

Our experiment presents a one-way information process from producer/seller to buyer/customer.

Under this peculiar condition (of an exogenously given quality) it is possible to derive a signaling equilibrium solution.

The experiment consists of a series of matching, with each subject being paired with a different partner. Six undergraduate students, half of them having the role of sellers and the other half having the role of buyers, distributed in two rooms[9]. In each room participants have the same role. Subjects are randomly paired with another partner in different sessions, and they do not know the real identity of the partners.

The experiment consists of a two-stage game. First the seller decides to assign the warranty or not and then the buyer decides the maintenance level.

The seller knows the real quality of the product (high/low quality). The buyer knows only the market distribution of low (1/3) and high (2/3) quality products.

The payoffs of the game are common knowledge, and they are given at each terminal node (8 nodes)[10].

We consider an application of the Brand and Holt (1992) experimental design, considering the analogy with the job-market (Spence, 1973)[11].

Theoretical analyses indicate that there are often many sequential equilibria in these signaling games due to the many inferences that the second player could make after observing the first player's signal choice.

We tested two possible signaling equilibria: separating equilibrium and pooling equilibrium.

If the cost of signaling is significantly lower for the high quality seller, then occurs a separating equilibrium in which the buyer can infer the unobservable quality from equilibrium signals.

Separating equilibrium allows for discrimination amongst unknown qualities. In this situation, the payoffs are able to distinguish perfectly, through a signal, the two types of sellers, high and low quality, in terms of dominant strategies. In this context, warranty is perfectly correlated with quality.

In order to detect the effects to the agents' behavior under different equilibria, we presented two different outputs schemes.

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9 Subjects were recruited from undergraduate classes at The University of Siena, Italy.

10 The payoffs were made in Italian currency. Subjects received 5,000Lire as initial payment in addition to all cash earnings obtained during the sessions.

11 We explicitly used terms such as: high quality, low quality, warranty, no warranty, maintenance, and no maintenance, to indicate all possible options.

Separating equilibrium payoffs scheme:
High quality (2/3):{w,m}=(2000,1250), {w, no m}=(1200,750),
{no w,m}=(1000,1250), {no w,no m}=(200,750);
low quality (1/3): {w,m}=(1000,750), {w,no m}=(200,1250),{no w, m}=(2000,750),
{no w,no m}=(1200,1250).
Pooling equilibrium payoffs scheme:
High quality (2/3): {w,m}=(**1400**,1250), {w,no m}=(**600**,750),
{no w,m}=(1000,1250), {no w,no m}=(200,750);
low quality (1/3): {w,m}=(1000,750), {w,no m}=(200,1250),{no w, m}=(**1400**,750),
{no w,no m}=(**600**,1250).

The payoffs are given at each terminal node, given the product quality, each combination of decisions leads to an outcome and an associated pair of payoffs[12].

Separating equilibrium payoffs differentiated the two types of sellers in terms of dominant strategies: “no warranty” is a dominant strategy for a low quality seller; “warranty” is a dominant strategy for a high quality seller.

By reducing the marginal value of the warranty, that represents the cost of signaling (from 1000 to 400), we determined two (theoretical) pooling equilibria: (i)both types of sellers (high/low quality) choose “warranty”, and buyer responds to “warranty” with “maintenance”, and to “no warranty” with “no maintenance”; (ii)both types choose “no warranty” and buyer responds to “no warranty” with “maintenance” and to “warranty” with “no maintenance”.

Both are sequential Nash equilibrium, in terms of consistency of beliefs and best responses.

The second pooling equilibrium can be ruled out by applying the notion of equilibrium dominance on which the “intuitive criterion” is based (Cho and Kreps, 1987).

Thus equilibrium elimination criterion is based on the notion of “reasonability”.

Equilibrium dominance involves an analysis of out-of-equilibrium beliefs by making a comparison of a player’s equilibrium payoff with the best payoff that could be obtained by deviating.

The first equilibrium (i) is supported by reasonable beliefs that a deviant sending the message “no warranty” (out-of-equilibrium message) is more likely to be of type “low quality”.

The second (ii) pooling equilibrium is unintuitive because the “no maintenance” response of the buyer to deviation is unreasonable. The implicit out-of-equilibrium beliefs are that a deviant that offered a warranty is a “low quality” seller. However the high quality seller is more likely to be a deviant, because he could increase his payoffs by deviating to “warranty”. In pooling equilibrium context, the signal is useless, and the buyer has to rely on prior beliefs (in our case, they are expressed in terms of market distribution of low (1/3) and high (2/3) products).

[12] Where: (seller’s earnings, buyer’s earnings), w=warranty, m=maintenance.

EXPERIMENT 2 (procedure and design)

We design and run a laboratory experiment in order to study a market for durable goods[13].

There is only one good in the market, and it is offered at each session with different warranty levels[14].

The market is composed of three participants[15]. The good can be of high or low quality. The quality is expressed in terms of the life of the good. The initial quality and the maintenance decision define the potential life of the good and its consumption value (which is represented by the participant redemption value).

A high quality good has a potential life of 10 years (periods), with a "good maintenance", and a life of 8 years with "bad maintenance"; a low quality good has a potential life of 7 years with "good maintenance", and 5 years with "bad maintenance".

The participants do not know the real quality of the good prior to purchase. However they know from the outset all possible values of the good through its potential life.

Once the good is on sale in the market, they have to make a purchasing offer based on conjectures relative to the initial quality of the good knowledge on the warranty level, and the redemption value scheme.

The participant that offers the highest price obtains the good.

After purchasing, the owner knows the real quality and the potential life of the good; he then has to decide how long he wants to hold the good and has to define the maintenance effort for each period. He could sell the good after at least one period, obtaining the highest price offered in that period.

It is possible that the good breaks before its normal life, and this probability is higher for the low quality good.

Each participant has a starting bank, which can be spent to purchase the new good (in the first period) and for the used good (in the following periods). The starting bank devaluates at a constant rate in all periods in which the participant does not obtain the good.

The life of the good depends on the initial quality and on the owner's maintenance decisions. In other words the maintenance effort is productive in terms of the final quality. A "good maintenance" has a cost for the owner of the good, while the "bad maintenance" does not imply any further expense.

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[13] The experiment was run on a local area network, with no external access. The agents were connected to a server with a browser (Netscape Navigator 3.0). The transactions were registered in real time in a database residing on the server.

For each transaction the offer value and the name of the agent were recorded on the occasion of a purchase, the database also archived the information relative to the maintenance of the product. The screen was designed with technology that permits interactions between agents, shows the information relative to an agent's status (for example wheter an agent has a product in a particular moment), and provides immediate connection with a remote database, both in writing and in reading. In the specific case we used Microsoft Access 97 on a server with Windows NT 4.0.

On the interface, we used various scripting programs: JavaScript, for the form's validation and the cash flow, ASP (Active Server Pages, by Microsoft) in order to detect agent information; and Internet Database Connector (Microsoft) for the connection to the database with query SQL.

[14] The warranty level is exogenously determined. And it is of 0-2-3-5 periods.

[15] Subjects are recruited from undergraduate classes at The University of Siena, Italy.

The owner may obtain the money back (the purchasing price) if the good breaks before the warranty expiration.
The experiment consists of a preliminary competition (bidding) for the good offered by the “machine auctioneer” and following trades for the second-hand good.
If the good is not broken, the session continues until trade is verified.
The participant’s final earnings depend on the value of the final bank.
The final bank is: *FB* = P_s + *total redemption values* - P_p - *maintenance costs*, in the case in which the participant resells the good; *FB* = *total redemption values* – P_p - *maintenance costs*, in the case in which the participant holds the good for all its life; *FB=IB* (devaluation rate)*(total product life)*, in the case in which the participant does not succeed in purchasing the good through its entire life (note: Where *FB* indicates the final bank, P_s = selling price, P_p = purchasing price, and *IB* = initial bank.).

IV. Experimental Results

The first experiment confirms the result of Spence (1977) and Grossman (1981): (a)warranty is a signal of high quality; (b)firms with high quality goods will offer more complete warranties.
However, this result crucially depends on the assumption of exogenous quality.
The second experiment endogenizes quality. Incentives for the sellers are affected by the interaction between quality and the effort of maintaining the product.

EXPERIMENT 1 (results)

We test two possible signaling equilibria: separating equilibrium, and pooling equilibrium.
Table A1 (Appendix1) shows how:

$R_{1:}$	All high quality products are offered with warranty.
$R_{2:}$	33% of low quality products are offered with warranty.
$R_{3:}$	17% of buyers respond to a warranted product with “no maintenance”.
$R_{4:}$	Only one buyer responds to a no warranted product with “maintenance”.

The results R_1 and R_2 derive from sellers’ choices, while R_3 and R_4 derive from buyers’ responses to sellers’ signals.
We test the equilibrium adjustment process using a logit analysis of the trend pattern of change over successive trials.
The dependent variable “Rational” assumes a value of one when the seller chooses warranty in presence of a high quality product and no warranty in presence of a low quality product and buyer chooses maintenance in presence of a warranted product and no maintenance in presence of an unwarranted product, and assumes a value of zero in all other possible situations.

The variable t refers to trial t=1,2, …, 27 , and the variable "Equilibrium" is an indicator (dummy) variable which has value 1 if the game form represent a separating equilibrium and 0 if the game form represent a pooling equilibrium.

Regression Analysis
Dependent variable: "Rational"
LOGIT estimation

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
Equilibrium	0.03	0.99	0.03	0.97
Trials, t	0.25	0.12	2.08	< 0.04

EXPERIMENT 2 (results)

Table1 shows how:

R_5: 82% of the buyers respond to a high quality product with a high effort decision. Results a significant difference (82% - 67%) between the buyers' high effort responses to high quality products and high effort in presence of "lemons".

Table 1
Frequency of buyers' choices
of High/Low effort for Quality/Lemon goods

Quality / Effort	High effort	Low effort
High quality	82%	18%
Lemon	67%	33%

We implement a logit analysis in order to study the relation between quality and effort.
The dependent variable "Effort" assumes a value of one when the buyer chooses high effort and a value of zero when he chooses low effort.
The variable "Quality" equals one when the product is a high quality product and zero when it is low quality product.

Regression Analysis
Dependent variable: "Effort"
LOGIT estimation

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
Quality	0.62	0.27	2.29	< 0.02

These results confirm that quality and effort are complements.

The effects of the presence of the warranty to the buyer's choice of effort are illustrated in Table 2.

$R_{6:}$ The warranty is a partial solution to the double moral hazard problem.
The warranty works as an incentive mechanism (in terms of the buyer's effort) in presence of a high quality product, while it works as a disincentive in the presence of a "lemon".

Table 2
Frequency of buyers' choices of High/Low effort
for Warranted (Quality/Lemon) / No Warranted (Quality/Lemon) goods

Warranty/No Warranty	Quality	High effort	Low effort
Warranty	High quality	84%	16%
No Warranty	High quality	80%	20%
Warranty	Lemon	63%	37%
No Warranty	Lemon	83%	17%

Regression Analysis*
Dependent variable: "Effort"
LOGIT estimation

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
Constant	2.09	0.70	2.98	< 0.01
Quality	0.60	0.51	1.19	0.23
Warranty	- 0.56	0.67	- 0.84	0.40
Trials, t	- 0.34	0.12	- 2.74	< 0.01

*Observations adjusted for heteroskedasticity.

Considering the Price Dynamics analysis (see Appendix2) of different warranty levels:

R_7: Full warranty represents an inefficient solution.

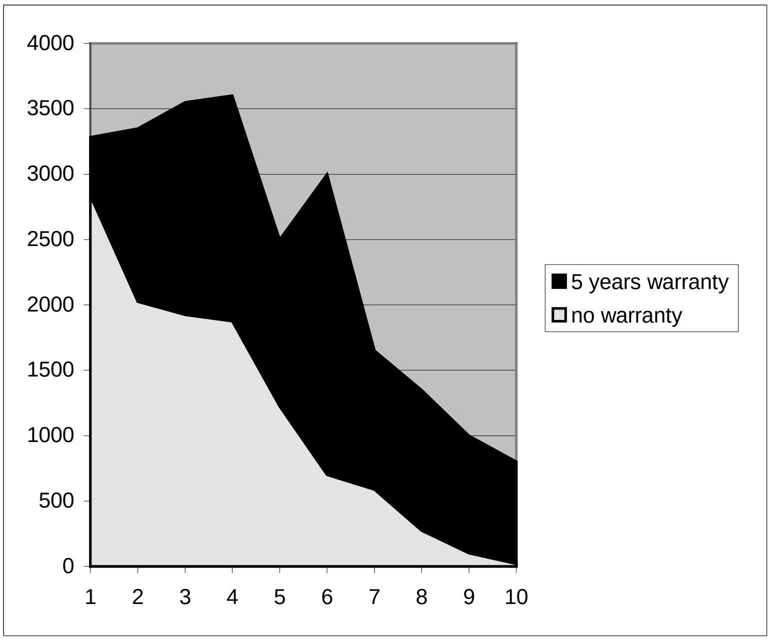


Fig.4

R_8: The block warranty is efficient.

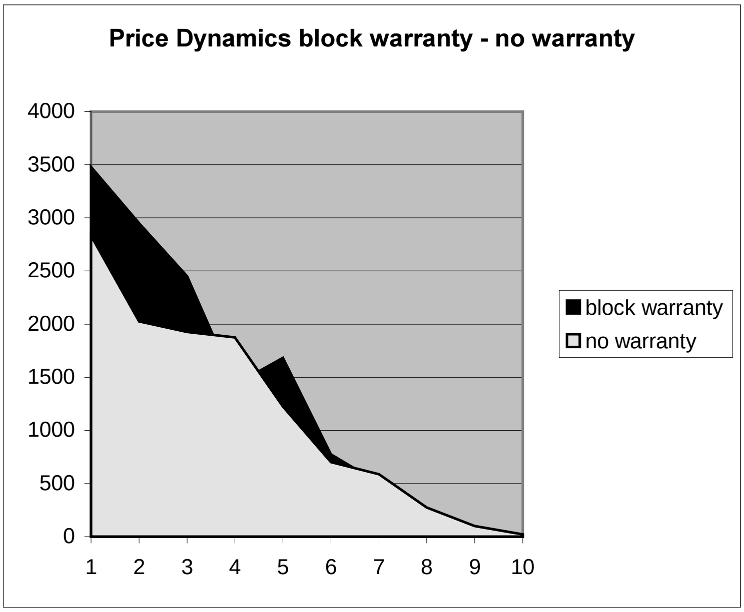


Fig.5

We test the efficiency of the various scenarios determined by different warranty levels (in terms of duration).
We consider the frequency of transaction as a measure of market efficiency.
We report four regressions (one for each warranty levels).

Regression Analysis
Logit estimation

Dependent variable: Transaction (no warranty)

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
Constant	- 17.2792	7.4676	- 2.31	0.02
Trials, t	1.7782	0.8337	2.13	0.04
Offers	0.0057	0.0026	2.23	0.03

Dependent variable: Transaction (block warranty)

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
Constant	- 18.6349	6.4601	- 2.88	< 0.01
Trials, t	2.0459	0.7767	2.64	0.01
Offers	0.0047	0.0016	2.81	< 0.01

Dependent variable: Transaction (three-year warranty)

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
Constant	- 1.44	0.5522	- 2.61	0.01
Trials, t	- 0.04	0.1430	0.33	0.74
Offers	5.70	0.0001	0.55	0.59

Dependent variable: Transaction (five- year warranty)

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
Constant	- 967.734	2.108543	- 0.05	0.96
Trials, t	72.948	1.582537	0.05	0.96
Offers	0.1986	4.382794	0.04	0.95

We can conclude that the block warranty represents the most efficient scenario.

Conclusions

With the first experiment we verify an equilibrium adjustment process, depending on the subjects experience in the game.

Our experimental analysis confirms the Camerer and Weigelt (1988) results: “after subjects have experience they play roughly like the sequential equilibrium (see: Kreps and Wilson, 1982), in which play is rational in every subgame of play from any point to the end, except they seem to have a ‘homemade’ belief about the prior probability of the other players’ payoff type, in addition to the prior probability we created in the experiment”.

The results, of the first experiment, crucially depend on these three assumptions:

1) Exogenous quality;
2) The buyer selects the maintenance level before knowing the intrinsic quality of the product.
3) Game of one period nature.

The result that a warranty is a good signal about quality is most readily applicable to the case in which product quality is exogenous. Indeed, to address key aspects of warranties, such as their duration and value, it is crucial to analyze a dynamic model, in which incentives are derived through an intertemporal optimization.

Empirical evidence seems inconsistent with the use of warranty as a signaling device, while the reputation mechanism is extremely more powerful than warranties, in the quality determination.

The second experiment is consistent with empirical evidence that shows: (a)the warranty is not an unambiguous signal of quality, and (b)that only partial coverage is offered.

Moreover, the second experiment is genuinely dynamic. Indeed, decisions about maintenance are repeated at different points in time.

Results show that quality and effort are complements. Thus, for a value of the warranty between zero and one (that is when the warranty is offered, but its coverage is not complete), the second best solution is possible.

Our main result relates to the optimality of the block warranty. Indeed, a warranty with decreasing coverage, ending before the death of the product, is an optimal solution.

The block warranty is optimal because by concentrating the coverage in the first period it maintains unaltered the incentives for producers, and induces the incentives of consumers and the social incentives to coincide. The results of our empirical analysis confirm this conclusion.

The price for a full warranted product is higher than the price for products of the same quality, but with a lower warranty level.

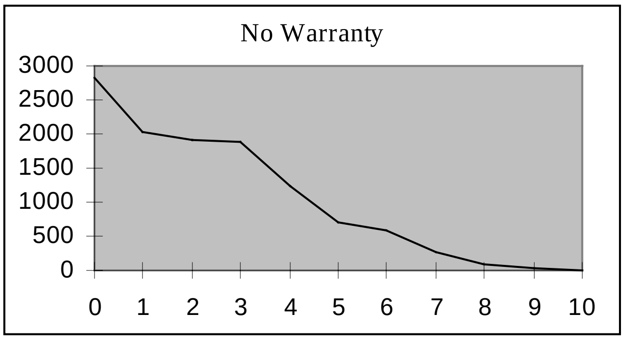
This situation clearly is an instance of market failure and a negative social externality.

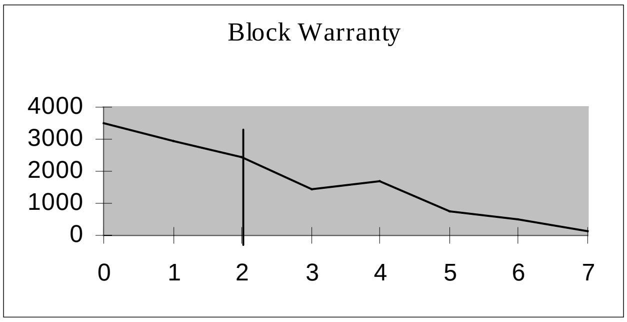
APPENDIX 1:

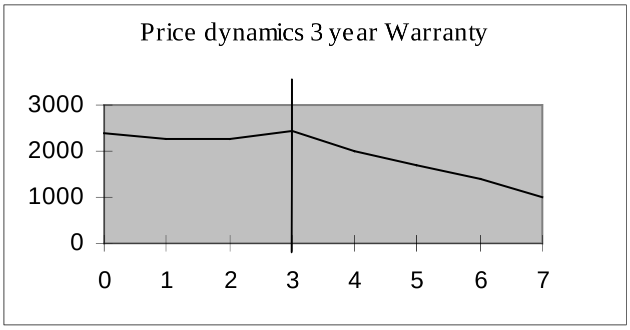
Table A1
Choices of Subjects
Experiment 1

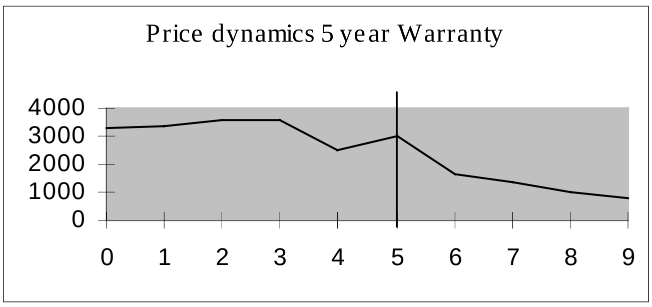
Equilibrium	Quality	Seller	Buyer	Sessions
Pooling	low	no warranty	no maintenance	1
Pooling	high	warranty	maintenance	1
Pooling	high	warranty	maintenance	1
Pooling	high	warranty	no maintenance	2
Pooling	low	warranty	maintenance	2
Pooling	high	warranty	no maintenance	2
Pooling	high	warranty	maintenance	3
Pooling	high	warranty	no maintenance	3
Pooling	low	warranty	maintenance	3
Separating	high	warranty	maintenance	4
Separating	low	no warranty	maintenance	4
Separating	high	warranty	maintenance	4
Separating	high	warranty	maintenance	5
Separating	low	no warranty	no maintenance	5
Separating	high	warranty	no maintenance	5
Separating	high	warranty	maintenance	6
Separating	high	warranty	maintenance	6
Separating	low	no warranty	no maintenance	6
Pooling	low	warranty	maintenance	7
Pooling	high	warranty	no maintenance	7
Pooling	high	warranty	maintenance	7
Pooling	high	warranty	maintenance	8
Pooling	high	warranty	maintenance	8
Pooling	low	no warranty	no maintenance	8
Pooling	high	warranty	maintenance	9
Pooling	high	warranty	maintenance	9
Pooling	low	no warranty	no maintenance	9

APPENDIX 2: Price Dynamics (Experiment 2)









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