

DOUBLE MORAL HAZARD: AN EXPERIMENT ON WARRANTIES

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1. Introduction

This paper carries out a theoretical and experimental analysis of the problem of double moral hazard arising in a context of asymmetric information. We focus on the seller-buyer relationship in a 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.

The focus of this paper differs from that of the previous literature on double moral hazard, as we consider the relationship between sellers and buyers of a warranted durable product. Section 2 reviews the theory of double moral hazard. The theoretical literature left unanswered several questions. The main object of this paper consists on finding some plausible explanation of the phenomenon of double moral hazard. We use the experimental method. Sections 3 and 4 describe the design and the result of our experimental analysis. In Section 5 we conclude the paper.

2. Survey of the literature on 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 a warranty. In this

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environment the performance of the product is determined by the actions of the two agents (buyer and seller).

The effects of warranties have four main dimensions. Warranties may act as (1) an incentive mechanism (for both sides of the market); (2) a risk-sharing contract; (3) a signal about product quality; and, finally, (4) a quality-assurance contract. We review in turn these four dimensions.

2.1 Incentive mechanisms

The role of warranties as incentive contracts 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; and the probability that the product will work is a function of the initial quality selected by the producer and of the maintenance effort 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 compensation to the buyer. Expected total costs for producers are the sum of production costs and the expected payout under 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 not even 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.¹

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, a buyer selects the effort level that maximizes her expected utility, given her 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 its 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 complementarity 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).² 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), because both parties have incentives to lower their supply of inputs that affect 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 research the empirical relationship between quality and effort in the presence of a warranty.

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

¹ It is thus possible to analyze the second stage of the game for an arbitrary couple of prices and warranty.

² The results by Cooper and Ross do not need the additional assumptions made by Kanbhu.

incentives are derived through an intertemporal optimization. In several cases the coverage of the warranty is strictly a function of time, because 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 limited? To answer to this question we next examine a few examples of multiperiod incentive problems.

Cooper and Ross (1988) show that under certain conditions, a “two-period warranty” theoretically implies 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 as a positive signal of quality of the product at the time of purchase, while because of its short life it is a deterrent to 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 to the contract. 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, because 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, 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 than 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.”³

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 theoretical contributions 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 now 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 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

³ 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.

(1982): “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.”⁴ 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 observability, introducing two types of mechanisms: a balanced mechanism and an unbalanced mechanism.⁵ He shows that it is possible to reach a solution “optimum optimum” through an unbalanced mechanism. This type of mechanism is equivalent to a situation in which there is a third party who receives compensation from the other two in exchange for a monitoring action (see Macho-Stadler and Perez-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 into a voluntary participant and that produces payoffs higher than those for a balanced mechanism.

Mann and Wissink (1988) analyze cases of money-back contracts.⁶ 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 terms of quality and effort, while in the third and final stage consumers decide whether to return the product. This process minimizes 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 that support the first best solution.

The models analyzed above (Kambhu, and Macho-Stadler and Perez-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 cannot be applied.

2.2 Optimal risk sharing

⁴ Holmstrom presents a formulation that is similar to that in Mirlees (1974).

⁵ 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.

⁶ In which sellers promise to give back to consumers part of the price paid for the product when the product is returned.

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 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 the optimal warranty of the one that yields an optimal distribution of risk, a main result of Heal is the 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 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. Therefore, the model by Heal cannot explain a fundamental characteristic of warranties, namely, the fact that they always offer partial coverage.

2.3 Signaling mechanism

According to Emons (1989, a), firms that cannot build a reputation do not have incentives to produce high-quality products if there is no warranty. This is due to the fact that “lemons” can be produced at lower costs. Thus, Emons argues that warranties represent a deterrent for production of lemons, because 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) shows the existence of an equilibrium in which a warranty with limited coverage and a low price signal high quality. This type of equilibrium is also found in our experimental analysis (experiment 1, section 3.1), in which in a signaling game we find the presence of non-intuitive equilibria. Empirical evidence seems inconsistent with the use of a warranty as a signaling device. 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.

2.4 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 past 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-reputation products is higher than the price for products of the same quality but lesser reputation. This situation is an instance of market failure and a negative social externality. In the short term, the high-reputation firm can have extra benefits 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.

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?

- Q₃: If it is possible, does this contract correspond to a block warranty?
- Q₄: Why does coverage fall over time?
- Q₅: Why is the life of a warranty usually shorter than the expected life of the product covered?
- Q₆: Is the warranty a good signal about quality?

In particular, we have designed the first experiment to find an answer to Q₆, and the second experiment to answer questions Q₁-Q₅.

3. Experimental Analysis

3.1 Procedures and design for experiment 1

Our first 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.

Fifty-four undergraduate students, half of them having the role of sellers and the other half having the role of buyers, were distributed in two rooms.⁷ In each room participants had the same role. Subjects were randomly paired, and they did not know the identities of their counterparts. The experiment consisted of a two-stage game. First, the seller decided whether to assign the warranty or not, and then the buyer determined the maintenance level. The seller knew the real quality of the product (high/low quality). The buyer knew only the market distribution of low (1/3) and high (2/3) quality products. The payoffs of the game were common knowledge, and they were given at each terminal node (8 nodes).⁸

We considered an application of the Brandts and Holt (1992) experimental design, considering the analogy with the job-market (Spence, 1973).⁹ 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 a separating equilibrium occurs in which the buyer can infer the unobservable quality from equilibrium signals. Separating equilibrium allows

⁷ Subjects were recruited from undergraduate classes at The University of Siena, Italy.

⁸ The payoffs were made in Italian currency. Subjects received 5,000Lire as initial payment in addition to all cash earnings obtained during the sessions.

⁹ We explicitly used terms such as: high quality, low quality, warranty, no warranty, maintenance, and no maintenance, to indicate all possible options.

for discrimination amongst unknown qualities. In this situation, the payoffs distinguish perfectly, through a signal, the two types of sellers, high and low quality, in terms of dominant strategies. In this context, a warranty is perfectly correlated with quality. In order to detect the effects on the agents' behavior under different equilibria, we presented two different output schemes (see *Table 1*).

Table 1 - Separating and Pooling equilibrium payoffs schemes

Quality	Seller's strategy	Buyer's strategy	Separating equilibrium payoffs	Pooling equilibrium payoffs
High quality	warranty	Maintenance	(2000, 1250)	(1400, 1250)
High quality	warranty	No maintenance	(1200, 750)	(600, 750)
High quality	No warranty	maintenance	(1000, 1250)	(1000, 1250)
High quality	No warranty	No maintenance	(200, 750)	(200, 750)
Low quality	warranty	maintenance	(1000, 750)	(1000, 750)
Low quality	warranty	No maintenance	(200, 1250)	(200, 1250)
Low quality	No warranty	maintenance	(2000, 750)	(1400, 750)
Low quality	No warranty	No maintenance	(1200, 1250)	(600, 1250)

The subjects were randomly assigned to two groups. In Group 1 we present the experimental task (see *Figure 1*) with the separating equilibrium payoffs, and in Group 2 we present the pooling equilibrium payoffs (see *Figure 2*). The payoffs were given at each terminal node. Given the product quality, each combination of decisions leads to an outcome and an associated pair of payoffs.¹⁰ Separating equilibrium payoffs differentiated the two types of sellers in terms of best responses: “no warranty” is the best response for a low quality seller; “warranty” is the best response for a high quality seller.

¹⁰ Where: (seller's earnings, buyer's earnings).

Figure 1 - Experimental Task (Experiment 1). Separating Equilibrium payoffs scheme

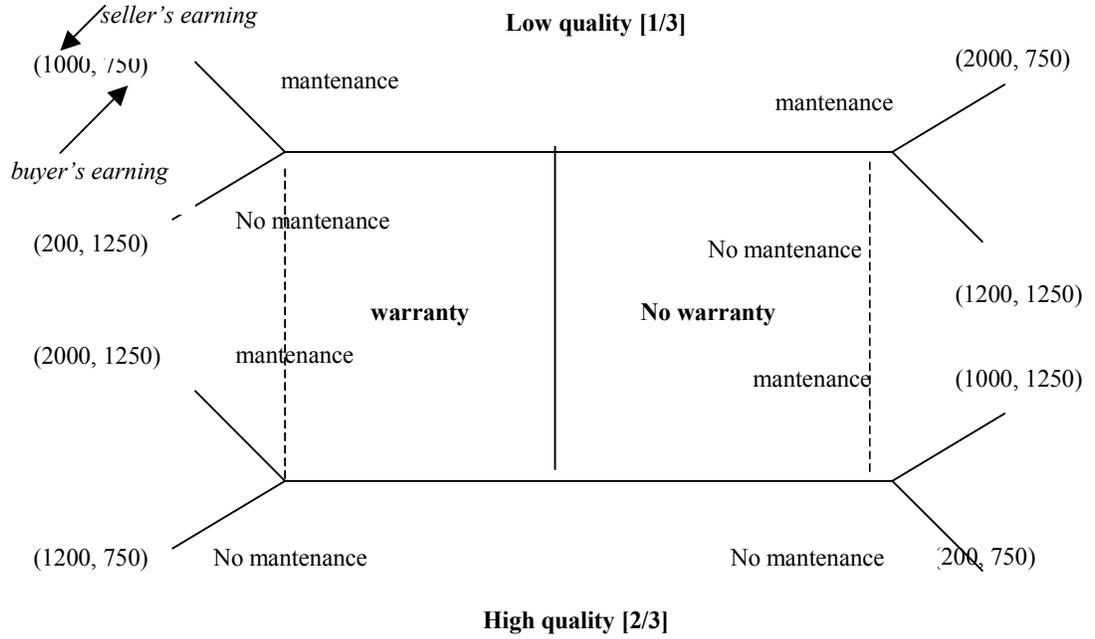
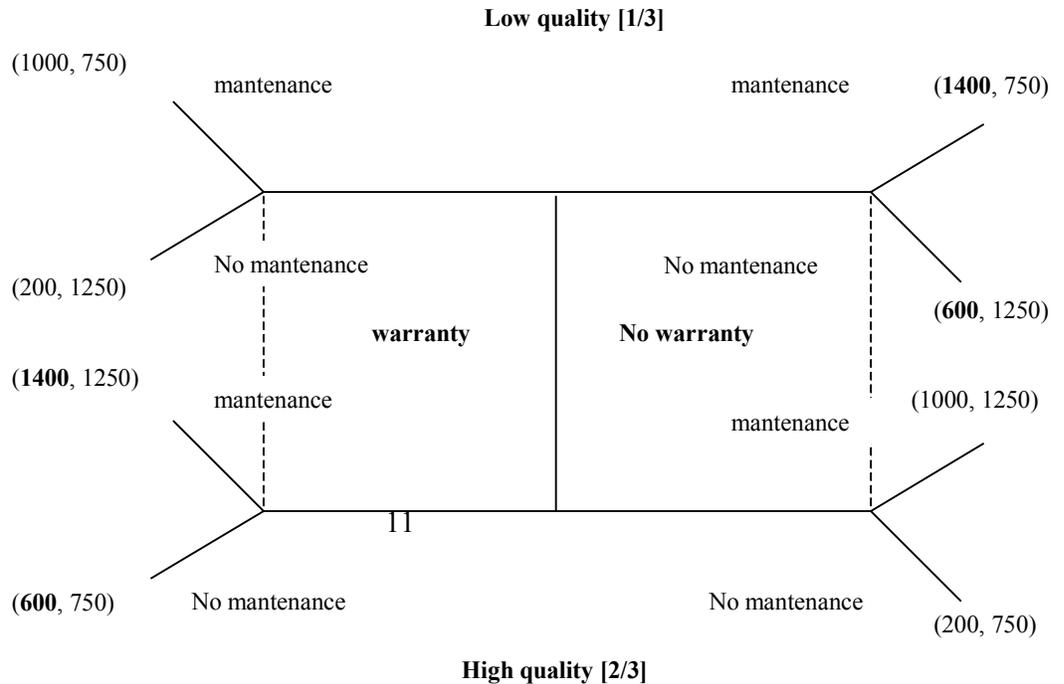


Figure 2 - Experimental Task (Experiment 1). Pooling Equilibria payoffs scheme



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 equilibria 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, the 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 the 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 the 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 a market distribution of low (1/3) and high (2/3) products).

3.2 Procedures and design for experiment 2

We designed and conducted a second laboratory experiment in order to study a market for durable goods.¹¹ There was only one good in the market,

¹¹ 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 whether 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. Place on the interface, we used various scripting programs: JavaScript, for the form’s validation and the cash flow,

and it was offered at each session with different warranty levels.¹² The market was composed of three participants. The subjects (39 students) were randomly assigned to one of the markets. The good could be of high or low quality. The quality was expressed in terms of the life of the good. The initial quality and the maintenance decision defined the potential life of the good and its consumption value (which is represented by the participant redemption value).

A high quality good had a potential life of 10 years (periods), with “good maintenance,” and a life of 8 years with “bad maintenance”; a low quality good had a potential life of 7 years with “good maintenance,” and 5 years with “bad maintenance.” The participants did not know the real quality of the good prior to purchase. However they knew from the outset all the possible values of the good through its potential life. Once the good was 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 offered the highest price obtained the good, as a first price auction. After purchasing, the owner learned the real quality and the potential life of the good; he then had to decide how long he wanted to hold the good and had 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 was possible that the good broke before its normal life, and this probability was higher for the low quality good.

Each participant had a starting bank, which could be spent to purchase a new good (in the first period) and a used good (in the following periods). The starting bank devaluated at a constant rate in all periods in which the participant did not obtain the good.

The life of the good depended on the initial quality and on the owner’s maintenance decisions. In other words, the maintenance effort was productive in terms of the final quality. A “good maintenance” had a cost for the owner, while the “bad maintenance” did not imply any further expense. The owner would receive the money back (the purchasing price) if the good broke before the warranty expiration.

The participant’s final earnings depended on the value of the final bank. The final bank was:

$FB = IB + P_s + \text{total redemption values} - P_p - \text{maintenance costs}$, in the case in which the participant resold the good;

$FB = IB + \text{total redemption values} - P_p - \text{maintenance costs}$, in the case in which the participant held the good for all its life;

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.

¹² The warranty level is exogenously determined. And it is of 0-2-3-5 periods.

$FB=IB * (\text{devaluation rate}) * (\text{total product life})$, in the case in which the participant did not succeed in purchasing the good through its entire life.

Where: FB indicates the final bank, P_s = selling price, P_p = purchasing price, and IB = initial bank.

4. Experimental Results

The first experiment confirmed the result of Spence (1977) and Grossman (1981):

(a) a warranty is a signal of high quality; and (b) firms with high quality goods offer more complete warranties. However, this result crucially depended on the assumption of exogenous quality. The second experiment endogenized quality. Incentives for the sellers were affected by the interaction between quality and the effort of maintaining the product.

4.1 Results for experiment 1

Table 2 - Observed choices. Experiment 1

Equilibrium	Quality	Seller's choice	Buyer's choice	Pair
Pooling	low	no warranty	no maintenance	1
Pooling	high	warranty	maintenance	2
Pooling	high	warranty	maintenance	3
Pooling	high	warranty	no maintenance	4
Pooling	low	warranty	maintenance	5
Pooling	high	warranty	no maintenance	6
Pooling	high	warranty	maintenance	7
Pooling	high	warranty	no maintenance	8
Pooling	low	warranty	maintenance	9
Separating	high	warranty	maintenance	10
Separating	low	no warranty	maintenance	11
Separating	high	warranty	maintenance	12
Separating	high	warranty	maintenance	13
Separating	low	no warranty	no maintenance	14
Separating	high	warranty	no maintenance	15
Separating	high	warranty	maintenance	16
Separating	high	warranty	maintenance	17
Separating	low	no warranty	no maintenance	18
Pooling	low	warranty	maintenance	19
Pooling	high	warranty	no maintenance	20
Pooling	high	warranty	maintenance	21
Pooling	high	warranty	maintenance	22
Pooling	high	warranty	maintenance	23
Pooling	low	no warranty	no maintenance	24

Pooling	high	warranty	maintenance	25
Pooling	high	warranty	maintenance	26
Pooling	low	no warranty	no maintenance	27

Table 2 shows how:

Result 1: All high quality products are offered with a warranty.

Result 2: 33% of low quality products are offered with a warranty.

Result 3: 17% of buyers responds to a warranted product with “no maintenance.”

Result 4: Only one buyer responds to a non-warranted product with “maintenance.”

Results 1 and 2 derive from sellers’ choices, while Results 3 and 4 derive from buyers’ responses to sellers’ signals.

We considered two signaling equilibria: separating equilibrium and pooling equilibrium. *Table 2* shows that 88% of the sellers and 78% of the buyers played according to the equilibrium solution. The predicted equilibrium outcome was achieved by 67% of the pairs.

4.2 Results for experiment 2

We used a Probit analysis of the data in order to study the relation between effort and quality (see *Table 3*). The dependent variable “Effort” assumes a value of one when the buyer chooses high effort, and a value of zero when she chooses low effort. The variable, “Quality” equals one when the product is a high quality product and zero when it is a low quality product. Additional variables are “Warranty” and “Trials.” The variable, Warranty assumes a value of one when the product is covered by a warranty, and assumes a value of zero in absence of a warranty. The variable, Trials indicates the period in which a decision is taken. The variable, “QW” is the interaction term between Quality and Warranty.

Table 3 - Regression Analysis. Dependent variable: “Effort”. PROBIT estimation.

VARIABLE NAME	COEFFICIENT	MARGINAL VALUE
Constant	1.29 (0.42)**	0.46 (0.14)**
Quality	0.62 (0.37)*	0.22 (0.13)*
Warranty	-0.17 (0.49)	-0.62 (0.18)
QW	-0.84 (0.64)	-0.32 (0.24)
Trials, t	-0.23 (0.77)**	-0.84 (0.28)**

Numbers in parentheses are Standard Errors.

* Significant at 10% confidence

** Significant at 5% confidence

Observations adjusted for heteroskedasticity.

These results confirm that quality and effort are complements. Having a good of high quality increases, on average, the probability of high effort by 13.36%.

This value has been calculated as follows:

$$\phi(0.22 \cdot \bar{Q}) \cdot 0.22 + \phi(-0.32 \cdot \overline{QW}) \cdot (-0.32)\bar{W} \quad (1)$$

where ϕ is the density function of the normal distribution, $\bar{Q}=0.59$ is the mean value of Quality; $\overline{QW} = 0.13$ is the mean value of QW; and $\bar{W}=0.27$ is the mean value of Warranty.

Result 5: Quality and Effort are complements.

This Probit analysis (Table 3) suggests that the presence of a warranty does not affect the probability of increase in the effort on maintenance.

Result 6: Warranty does not increase Effort.

We tested the efficiency of the various scenarios determined by different warranty levels (in terms of duration). We considered more efficient a scenario with lower offer prices. We conducted a Tobit estimation of the “Offers” on the different levels of warranty (see Table 4). The reference

group is No Warranty. The variables w2, w3 and w5 indicate, respectively, products with a two-year warranty, three-year warranty, and five-year warranty.

Table 4 - Regression Analysis. Dependent variable: "Offers". TOBIT estimation.

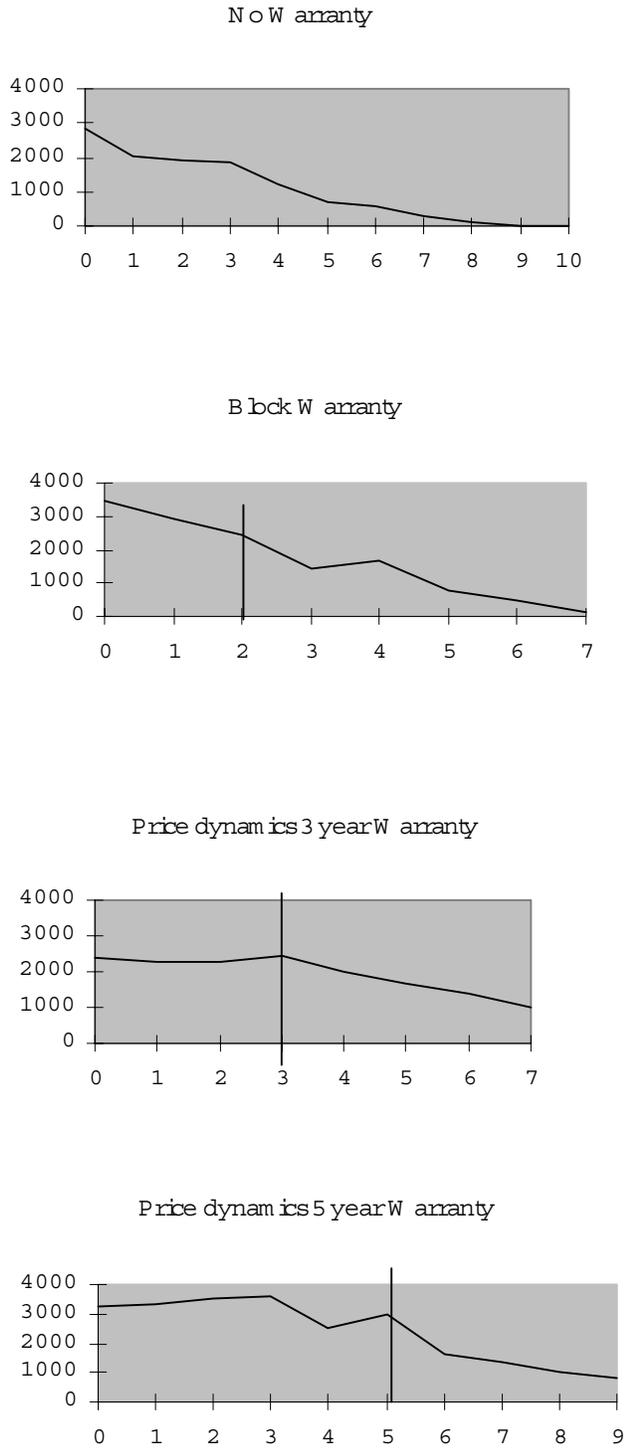
VARIABLE NAME	COEFFICIENT
Constant	2515.71 (138.89)**
w2	371.17 (149.72)**
w3	390.42 (139.74)**
w5	1191.56 (189.11)**
Trials, t	-296.22 (21.7)**

Numbers in parentheses are Standard Errors.

* Significant at 10% confidence

** Significant at 5% confidence

Figure 3: Price Dynamics of different warranty levels. Experiment 2



We conclude that the block warranty (w_2) represents the most efficient scenario. The price offer increases with the length of the warranty. Considering the Price Dynamics analysis (*Figure 3*) of different warranty levels:

Result 7: Full warranty represents an inefficient solution.

Result 8: The block warranty is the most efficient warranty-scheme.

The results on price dynamics show that 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 result indicates that buyers are willing to accept deviation from equilibrium price induced by sellers of durable goods with warranty. The size of the deviation is proportional to the length of the warranty.

5. Concluding remarks

The results of the first experiment crucially depend on these three assumptions: (i) exogenous quality; (ii) the buyer selects the maintenance level before knowing the intrinsic quality of the product; (iii) the game has a single period. 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 interaction. 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 provides experimental evidence that: (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 (see *Table 3*). 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 (see Cooper and Ross, 1988). 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. This result indicates that buyers will accept deviation from equilibrium price induced by sellers of durable goods with warranties. The entity of the deviation from equilibrium price is proportional to the length of the warranty (see *Table 4*).

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