Testing the « Lemons » Model: an Experimental Market for Insurance

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Abstract
Akerlof's (1970) classical paper demonstrated that adverse selection can eliminate markets. These findings by Akerlof gave rise to a proliferation of theoretical models on insurance with adverse selection. However, there exists no empirical test for the model of Akerlof in the context of insurance. In fact, it is not possible to observe a market a la Akerlof in a real context, since that market would have in fact disappeared. The main objective of this work is to test the predictions made by Akerlof, in the context of an experimental insurance market. This experiment is, to our knowledge, the first done in this area. The major interest of this experiment lies in that it allows us to bypass the usual obstacles for testing the model of Akerlof.

To fit in perfectly within the framework of analysis drawn by Akerlof, we integrate the assumption that individuals differ in their level of risk aversion (heterogeneity). Also, we allow for the possibility that the insurers adopt strategies of pricing contracts that differ according to the reasoning adopted. We conduct eleven independent experimental sessions in which two insurers in Bertrand competition interact over 60 rounds with height potential insurance contributors. The latter differ in their risk level and can not be differentiated by insurers. The data shows that market functioning depends on insurers’ reasoning (sophisticated versus naïve) and individuals’ risk-aversion levels. Yet, in line with the theoretical prediction, low-risk individuals are driven out of the insurance market.

Keywords: Information asymmetry, laboratory experiments and insurance microeconomics.

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Introduction

As early as 1970, Akerlof identified problems raised by the imperfect information relative to individual risks. Adverse selection disrupts the market: the “good ones” are excluded from the market. Then there may be no supply, or simply inefficient supply. These findings by Akerlof gave rise to a proliferation of theoretical models on insurance with adverse selection. However, the empirical literature on this topic is brief and provides few benchmarks. Indeed, there exists no empirical test for the model of Akerlof in the context of insurance. For, as Akerlof points out in his paper, insurance agents rely in practice to correcting mechanisms (franchise, risks classification, medical exams, etc.) in order to prevent their market from disappearing. As a result, it is not possible to observe a market a la Akerlof in a real context, since that market would have in fact disappeared.

Although there exists no empirical test for Akerlof’s model in the context of insurance, researchers have found ways to empirically test such model in other areas. The results of these tests differ according to the fields of application. Indeed, several empirical works [Pratt and Hoffer (1984), Lacko (1986), Chezum and Wimmer (1997) and Mocan (2003)] confirm the predictions made by Akerlof and conclude that there is a surplus of bad quality products and services in the markets. But other empirical studies [Bond (1982) and Genesove (1993)] have placed some doubt on the role that plays adverse selection by denying the hypothesis of over-representation of “lemons” in the markets in question.

The main objective of this work is to test the predictions made by Akerlof, in the context of an experimental insurance market. This experiment is, to our knowledge, the first done in this area. The major interest of this experiment lies in that it allows us to bypass the usual obstacles for testing the model of Akerlof. Also, our work aims at enriching the existing literature and at shedding some new light in this area of research.

In order to validate or refute a theoretical prediction by the means of an experimental analysis, it is convenient to remain as closely as possible to the conditions of the theoretical model. In our case, to fit in perfectly within the framework of analysis drawn by Akerlof, it would mean to be able to control for the preferences of the agents. Indeed, in the classical approach of the insurance markets, all people insured are assumed to be identical in all points, except for what concerns the likelihood of accident. The agents are therefore characterized by the same utility function and thus by the same risk aversion. It becomes then impossible to conduct the experiment in the ideal conditions of the theory. For that reason, we tried to modify the model of Akerlof by integrating the assumption that individuals differ in their level of risk aversion (heterogeneity). Also, we allow for the possibility that the insurers adopt strategies of pricing contracts that differ according to the reasoning adopted.

In this paper, we first present the theoretical model corresponding to our experimental context. Thereafter, we describe the experimental protocol of our experiment. The main results obtained are finally presented in the last two sections of this chapter.

I. The model

Consider an insurance market characterized by an asymmetry of information between insurers and potential insured individuals. The latter hold more information on their own level of risk than the insurers, which are not able to distinguish low risk individuals from high risk ones. Let us consider that there are only two types of individuals: low risk individuals (B) with a probability $q_B$ of filling a claim (in the occurrence of a disaster), and high risk individuals (H) with a probability $q_H > q_B$. Let $\lambda_i$ indicates the proportion of individuals of type i present in the insurance market, with $i = [H, B]$ and $\lambda_H + \lambda_B = 1$. All individuals (either B or H) face the same risk of losing X. Finally, these individuals cannot influence the likelihood of a disaster nor the amount of the damage.
Let us assume that each individual has a strictly concave utility function, and satisfies the Von Neumann-Morgenstern axioms. Hence, all individuals are risk averse and maximize their expected utilities. Let us suppose, moreover, that all individuals differ in their level of risk aversion: there exist as many levels of risk aversion as there are individuals in each class of risk. Those levels of risk aversion are undistinguishable by the insurers.

Each individual has the possibility to contract for insurance. Only one category of insurance is offered in this market: a complete insurance with full coverage of the disaster. Thus, in case of a disaster, each insured individual benefits from a total coverage of his losses, in exchange of an insurance premium $P$ paid to the insurer. Note that an individual $j$, whatever his class of risk, buys an insurance only if the maximum amount he wishes to devote to the insurance, $MA_j$, is greater than the premium $P$ charged by the insurer. Given the risk aversion of individuals, $MA_j$, is always greater than the actuarial premium $q_iX$.

In the other hand, the market for insurance corresponds to a duopoly where insurers are in competition a la Bertrand over prices. Insurers are risk neutral and maximise the expected value of their profits. Each insurer must set a premium for the complete insurance contract. Let $p_i$ be the insurance premium proposed by the insurer 1, and $p_2$, the insurance premium proposed by the insurer 2. Let $D_i(P)$ be the proportion of individuals of type $i$ having bought insurance, with $i = \{H, B\}$. If $d_i(p)$ indicates the proportion of individuals who have bought insurance from the insurer 1, hence: 

$$d_1(p_1) = \begin{cases} 
D_B(p_1) + D_H(p_1) & \text{if } p_1 < p_2 \\
\frac{D_B(p_1) + D_H(p_1)}{2} & \text{if } p_1 = p_2 \\
0 & \text{if } p_1 > p_2 
\end{cases}$$

The key idea of the competition a la Bertrand is that there exists a conflict between the incentives for high prices in order to realize high profits and the incentives for low prices in order to compete with the competitor. At the equilibrium, price equals marginal cost and profits are zero, even in the case of a duopoly (Bertrand, 1883).

In addition to price competition, the profitability of the proposed contracts depends on the percentage of risky individuals among the population of individuals who contracted for insurance. In setting the premiums, each insurer can adopt one of the following lines of reasoning:

1. A “naïve” reasoning: the insurer does not take into account the phenomenon of adverse selection in his contract pricing process. He considers that the proportion of risky individuals in the population of insured individuals is the same as the one in the market (i.e., does not vary with the premium proposed).

2. A “sophisticated” reasoning: the insurer takes into consideration the phenomenon of adverse selection in his contract pricing process. He considers that the proportion of high risk individuals in the population of insured individuals depends on the premium proposed.

Hence, the duopoly can be as follows: both insurers are naïve, both insurers are sophisticated or one of the two insurers is naïve.

**Case 1 : Both insurers are naïve**

Each insurer does not predict the effects of his action (premium) on the behaviour of the insured individuals, and thus on the profitability of the contracts. Only competition is taken into account in his pricing process. In fact, he does not anticipate the fact that at high premiums, low risk individuals chose to remain out of the market. Hence, naïve insurer will propose a premium equal to the average actuarial premium of the total population $\overline{q}.X$, where

1 The greater the difference between $MA_j$ and $q_iX$, the higher the level of risk aversion of the individual in question.
\(\tilde{q}\) indicates the average probability of a disaster in the whole population (\(\tilde{q}=(\lambda_{ii})q^i+(\lambda_{ii})q^e\)). When the proposed premium is equal to \(\tilde{q}.X\), all risky individuals in the market choose to buy insurance \((D_{ii}(\tilde{q}.X)=\lambda_{ii}\) since \(\tilde{q}.X<q_{ii}.X<MA_1<MA_2<...<MA_n\)); of the low risk type, only the most risk averse individuals choose to buy insurance in the market \((D_{ii}(\tilde{q}.X)<\lambda_{ii}\) since \(MA_1<MA_2<...<MA_k<\tilde{q}.X<MA_{k+1}<MA_{k+2}<...MA_n\)).

Given that the proportion of risky individuals in the population of insured individuals is greater than that of the entire population, the insurers are incurring losses. Indeed, the average actuarial premium of the entire population is lower than the average actuarial premium of the population of insured individuals. In order to absorb the losses, this contract will then be removed from the market for the benefit of a contract with a higher insurance premium. However, the same reasoning will lead to the disappearance of this last contract if the insurer still does not take into account the phenomenon of adverse selection in his contracts pricing process. The equilibrium is reached when the premium equals the average actuarial premium of the population of insured individuals. This latter range between the average actuarial premium of the total population \((\tilde{q}.X)\) and the actuarial premium of high risk individuals \((q_{ii}.X)\). At this level of premium, there is no profit. If no individual is willing to get insured at a premium equal to \(\tilde{q}.X\) since \(MA_1<MA_2<...<MA_k<\tilde{q}.X<MA_{k+1}<MA_{k+2}<...MA_n\), the theoretical equilibrium corresponds to the actuarial premium of high risk individuals \((q_{ii}.X)\).

**Case 2: Both insurers are sophisticated**

In opposition to a naïve insurer, any sophisticated insurer takes into account the heterogeneity in risk aversion levels and is conscious that, if he proposes a premium equal to \(\tilde{q}.X\), all the high-risk individuals will buy an insurance whereas only some low risks individuals will \((D_{ii}(P)\leq\lambda_{ii}\) and \(P=\lambda_{ii}\)). This over-representation of the high risks in the population of insured individuals would make the contract offered unprofitable. By a similar reasoning, each insurer can anticipate that any increase in the level of the insurance premium would result in excluding more low risk individuals without however reducing the losses generated by this contract. So, each sophisticated insurer can easily come to the conclusion that the only insurance premium guaranteeing nonnegative profits would be a premium equal to the actuarial premium of the high risks \((q_{ii}.X)\). If no low-risk individual buys insurance at this level of premium, then the actuarial premium of the high risks corresponds to the premium of the theoretical equilibrium with zero profits. If some low-risk individuals buy premiums equal to \((q_{ii}.X)\), then the profit generated by this contract is positive. Thus, the actuarial premium of the high risks cannot be equilibrium. Competition over prices between the insurers induces them to lower the insurance premiums. Equilibrium is reached when the premium offered is equal to the average actuarial premium of the population of insured individuals. At this level of premium, there is no profit.

**Case 3: One of the two insurers is naïve**

The functioning of the market as well as the equilibrium reached are the same as those observed when the two insurers are naïve. Indeed, since the naïve insurer is the one who proposes the lowest premiums, he will be the only one to sell contracts on this market.

It is interesting to analyze the effect of an increase in the proportion of the high risks on the market for insurance. Let us recall that the average actuarial premium of the total population increase when the proportion of high-risk individuals increases. If the insurers are naïve, the exclusion of the low risks will be all the faster as the value of average actuarial premium is high. On the other hand, if the insurers are sophisticated, a variation of the concentration of the market as high-risk individuals will not have any impact on the behaviour of the high and
low risks since the insurers start by proposing premiums which are equal to actuarial premium of high risks. We can thus conclude that the exclusion of the low risks is inescapable, as predicted by Akerlof. Nevertheless, its occurrence is all the faster as the insurers are sophisticated or as the proportion of the high risks is high.

II. The experiment

The experiment was carried out in March 2002 in the Bell university laboratories, experimentation centre - CIRANO in Montreal. The software used for the course of the experiment is "Regate". Overall, 110 people took part in this experiment, half of which are students in economics. We organized eleven experimental sessions. Each session lasted on average an hour and a half and proceeded in four stages. During the first stage, the participants answer a questionnaire aimed at inferring their level of risk aversion. This questionnaire enabled us to justify the assumption of the theoretical model according to which the individuals are heterogeneous from the point of view of their risk aversion. During the second stage, the participants answer “entertainment” questions to familiarize them with the procedure of the experiment. This second stage is preceded by the oral reading of the rules of the game distributed beforehand to the participants. During the third stage, the participants answer the questions of the experiment. This stage only begins once all the participants have answered the entertainment questions correctly. The fourth stage corresponds to the stage of remuneration of the participants. The latter receive an amount of money for their participation. The earnings of the participants depend partly on their decisions during the game and partly on chance. They are individually given to them at the end of the experiment. The participants earned on average twenty five Canadian dollars in one hour and a half of play.

Each experimental session corresponds to an insurance market including eight potential insured individuals (or customers) and two insurers in competition over prices. The institution of exchange adopted corresponds to the posted biddings. Only one insurance contract is offered on this market: a complete insurance. The distribution of the roles of insurers/insured is carried out by drawing lots at the beginning of the experiment.

On this experimental market for insurance, the demand for insurance emanates from two classes of risk: high-risk and low-risk individuals, which are indistinguishable by the insurers. The distribution of high risk/low risk types is carried out by drawing lots at the beginning of the experiment. The roles and the classes of risk assigned to the participants are maintained during all the session.

We carried out two treatments. The first treatment is characterized by an equal proportion of high and low-risk individuals. The market for insurance is then made up of four high-risk individuals, each of whom having 30 percent chances of losing 200 EMU (experimental monetary units), and of four low-risk individuals, each of whom having 10 percent chances of losing 200 EMU. The second treatment is characterized by a small proportion of high-risk individuals. The market for insurance is then made up of two high-risk individuals, each of whom having 30 percent chances of losing 200 EMU, and of six low-risk individuals, each of whom having 10 percent chances of losing 200 EMU. The first treatment proceeded in five independent sessions. The second treatment proceeded in six independent sessions. During each session, the participants know the proportion of high-risk individuals there is on the market.

Each market for insurance consists of sixty periods of exchange. At the beginning of each period of exchange, each insurer is given initially a sufficient endowment, so that he can sell as many contracts as he wants. In addition, all insured individuals are provided with the same initial endowment whatever their class of risk. The participants finance premiums, disaster and allowances, from their endowment.
Each period of exchange proceeds in three stages. During the first stage, each insurer must set a single insurance premium intended for all the prospective customers, whatever their class of risk. The insurer whose insurance premium is the lowest for a given contract will be the only one with the ability to sell this same contract during the period of exchange in progress. Only the lowest insurance premium is known to the insured individuals and to insurers. If, during the period of exchange, the two insurers propose the same insurance premium for the same contract, the computer chooses randomly which one of them will in effect be given the opportunity to sell the insurance contract. Let us note that there are no transaction costs and that the insurers are free to set higher or lower premiums than the actuarial level. During the second stage, each customer must decide whether or not to buy insurance. During the third stage, a lottery determines the customers who suffer disasters. The computer is then given the responsibility to calculate the final endowments of each customer and to post them on their screens. In the same way, each insurer is informed of the number of contracts sold on the market, of the paid allowances, of the profit earned and of his endowment at the end of the exchange period.

III. Aggregate results

We will present in what follows the principal results obtained. We will be interested successively in the behaviour of supply and demand for insurance in the various sessions carried out. The analysis will be done mainly on the basis of the average decisions of the insurers (premiums) and the agents (choice of insurance) in each of the eleven independent sessions carried out. By incorporating the data, we partly control for the heterogeneity of the individuals (mainly the risk aversion). For each statistical test we require a level of significance of 5%.

III.1. Supply of insurance

The average data relative to the supply of insurance are presented in table 1.

In what follows, we will analyze the insurance premiums offered by the insurers. Using non-parametric tests, this analysis will allow us to verify or deny the theoretical predictions of our model. In what regards the analysis of individual choices, the experimental protocols are always defined to some extent of questions or hypotheses that one seeks to validate. We retained the three following underlying questions:

1. What are the effects of a change in the proportion of the high risks on the premiums offered?
2. Do the observed insurance premiums converge towards the theoretical equilibrium?
3. Which process of contracts pricing adopts the insurers: naive or sophisticated?

The theoretical model agrees to saying that the operation of the market is likely to be affected by the concentration of the market as high-risk individuals if the insurers adopt a naive behaviour. It is thus natural to first analyze the effect of the treatment on the insurers' supply in order to better determine the pricing process of the insurers.

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2 Let us recall that the theoretical equilibrium corresponds to the average actuarial premium of the population of insured individuals. Because of competition, the profit earned at the equilibrium is equal to zero. If, as predicted by Akerlof, no low-risk individual is insured in the market, the theoretical equilibrium corresponds to the actuarial premium of the high-risk individuals.

3 If the convergence towards the theoretical equilibrium is done from top to bottom, they are then sophisticated insurers. If not, they are naive insurers.
Result 1: overall, the level of the insurance premiums is independent of the treatment, thus of the two proportions of high risks successively experimented (figure 1).

According to the U test of Mann Whitney, we cannot reject the hypothesis according to which the treatment does not have an effect on the average premiums offered in each session ($Z = -0.183; \text{Probability} >|Z|= 0.8548$). This first result indicates that the differential in the proportions of high risks of the two treatments does not lead the insurers to behave differently. This result suggests that the insurers adopt a sophisticated reasoning. In accordance with this first result, the next analyses will be done without distinction of treatment.

Result 2: From the first period of exchange, the insurance premiums are higher than the theoretical level.

The application of the Wilcoxon signed-rank test shows that the premiums offered in the first period of each experimental session are significantly higher than the average actuarial premium of the population of insured individuals ($Z = 2.134; \text{Probability} >|Z|= 0.0329$). This second result consolidates the idea according to which the insurers anticipate correctly that the low risks are excluded from the insurance market and thus suggests that they are sophisticated.

In what follows, we will try to analyze the convergence of the premiums offered towards the theoretical equilibrium. For this, we will proceed in the analysis of the evolution of the insurance premiums over time. Each sixty-period session of exchange is broken up into three equal and successive intervals, of twenty periods of exchange each I1, I2 and I3. The comparison of the average insurance premiums in each interval will inform us about the evolution of the supply of insurance over time.

Result 3: The premiums do not increase over time

Considering the level of the average premiums per session in each one of these three intervals, the application of the Wilcoxon signed-rank test on the average premiums shows that we cannot reject the null hypothesis according to which:

- The average premiums do not change according to whether one is in I1 or I2 ($Z = 0.000; \text{Prob} >|Z|= 1.0000$).
- The average premiums do not change according to whether one is in I2 or I3 ($Z = -0.222; \text{Prob} >|Z|= 0.8239$).

Thus, the level of the insurance premiums is stable over time. The stability of the premiums being shown, we will try in what follows to determine the equilibrium premium which emerges.

Result 4: The premiums are higher than the theoretical equilibrium (figure 2).

The application of the Wilcoxon signed-rank test shows that the average premiums per session are significantly higher than the average actuarial premiums of the population of insured individuals ($Z = 2.223; \text{Prob} >|Z|= 0.0262$). This result indicates that the insurers do not propose premiums equal to the theoretical equilibrium, namely the actuarial premium of the population of insured individuals.

Result 5: The premiums are equal to the actuarial premium of the high-risks.

As indicated by the preceding figure, the average premiums per session are not significantly different from the actuarial premium of the high risks. Indeed, the application of the Wilcoxon signed-rank test shows that we cannot reject the null hypothesis according to which the average premiums per session are equal to the actuarial premium of the high risks ($Z = 0.849; \text{Prob} >|Z|= 0.396$). Thus, premiums proposed converge towards the actuarial premium of the high risks $q_H X$. 
The difference that exists between the theoretical equilibrium and the premiums proposed can be explained by the fact that the average profits earned in each session are not significantly different from zero (Wilcoxon signed-rank test: $Z = -0.445; \text{Prob} > |Z| = 0.656$). Thus, the effective theoretical equilibrium inducing zero profits is above the actuarial premiums of the population of insured individuals. This equilibrium corresponds in our case to the actuarial premium of the high risks. We can thus consider that the insurers propose many premiums equal to the theoretical equilibrium.

III.2. Demand for insurance

The average data relative to the demand of insurance are presented in table 2.

The main hypothesis relative to the demand for insurance that we seek to test supposes that the problem of adverse selection causes the exclusion of low-risk individuals and, in extreme cases, the disappearance of the market. From this hypothesis, we retained the three following underlying questions:

1. What are the effects of an increase in the proportion of the high risks on the demand for insurance?
2. Is there ousting of the low risks from the insurance market?
3. Is there disappearance of the market?

In the reference model, when the proportion of high risks on the market increases, the exclusion of the low risks is all the more significant as the insurers are naïve. To take account of this key-variable that is the proportion of high risks, we applied two treatments, bringing into play two different proportions of high risks. We test, initially, the effect of the treatment on the demand for insurance.

Result 6: Overall, the choices of the insured individuals are independent of the treatment, hence of the two proportions of high risks successively experimented.

According to the U test of Mann Whitney, we cannot reject the null hypothesis according to which the treatment does not have a significant effect on:

- The average percentage of high-risk insured individuals in each experimental session ($Z = 0.64; \text{Prob} > |Z| = 0.5219$).
- The average percentage of low-risk insured individuals in each experimental session ($Z = 0.274; \text{Prob} > |Z| = 0.7837$).

This result is in accordance with Result 1 which stipulates that the treatment does not have an effect on the insurance premiums. Thus, the difference in the proportions of high risks of the two treatments does not lead the agents of the market to behave differently. In accordance with this last account, the next analyses will be done without distinction of treatment.

In what follows, we will analyze successively the average behaviour of the individuals of high and low-risk types. The objective is to measure the impact of adverse selection on the demand for insurance emanating from each class of risk.

Result 7: No ousting of the high risks

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4 In the theoretical model, we showed that the equilibrium corresponds to the actuarial premium of the population of insured individuals. This theoretical equilibrium rests on the implicit assumption that the law of the great numbers relative to the occurrence of disasters is verified. However, taking into account the reduced number of participants and of periods of play in an experimental context, this law is not always verified. Thus, it happens that the number of disasters experienced by the insured individuals is higher than the expected number of disasters (6 sessions out of 11). This situation causes losses for the insurers and leads them to set premiums higher than the actuarial premium of the population of insured individuals.
Considering the behaviour of the high risks in each of the three intervals I1, I2 and I3 previously defined, the application of the Wilcoxon signed-rank test on the average number of bought contracts gives the following results:

- The high-risk individuals buy as much insurance in I1 as in I2 ($Z = -1.87; \text{Prob} > |Z| = 0.0615$).
- The high-risk individuals buy as much insurance in I2 as in I3 ($Z = -1.204; \text{Prob} > |Z| = 0.2284$).

The high-risk individuals are not ousted from the insurance market mainly because the premiums proposed are not significantly different from their actuarial premium (Result 5).

**Result 8: An ousting of the low risks which intensifies over time (figure 5).**

Considering the behaviour of the low risks in each of the three intervals I1, I2 and I3, the application of the test of Wilcoxon on the percentage of bought insurance contracts shows that the low risks are ousted from the insurance market. Indeed, the low risks choose to buy less insurance in I2 than in I1 ($Z = 2.93; \text{Prob} > |Z| = 0.003$). In the same way, the low risks choose to buy less insurance in I3 than in I2 ($Z = 2.44; \text{Prob} > |Z| = 0.01$). The ousting of the low risks being shown, it is interesting to see whether this ousting is total.

**Result 9: The ousting of the low risks is not total**

The observation of the average percentage of insured individuals indicates that the ousting of the low risks is not total. Indeed, the application of the test of Wilcoxon shows that the average percentage of low-risk insured individuals in each session during the last twenty-period interval of exchange is different from zero ($Z = 2.895; \text{Prob} > |Z| = 0.0038$). This result can be explained by the fact that some individuals with low risks (those who keep their insurance) would have a high level of risk aversion.

**Result 10: The high-risk individuals buy more often insurance than the low-risk ones (figure 5)**

The comparative analysis of the behaviour of the individuals according to their class of risk indicates that the high-risk individuals buy more insurance than the individuals with low risks. Indeed, the application of the test of Wilcoxon to the average numbers of insurance contracts bought by each class of risk during each session shows that the high risks buy significantly more insurance than the low risks ($Z = 2.93; \text{Probability} > |Z| = 0.0033$). This last result indicates that adverse selection reduces the opportunities for insurance offered to the low-risk individuals compared to those offered to the high-risk individuals. This supports the assumption that adverse selection disrupts the market.

The review of the various results obtained (Results 1 to 10) shows that the average data of the experiment validate the theoretical predictions of our model:

a. The premiums offered are equal to the level of the theoretical equilibrium

b. The market is made up mainly of high-risk individuals

**IV. The operating of the market systems**

The analysis of average data is certainly necessary. Nevertheless, it gives no information about individual specificities. By separately considering the data of each session, we observe that there are several market systems. In what follows we will analyze how the various market systems seen in this experiment operate.
In order to analyze this heterogeneity, we apply the method of cluster analysis. The cluster analysis is a statistical method having for function to classify a set of multivariate data in homogeneous sub-groups. The idea of this method is to identify the principal market systems that operate identically. The first stage of this cluster analysis is to identify the key criteria for the classification of the markets according to their operating systems. Every insurance market is distinct by the nature of the confrontation of supply and demand. It is thus reasonable to believe that the level of the premiums as well as the percentage of insured individuals are strong indicators of a specific market system. In order to gather the sessions of markets having similar operating systems, we retained the nine following selection criteria:

- Criteria relative to the supply of insurance: for each session, we keep the average insurance premiums in each of the three twenty-period intervals of exchange I1, I2 and I3.
- Criteria relative to the demand for insurance: for each session, we keep the average percentage of insured individuals with high and low risks in each of the three twenty-period intervals of exchange I1, I2 and I3.

The cluster analysis revealed the existence of three market systems. The following graph identifies the market systems having similar operating systems (clusters). There would be seven clusters to sum up the various scenarios observed. Nevertheless, three clusters seem to be sufficient to oppose three different market systems.

The use of an “inter-sessions” classification can be verified by testing the two following assumptions: first, the supply as well as the demand in the various sessions are significantly heterogeneous from a cluster to another. Second, the supply as well as the demand are significantly homogeneous within each cluster. The application of the Kruskal-Wallis signed-rank equality test made it possible to validate these two assumptions.

The various operating market systems are illustrated by the following scenarios.

**Scenario 1: sophisticated insurers in competition**

In this scenario, the insurers set premiums ranging between the actuarial premiums of the population of insured individuals and the actuarial premium of the high risks. Indeed, the application of the Wilcoxon signed-rank test indicates that:

- The premiums offered at each period of exchange are significantly higher than the actuarial premiums of the population of insured individuals \(Z = 7.106; \text{Prob} > |Z| = 0\).
- The premiums offered at each period of exchange are significantly lower than the actuarial premium of the high-risk individuals \(Z = -4.083; \text{Prob} > |Z| = 0\).

In addition, the analysis of the profits earned on the markets in this scenario enables us to assume that competition between the insurers was efficient. Indeed, the application of the Wilcoxon signed-rank test shows that we cannot reject the null hypothesis according to which

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5 Agglomerative hierarchical clustering (AHC) technique (Everitt (1993) and Gordon (1999)).
6 Percentage of insured individuals = (number of effective insured individuals)/(Number of potential insured individuals).
7 After having decided which method of classification to use, the choice of the number of partitions to be retained is essential. Insofar as we seek to determine different groups of markets, we want to preserve the greatest differences between groups. We can examine the decreasing curve of the distances between amalgamated partitions at each stage. This curve should decrease in a monotonous way as more similar partitions are amalgamated at each stage. If, at an iteration, a clear difference arises then, it is reasonable to think that to seek to gather other partitions is not reasonable, the observations being too similar.
8 Table 3 presents the results of the tests used to validate the hypothesis of the heterogeneity of the supply and demand within clusters. Table 4 presents the results of the tests used to validate the hypothesis of the homogeneity of the supply and demand within clusters.
the profits earned at each period are null \((Z = -1.264; \text{Prob } > |Z| = 0.2062)\). Let us note finally that the pricing strategy followed by the insurers in this scenario is stable over time\(^9\). These last results suggest that in this first scenario:

- The insurers are \textit{sophisticated}: they correctly anticipated that the population of insured individuals will be made up mainly of high-risk individuals.
- The premiums proposed by the insurers are equal to the theoretical level (the insurers earn no profit).

Considering the behaviour of the demand, two orientations emerge as illustrated by the following figure: first, only the low risks are excluded from the insurance markets\(^10\). Second, the high risks buy significantly more insurance than the low risks\(^11\).

\textbf{Scenario 2: naïve insurers}

This scenario appears in sessions 3, 4 and 8 (figure 8). In this scenario, the insurers set lower insurance premiums than the actuarial premiums of the population of insured individuals during the first periods of exchange. The theoretical equilibrium is reached only after several periods of play.

Indeed, the use of the Wilcoxon signed-rank test indicates that:

- The premiums offered during the first forty periods of exchange \((I_1\text{ and } I_2)\) are significantly lower than the average actuarial premiums of the population of insured individuals \((Z = -7.97; \text{Prob } > |Z| = 0)\).
- The premiums offered during the last twenty periods of exchange are not significantly different from the average actuarial premiums of the population of insured individuals \((Z = 1.068; \text{Prob } > |Z| = 0.2854)\).

This result suggests that the insurers continuously revise their offer and propose increasingly higher premiums over time\(^12\).

In addition, as predicted by the theoretical model, this pricing strategy creates losses for the insurers. In fact, the application of the Wilcoxon signed-rank test shows that the profits earned by the insurers at each period are significantly lower than zero \((Z = -6.837; \text{Prob } > |Z| = 0)\).

These last results bring us to the two following conclusions:

- In this scenario, the insurers do not take into account the problem of adverse selection in their pricing process. We can consider that they are naïve because they do not anticipate that in the presence of adverse selection, the population of insured individuals is made up mainly of high-risk individuals.
- The learning by experiment (losses incurred) led the insurers to revise their offer and to increase the insurance premiums.

Considering the behaviour of the demand, two orientations emerge as illustrated by the figure 9: First, the high risks as well as the low risks are excluded from the insurance markets\(^13\). Second, the high risks buy significantly more insurance than the low risks\(^14\).

\(^9\) The correlation coefficient between the premiums offered and time is equal to 0.0276.
\(^10\) The correlation coefficients between time and the percentage of insured individuals of high and low risks are respectively of -0.04 and -0.278.
\(^11\) The use of the Wilcoxon signed-rank test on the data of each period shows that the percentage of high-risk individuals is greater than the percentage of low-risk individuals \((z=6.35; \text{p-value}=0)\).
\(^12\) The correlation coefficient between the premiums offered in each period and time is negative and equal to -0.24.
\(^13\) The correlation coefficients between time and the percentage of insured individuals of high and low risk types are respectively of -0.35 and -0.568.
\(^14\) The use of the Wilcoxon signed-rank test on the data of each period shows that the percentage of high-risk insured individuals is greater than the percentage of low-risk insured individuals \((z=6.533; \text{p-value}=0)\).
**Scenario 3: Sophisticated insurers in collusion**

This scenario appears in sessions 2, 5 and 10 (figure 10). In this scenario, the insurers set higher premiums than the theoretical equilibrium. Indeed, the use of the Wilcoxon signed-rank test shows that the premiums suggested are significantly higher than the actuarial premium of the high risks and thus than the average actuarial premiums of the population of insured individuals ($Z = 11.409; \text{Prob } > |Z| = 0$). In addition, the analysis of the profits earned on the markets in this scenario enables us to make the assumption according to which competition between the insurers was not efficient. Indeed, the use of the Wilcoxon signed-rank test shows that we can accept the alternative hypothesis according to which the profits earned at each period are positive ($Z = 6.314; \text{Prob } > |Z| = 0$). Let us note finally that the pricing strategy followed by the insurers in this scenario is stable over time$^{15}$. The last results obtained bring us to the two following conclusions:

- The insurers correctly anticipated the exclusion of the low risks from the market. By referring to the theoretical model, we can qualify these insurers as being sophisticated.
- The insurers propose premiums higher than the theoretical equilibrium. Given the positive profits earned, we can argue that competition was not efficient in these markets.

Considering the behaviour of the demand, two orientations emerge as illustrated by the figure 11: First, only the low risks are excluded from the insurance markets$^{16}$. Second, the high risks buy significantly more insurance than the low risks$^{17}$.

**V. Concluding remarks**

We have empirically investigated the problem proposed by Akerlof. His paper has received a great deal of attention but no direct tests in the context of insurance market. We run experiments in which subjects faced the same constraints postulated in the theory. There are three substantive conclusions to be drawn from this study. First, considering the behaviour of the supply of insurance, the results obtained confirm the predictions of our theoretical model. Indeed, we observe that on average, the insurers take into account adverse selection in their pricing process (the premiums offered are equal to the premium of the theoretical equilibrium and the average profits earned are zero). The second conclusion concerns the behaviour of the demand, we observe that the low-risk individuals are excluded from the insurance market due to adverse selection. The third result concerns the strategic anticipations of insurers (naive or sophisticated), we observe that the insurers are not always able to anticipate the behaviour of the individuals in the presence of asymmetric information. When the insurers are “sophisticated”, the theoretical equilibrium is reached instantaneously. If not, the theoretical equilibrium is reached only at the end of several periods of exchange. There are two major directions for further experimental research that we regard as particularly interesting. One idea that has been suggested concerns the existence of two operating market systems: competitive markets with premiums generating no profit (session 1, session 6, session 7, session 9 and session 11) and of collusive markets with premiums generating positive profits (session 2, session 5 and session 10)$^{18}$. We are interested in finding out whether the various

$^{15}$ The correlation coefficient between the premiums offered and time is equal to 0.062.
$^{16}$ The correlation coefficients between time and the percentage of insured individuals of high and low-risk types are respectively 0.08 and -0.23.
$^{17}$ The use of the Wilcoxon signed-rank test on data in each period shows that the percentage of high-risk insured individuals is greater than that of the low risks ($z=7.409; p\text{-value}=0$).
$^{18}$ Let us note that in the three scenarios, the insurers share the market equitably. Indeed, the use of the Wilcoxon signed-rank test on the average percentage of success of each insurer in each session reveals clearly that the two insurers share the market ($Z = 0178; \text{Prob } > |Z| = 0.8589$). Let us note that the percentage of success corresponds
market systems continue to dominate when the number of insurers in competition increases. The second question of interest to us concerns the market functioning as in Rothschild and Stiglitz (1976). We are particularly interested in finding out whether the introduction of deductibles will generate the no ousting of low risks.

References:

### Tables

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<tbody>
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<td>69</td>
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<td>1</td>
<td>56</td>
<td>40</td>
<td>71.65</td>
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<td>89</td>
<td>70</td>
<td>54</td>
<td>52</td>
<td>86.5</td>
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<td>50</td>
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<td>2</td>
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<td>50</td>
<td>60</td>
<td>41.74</td>
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<td>40.8</td>
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Table 1: Supply data

<table>
<thead>
<tr>
<th>i: Session</th>
<th>j: Treatment</th>
<th>Percentage low-risk insured individuals</th>
<th>Percentage low-risk insured individuals</th>
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<tbody>
<tr>
<td>Percentage of insured individuals</td>
<td>Average periods [1-60]</td>
<td>Average periods [21-40]</td>
<td>Average periods [41, 60]</td>
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<tr>
<td>I=1; j=1</td>
<td>0.08</td>
<td>0.25</td>
<td>0.5</td>
</tr>
<tr>
<td>I=2; j=1</td>
<td>0.09</td>
<td>0.25</td>
<td>0.1</td>
</tr>
</tbody>
</table>

to the relationship between the number of times that an insurer wins the market and the overall number of periods.
Table 2: Demand data

<table>
<thead>
<tr>
<th>Test</th>
<th>Kruskal-Wallis</th>
<th>Kruskal-Wallis</th>
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</thead>
<tbody>
<tr>
<td>$H_0$</td>
<td>Average premiums in $I_1$, $I_2$ and $I_3$ are equal when one passes from a market system to another</td>
<td>Average percentages of insured individuals in $I_1$, $I_2$ and $I_3$ are equal when one passes from a market system to another</td>
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<tr>
<td>Result</td>
<td>Reject $H_0$: [Chi-square=19.430; Prob=0.0001]</td>
<td>Reject $H_0$: high risks [Chi-square=12.755; Prob=0.0017]; Low risks [Chi-square=8.518; Prob=0.0141]</td>
</tr>
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</table>

Table 3: Heterogeneity of supply and demand between clusters

<table>
<thead>
<tr>
<th>Test</th>
<th>Kruskal-Wallis signed-rank equality test</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_0$</td>
<td>Average premiums by session in $I_1$, $I_2$ and $I_3$ are not different within the same cluster</td>
</tr>
<tr>
<td>Result</td>
<td>Accept $H_0$:</td>
</tr>
<tr>
<td>Cluster 1</td>
<td>[Chi-square=2.463; Prob=0.2918]</td>
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<tr>
<td>Cluster 2</td>
<td>[Chi-square=0.467; Prob=0.7919]</td>
</tr>
<tr>
<td>Cluster 3</td>
<td>[Chi-square=2.42; Prob=0.2979]</td>
</tr>
<tr>
<td>The average percentages of insured low risks by session in $I_1$, $I_2$ and $I_3$ are not different within the same cluster</td>
<td></td>
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<tr>
<td>Result</td>
<td>Accept $H_0$:</td>
</tr>
<tr>
<td>Cluster 1</td>
<td>[Chi-square=7.208; Prob=0.124]</td>
</tr>
<tr>
<td>Cluster 2</td>
<td>[Chi-square=0.622; Prob=0.7326]</td>
</tr>
<tr>
<td>Cluster 3</td>
<td>[Chi-square = 1.067; Prob=0.5866]</td>
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<tr>
<td>The average percentages of insured high risks by session in $I_1$, $I_2$ and $I_3$ are not different within the same cluster</td>
<td></td>
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<tr>
<td>Result</td>
<td>Accept $H_0$:</td>
</tr>
<tr>
<td>Cluster 1</td>
<td>[Chi-square = 9.892; Prob=0.0723]</td>
</tr>
<tr>
<td>Cluster 2</td>
<td>[Chi-square=0.622; Prob=0.7326]</td>
</tr>
<tr>
<td>Cluster 3</td>
<td>[Chi-square = 4.622; Prob=0.0992]</td>
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</tbody>
</table>

Table 4: Homogeneity of supply and demand within clusters

Figures

Figure 1

Figure 2
Average percentage of low-risk insured individuals

Average percentage of high-risk insured individuals

Average percentage of insured individuals

Sophisticated insurers
Scenario 1: Sessions 1, 6, 7, 9 and 11

Average premiums

Naïve insurers
Scenario 2: Sessions 3, 4 et 8

Average Premiums

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9
Sophisticated insurers

Scenario 3: Sessions 2, 5 and 10

Collusion

Average premiums

Actuarial premiums of low risks

Actuarial premiums of high risks

Theoretical equilibrium

Percentage of insured individuals

Scenario 3: Sessions 2, 5 and 10

Figure 10

Figure 11