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Competitive Insurance Markets and Adverse Selection in the Lab

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We provide an experimental analysis of competitive insurance markets with adverse selection. Our parameterised version of the lemons' model of Akerlof in the insurance context predicts total crowding-out of low risks when insurers offer a single full insurance contract. The therapy proposed by Rothschild and Stiglitz consists of adding a partial insurance contract so as to obtain self-selection of risks. We test the theoretical predictions of these two models in two experiments. A clean test is obtained by matching the parameters of these experiments and by controlling for the risk neutrality of insurers and the common risk aversion of their clients by means of the binary lottery procedure. The results reveal a partial crowding-out of low risks in the first experiment. Crowding-out is not eliminated in the second experiment and it is not even significantly reduced. Finally, instead of the predicted separating equilibrium, we find pooling equilibria. The latter can be sustained because insureds who objectively differ in their risk level do not perceive themselves as being so much different.
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Introduction

Akerlof[1] first identified market failures created by asymmetric information between buyers and sellers regarding the amount of product-specific quality of

[1] Akerlof (1970).

the goods to be exchanged or the amount of individual-specific risk to be covered. *Adverse selection* disrupts the market as the better-quality goods or lower-risk individuals are driven out of the market so that only 'lemons' are eventually exchanged. The lemons' model gave rise to a huge literature on the economics of information in search for practical remedies against the inefficiencies generated by informational asymmetries. One of the best known papers in that literature was proposed by Rothschild and Stiglitz[2] who provide an illuminating solution to the adverse selection problem on competitive insurance markets. If insurers cannot categorise individuals by their exposure to risk, they suggest that a second-best competitive equilibrium can be attained by supplying a menu of insurance policies such that the specific contract freely chosen by each individual reveals his true level of risk. When the proportion of high-risk individuals is relatively high, a *separating equilibrium* arises, providing for full coverage of high risks and partial coverage of low risks; when the proportion of high-risk individuals falls below a certain threshold, there is no equilibrium. This approach solves the problem raised by the crowding-out of low-risk agents through the self-selection of risks. Moreover, it suggests a rationale for the presence of partial insurance contracts (i.e. with a deductible) on insurance markets that is valid in the absence of transaction costs: the deductible provides a risk selection mechanism.

The proposals advanced by Akerlof and Rothschild and Stiglitz (RS) subsequently gave rise to a number of further developments.[3] These approaches, whether or not they allow for the possibility of cross-subsidisation between risk classes, provide a very strong rationale for deductibles.

While there is a voluminous body of theoretical work on the economics of insurance with adverse selection, empirical applications remain scarce. Furthermore, they come to contradictory conclusions. Some analyses conclude that adverse selection does not appear on the data.[4] Others claim that adverse selection is a major problem on insurance markets.[5] Consequently, there is no consensus on either the impact of adverse selection or on the nature of the resulting equilibrium on insurance markets. Furthermore, the lemons' model has never been empirically tested in the context of insurance for the simple reason that a pure market *à la* Akerlof—deprived of any corrective mechanisms (deductibles, categorisation, bonus-malus, etc.) to prevent the market from collapsing—cannot be observed in the real world because it would vanish as soon as it appears.

[2] Rothschild and Stiglitz (1976).

[3] (Miyazaki, 1977; Wilson, 1977; Spence, 1978; and Riley, 1979).

[4] (Beliveau, 1984; Cawley and Philipson, 1999; Richaudeau, 1999; Chiappori and Salanié, 2000; Dionne *et al.*, 2001).

[5] (Dahlby, 1983; Browne and Doerpinghaus, 1993; Goodwin, 1993; Puelz and Snow, 1994; Goodwin and Smith, 1995).

These issues led us to opt for experimental methods to test predictions of the Akerlof[1] and Rothschild and Stiglitz[2] models. In the controlled environment of a laboratory, we can simulate the working of spot markets repeatedly until a stationary equilibrium emerges or even until the experimental market disappears. Thus, we created an experimental insurance market bringing together three types of agents: insurers, high-risk individuals and low-risk individuals. In order to be consistent with the simplifying assumptions of models of insurance with adverse selection, participants' preferences were experimentally controlled using the binary lottery procedure (to be explained further down) originally developed by Roth and Malouf[6] and subsequently expanded by Berg *et al.*[7], Prasnikar[8] and Berg *et al.*[9] The insurers behave as risk-neutral agents, and the insured individuals behave as risk-averse agents with equal endowments and risk aversion who only differ by their risk level.[10]

Our study focuses on four primary goals: (i) In a first experiment, test the predictions of an adaptation of the lemons' model to insurance; (ii) In a second experiment, test the predictions of a parameterised version of the RS model; (iii) Identify the nature of the equilibria that emerge on competitive insurance markets with adverse selection; (iv) Assess the efficiency of deductibles as a mechanism of risk selection.

The related experimental studies are few. It seems that only three experiments have tested the predictions of the RS model so far. Shapira and Venezia[11] conducted separate experiments for supply and for demand in a context of insurance with adverse selection. According to their point of view, the first step for a test of the RS model requires to confirm that insureds are inclined to self-selection while insurers are induced to screen their customers. Their experimental data provide partial support to the RS model and some evidence of learning. A major difficulty in testing this model on insurance data is that the risk neutrality of insurers and the common risk aversion of all insureds are not controlled for. The paper of Posey and Yavas[12] remedies this problem by

[6] Roth and Malouf (1979).
[7] Berg *et al.* (1986).
[8] Prasnikar (2000).
[9] Berg *et al.* (2006).
[10] Recent contributions to the theory have introduced heterogeneity of risk aversion in addition to the heterogeneity of exposure to risk.[26] Although these contributions confirm the role played by deductibles as a mechanism for risk selection, the resulting equilibria are more complex: possibilities of separating, partially separating and pooling equilibria. These theoretical contributions stress the necessity to control for the degree of heterogeneity in risk aversion. In the absence of such control, our experimental work would offer a test of these recent contributions instead of a test of RS.
[11] Shapira and Venezia (1999).

focusing on the competitive behaviour of insurers confronted to "computer-simulated" high-risk and low-risk individuals. Depending on the proportions of high-risk and low-risk individuals on the market, the theoretical prediction is a separating equilibrium (if low-risk individuals are relatively few) or a pooling equilibrium (if low-risk individuals are relatively many). Posey and Yavas[12] found a convergence of observed behaviour towards the equilibrium prediction. However, their simulated customers are not subjects in flesh and blood. They are programmed agents that behave as a group of individual expected utility maximisers with the same risk aversion and two risk types. Moreover, each insurer was informed in their experiment, after all decisions were made for a trading period, about the type of individual (high or low risk) who purchased each contract, a feature which should help convergence towards a separating equilibrium. The experimental analysis of Asparouhova[13] is the first one that considers explicitly the interactions between supply and demand. Asparouhova[13] developed an extension of the RS equilibrium in the context of competitive lending under adverse selection and her experimental results confirm the theory. When the proportion of high-risk entrepreneurs is sufficiently high, a separating equilibrium is obtained. When the same proportion is relatively low, lending markets meet difficulties to settle down.

Compared with these earlier studies, our experiment is the second one involving a full interaction between supply and demand on a competitive market with adverse selection and the first one to do it in the context of an insurance market. In our experiments, both insureds and insurers are true subjects who make repeated decisions for money. As required by the RS model, insurance contracting is not compulsory and a subject has always the opportunity to refuse it. In order to be in perfect accordance with the assumptions of the RS model, we used the binary lottery procedure to induce insurers to be risk-neutral and insureds to share the same concave utility function.[14] To our knowledge, these are the first experiments designed to test the predictions of models of insurance with adverse selection while controlling for the risk preferences of participants.

To summarise, the originality of our experiments lies primarily in the following. First, no experiment has yet represented both the supply of and demand for insurance in testing predictions of Akerlof[1] or Rothschild and Stiglitz[2] in this context. Second, no experiment with controls for preferences has been conducted before in the context of insurance. Third, by designing two successive experiments, we are able to assess the effectiveness of deductible

[12] Posey and Yavas (2007).
[13] Asparouhova (2006).
[14] In the model of Rothschild and Stiglitz,[2] all individuals are endowed with the same utility function.

contracts as a mechanism for risk selection and as a solution to the problem of adverse selection. Indeed, the lemons' market outcomes can serve as a counterfactual to the RS-type ones.

This paper is organised as follows. First we present the theoretical predictions to be tested. Next, we introduce the experimental protocol and implementation of the binary lottery procedure. The latter sections describe the results of the first and second experiments. A general discussion and conclusion follow in the last section.

The theoretical predictions to be tested

We consider the market supply of an insurance policy to a population composed of two types, H (for high risk) and L (for low risk), that only differ by their probability of loss q_i, $i=(H, L)$. Thus, $q_L < q_H$. These two types are in proportions λ_H and λ_L respectively, with $\lambda_H + \lambda_L = 1$. The problem of adverse selection arises when insurers know these proportions but cannot observe the risk type of each individual.

Individuals are assumed to maximise the expected utility of wealth. With the exception of their risk type, individuals are homogeneous: they are endowed with the same initial wealth W_0, are at risk of losing the same amount[15] X, and share the same concave Von Neumann-Morgenstern (VNM) utility of wealth function $U(W)$, assumed here to be CARA (Constant Absolute Risk Aversion):

$$U(W) = -e^{-\alpha W}, \tag{1}$$

with $\alpha > 0$ indicating the degree of absolute risk aversion. Thus, individuals are supposed to be all equally risk averse. The numerical value of α in both experiments is 0.005.

On the supply side, we consider a *competitive* market on which insurers offer insureds, against the payment of a sure premium P, the guarantee to compensate them for a random loss X by an indemnity I ($0 < I \leqslant X$). Insurers are risk-neutral and maximise their expected profits. Competition drives profits down to zero and the competitive market premium at which an insurance policy is sold in the absence of transaction costs (loading) is the "fair" premium $P=qI$, where q stands for the average probability of risk among individuals who are expected to purchase this insurance policy.

In the first experiment, which reproduces the lemons' model, we assume that insurers are unable to discriminate between risk types and compete on the price

[15] Individuals are assumed to be unable to influence the probability of a claim or the amount of loss.

of a single full insurance policy.[16] Individual agents only have the option of purchasing full insurance at the market price or no insurance at all. They buy insurance if their expected utility with insurance is at least as great as their expected utility without insurance:

$$U(W_0 - P) \geqslant (1 - q_i)U(W_0) + q_i U(W_0 - X) \forall i = [H, L],$$

The willingness to pay for a full insurance contract (WTP^i) of an individual of type i is the maximum premium, that is, with the CARA utility function (1):

$$WTP^i = \frac{\ln[1 + q_i(e^{\alpha X} - 1)]}{\alpha}. \tag{2}$$

Thus, if competing insurers supplying full insurance set the insurance premium on the basis of the average probability of loss across all individuals, q_{HL}=[$\lambda_H q_H + \lambda_{LqLs}$], Ls will not buy insurance if and only if their WTP is below the average fair premium of the whole population, that is, iff

$$WTP^L < q_{HL} \times X. \tag{3}$$

When the latter condition holds, Ls stay out of the market and only Hs buy insurance. Since the average fair premium is lower than the high-risk fair premium, insurers' profits are negative. The policy will be withdrawn and replaced by a new policy that targets type H individuals. Adverse selection would thus restrain the supply of insurance to a contract offering full insurance at a fair price for Hs. At this price, Ls are crowded out of the market, insurers compete exclusively for Hs and competition drives profits down to zero. This is the prediction we wish to test with the first experiment. For this purpose, condition (3) is imposed on our data. Letting q_H=0.30, q_L=0.10, λ_H=λ_L=0.50, X=200, fair premiums amount to 20 for Ls, 60 for Hs and 40 on average; since WTP^L=31.7<40, condition (3) is respected.

In the second experiment, which reproduces the RS model, we still assume that insurers are unable to discriminate between risk types but they now compete on a menu of contracts which includes a full insurance policy and a partial insurance policy. Since the VNM utility function of all individual agents is given by (1), we are able to compute the menu of profitable

[16] In this experiment, the observed price p and premium P of an insurance contract may be confounded because they remain proportional: $P \equiv pX$.

incentive-compatible policies that allows low risks to get the best coverage and high risks to be separated from low risks under the model's assumptions. Each insurer proposes a policy with a deductible D appealing to Ls and a full insurance policy appealing to Hs. In this separating equilibrium, competition drives profits down to zero on both contracts. Thus, the full insurance premium is fair to its H clients:

$$P_F = q_H \times X \tag{4}$$

and the deductible policy premium is also fair to its L clients:

$$P_D = q_L \times (X - D). \tag{5}$$

Ls self-select the partial insurance policy, and this policy allows them to maximise their expected utility under the constraint that high risks self-select the full insurance policy:

$$U(W_0 - P_F) \geqslant (1 - q_H)U(W_0 - P_D) + q_H U(W_0 - P_D - D).$$

Thus, the last constraint is saturated, and, with CARA utility function (1), the optimal deductible D offered to Ls is the solution of:

$$q_H X - q_L(X - D) = \frac{\ln\lfloor 1 + q_H(e^{\alpha D} - 1)\rfloor}{\alpha}. \tag{6}$$

Or, using (2), (4), (5): $P_F = P_D + WTP^H(D)$

Thus, the excess premium paid by Hs to get full insurance rather than partial insurance equals their WTP for the coverage of deductible D. With the CARA utility function (1), $q_H = 0.30$, $q_L = 0.10$, $\lambda_H = 0.60$, $\lambda_L = 0.40$, $X = 200$, we compute: $P_F = 60$, $P_D = 6$, $D = 140$. However, a separating equilibrium can only obtain if partial insurance for Ls at fair price dominates pooling contracts at an average fair price, that is, if the proportion of high risks is sufficiently large. With our experimental parameters, $\lambda_H > 0.12$. If there are not enough high risks, the RS model has no equilibrium. The equilibrium value of deductible is imposed on the data and the chosen proportion of Hs (60 per cent) is well above the computed threshold value.

The theoretical prediction we wish to test in the second experiment is that a separating equilibrium obtains at fair prices, with Hs purchasing the full insurance contract and *L*s purchasing the partial insurance contract while insurers make no profit on both contracts.

Experimental design

General features

The two experiments were conducted in Bell University Laboratories′ experimental economics centre at CIRANO in Montreal, using the Ztree software.[17] We ran five sessions in the first experiment and six in the second. Each session consists of an insurance market with "clients" and with "insurers" competing on prices. The allocation of the roles insurer/client is determined by a random draw at the beginning of the experiment and the roles assigned to the participants do not change throughout the session. Each insurance market is made up of 60 trading periods. This relatively long time-horizon was chosen to facilitate the emergence of a stationary equilibrium. The currency used for transacting is the experimental money unit (EMU). At the beginning of each trading period, every insurer receives an initial endowment of 5,000 EMU, which makes it possible to cover all contingencies. All potential insureds receive the same initial endowment, equal to 1,000 EMU, regardless of their risk profile.

The supply of insurance is provided by *four* insurers who compete on prices.[18] The trading mechanism adopted in both experiments corresponds to the institution of posted prices.[19] The demand for insurance emanates from two risk types: high-risk and low-risk clients, who are indistinguishable to insurers. Each high risk (*H*) has a 30 per cent probability of losing 200 EMU, and each low risk (*L*) has a 10 per cent probability of losing the same amount. Thus, the fair premium reached under perfect competition is 60 EMU for *H*s and 20 EMU for *L*s.

In the first experiment, the demand for insurance comes from *four* high-risk and *four* low-risk clients who have a choice between full insurance (F) and no insurance (N). In the second experiment, the demand for insurance comes from *six* high-risk and *four* low-risk clients[20] who have the two same choices (*N, F*) and an additional choice of partial insurance with a deductible (*D*). When a

[17] (Fischbacher, 2007).

[18] All experiments that previously tested the institution of posted auctions indicate that competitive prices will only be obtained systematically with three sellers at least, even though, in theory, Bertrand competition allows competitive prices to be attained with as few as two sellers.

[19] Holt (1995, p. 375) recommends the use of posted prices for the experimental simulation of competitive insurance markets.

loss occurs, clients get a full coverage of 200 EMU if they chose full insurance, only 60 EMU—that is, 200 EMU minus a deductible of 140 EMU—if they opted for partial insurance and nothing if they didn't purchase insurance. The deductible was derived from a numerical version of the RS model in which all clients have a CARA utility function (1) with α=0.005.

Each session is divided in three steps. The first consists of training questions for the participants to familiarise themselves with the experimental protocol. The second corresponds to the experiment itself. Finally, during the third step, the participants are compensated. Participants' earnings depend partly on decisions made during the game and partly on luck. Compensation is distributed individually at the end of the experiment. Participants earned an average of 25 Canadian dollars in one-and-a-half hour.

The trading periods

Each trading period of an experiment involves three stages.

First stage

In the first stage, insurers compete for the lowest premium of each contract they may offer: a full insurance contract (F) only in the first experiment; or a full insurance (F) and a partial insurance contract with a deductible (D) in the second experiment. The insurer with the lowest insurance premium will be the only one to sell policies during the active trading period. If two insurers at least offer the same premium in a given trading period, the computer determines which one will sell insurance by a random draw. There are no transaction costs, but insurers are free to fix the premiums above or below their actuarial level.

Second stage

Each client is informed of the amount of the market premium for each contract, that is, F in the first experiment, and (F, D) in the second. Then, she must choose her preferred insurance policy or no insurance (N).

Third stage

A lottery determines which clients suffer losses. The computer then computes the final endowment of each client and insurer, and displays it on screen. Each insurer is informed of how many policies of each type she sold, the claims she

[20] Given the preferences induced by the binary lottery procedure, we mentioned in the previous section that the separating menu (F, D) is an equilibrium if the proportion of high risks exceeds 12 per cent. The selected proportion of 60 per cent considerably exceeds this threshold.

must pay, the profit yielded by each policy and her endowment at the end of the trading period.

Uninsured clients pay no premium and totally cover their own losses. In contrast, insured clients pay insurance premiums and receive indemnities from their insurer if they suffered a loss. From the insurers' perspective, profits increase their endowment, while from the clients' perspective, premiums and uncovered losses reduce their endowment.

Implementation of the binary lottery procedure

Compensation to participants

Participants are compensated on the basis of the earnings (in EMU) obtained at the end of one of the 60 trading periods, randomly selected by computer at the end of the experiment. All trading periods have an equal likelihood of being drawn.

However, subjects do not receive their earnings as payments. The binary lottery procedure that we use to control for their risk attitude[21] requires that each participant may only win one of the two following prizes: the "high prize", equal to C\$30, or the "low prize", equal to C\$10. The more a participant earns at the end of the selected trading period, the higher will be his likelihood of winning the high prize. Indeed, each level of final wealth corresponds with a number of degrees on a wheel which determines, by proportionality, the *probability* of winning.

Let us see now how the binary lottery procedure induces the same utility function to all individuals playing the same role. The binary lottery procedure transforms sure wealth W into a binary lottery which yields either high prize M with probability $P(W)$ or low prize m with probability $1-P(W)$. Thus, instead of valuing a risky option yielding W_1 in the good state with probability r and W_2 in the bad state with probability $1-r$, subjects will value a compound lottery yielding either M with probability $[rP(W_1)+(1-r)P(W_2)]$ or m with probability $[r(1-P(W_1))+(1-r)(1-P(W_2))]$. Since the potential earnings are the same (i.e. M or m) for all options, the option with the highest compound probability of winning $[rP(W_1)+(1-r)P(W_2)]$ dominates others. Hence, subjects choose a risky option as if they maximised an expected utility with the induced VNM utility function $P(W)$. It is worth mentioning that this property

[21] Previous applications of the binary lottery procedure in experiments are Berg *et al.*[7] on decision-making under risk, Rietz (1993) and Walker *et al.* (1990) on auctions, Roth and Malouf[7] on game-theoretic models of bargaining, and Dittrich and Maciejovsky (2005) on investment. Surprisingly, to our knowledge the binary lottery procedure had never been applied to insurance.

of the binary lottery procedure to control for the utility function continues to hold when subjects transform the probabilities of the risky options.

Going back to our experiments, there are two different wheels for insurers and for clients. For insurers, the function that translates wealth into degrees is linear and implies risk neutrality:

$$Degrees = 360\left[\frac{(W-4000)}{2000}\right],$$

where W indicates total earnings at the end of the selected trading period. For clients, the function translating earnings into degrees is CARA and implies a constant absolute risk aversion equal to 0.005:

$$Degrees = 360 - 360e^{-0.005(W-790)}.$$

Participants do not see these functions but either Figure 1 or Figure 2, indicating the conversion of their potential earnings into degrees according to their role in the experiment. They could also consult a conversion table containing precise numerical values.

Once the experimenter knows the participant's probability of winning and has delimitated her winning zone on the appropriate wheel, the latter spins the arrow on the wheel clock-wise. If the arrow comes to rest in the winning zone, she wins C\$30. If the arrow lands outside of the winning zone, the earnings are only C\$10. Figure 3 illustrates these two scenarios.

Does the binary lottery procedure control for risk aversion?

Before showing the results, we wish to check that we effectively control for the risk attitude of clients with the binary lottery procedure.[22] For this purpose, we administered the Holt and Laury's[23] procedure to our subjects at the beginning of each experiment in order to establish their risk attitude. Every participant had to choose 10 times between two options A and B, each of which corresponds to a binary lottery with payoffs. A is a safe bet with payoffs C\$4 and C\$3.20 and B is a risky bet with payoffs C\$7.70 and C\$0.20. Probabilities of the higher payoffs are equal for the two lotteries and vary by steps of 0.10 from

[22] Risk neutrality was also imposed on insurers by the same procedure. We shall test, in subsections "Implementation of the binary lottery procedure" (Result 2) and "Results of the first experiment" (Result 5), that insurers effectively compete and make no profit.

[23] Holt and Laury (2002).

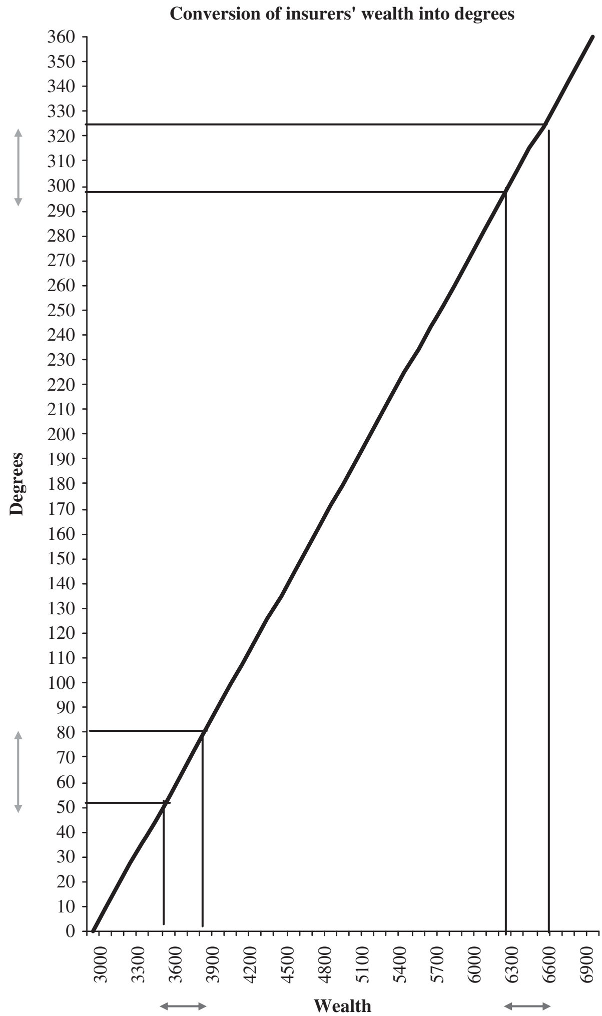

Figure 1. Conversion of insurers' wealth into degrees.

0.10 to 1.00. Normally, subjects switch once from A to B for one value of this probability and the number of safe choices serves as an index of risk aversion. Values between 0 and 3 indicate risk loving, an index of 4 signals risk neutrality, and values between 5 and 9 indicate risk aversion. We gave participants an incentive to reveal their true risk attitude by telling them that one of the 10 choices made would be randomly selected and played for money. On average, they received C$5.35 for this task. We first checked by a Kruskal-Wallis

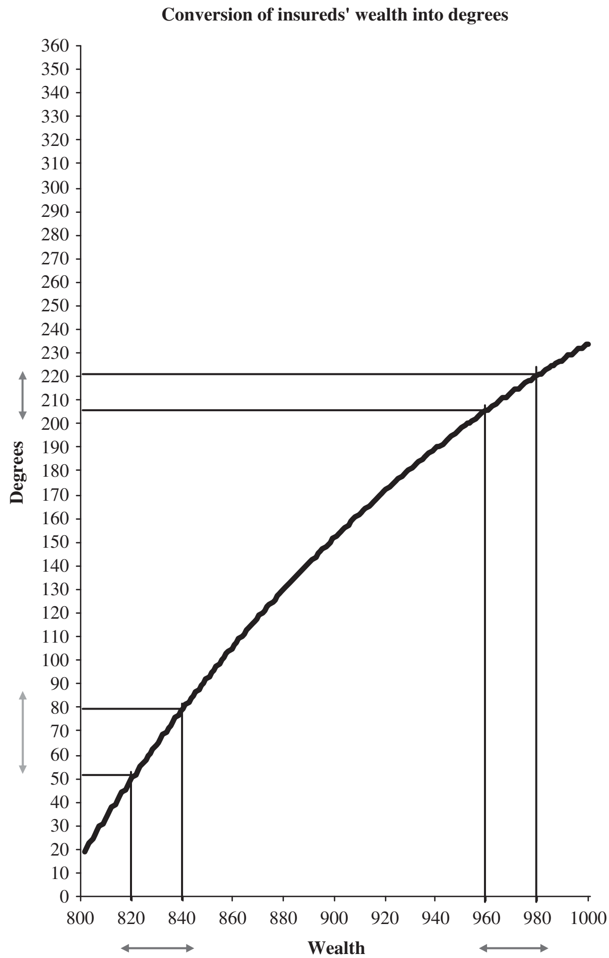

Figure 2. Conversion of insureds' wealth into degrees.

test that we could not reject the hypothesis that the four distributions of risk attitudes (number of safe choices) in 10 categories across experiments (1 and 2) and risk types (*H* and *L*) were identical (χ^2=0.516; Prob=0.9154). Then, we divided each of the four samples in two broader categories of roughly equal size: (1) Non-risk averse (i.e., risk neutral and risk loving); (2) Risk averse. In order to examine whether the binary lottery procedure has allowed us to equalise the risk preferences of clients, we compared the choice frequencies of insurance contracts between these two categories of risk

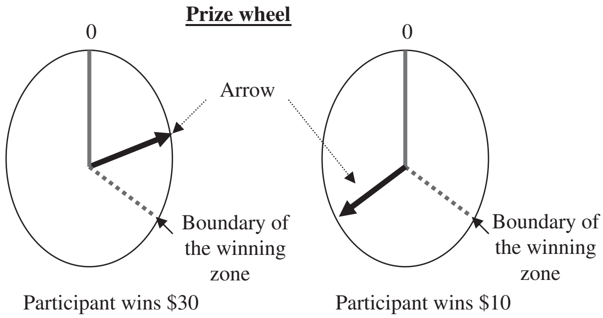

Figure 3. The Prize Wheel and two scenarios.

attitude. In both experiments, a Wilcoxon signed-rank test reveals that the average frequency of choices of insurance does not differ significantly between the two categories of risk attitude. In the first experiment, the test results are (z=0.566; Prob > $|z|$=0.5716) for Hs and (z=−1.483; Prob > $|z|$=0.1380) for Ls; and, in the second experiment, they are (z=−0.863; Prob > $|z|$=0.3883) for Hs and (z=1.054; Prob > $|z|$=0.2918) for Ls. These results show that the binary lottery technique allowed us to control for the risk attitude of clients in both experiments.

In the following we consider that participants' risk preferences are controlled for and that our experiments offer a clean test of the classical models of competitive insurance markets with adverse selection proposed by Akerlof[1] and Rothschild and Stiglitz.[2] The nonparametric analyses will primarily be based on average choices made by insurers (premiums) and clients (choice of insurance) in each of the independent sessions. For each test, we require a confidence level of no less than 95 per cent.

Results of the first experiment

We first test on the five sessions of our first experiment (one policy) the following predictions of the lemons' model of competitive market with adverse selection:

P1.1: The market premium equals (converges towards) the fair premium of Hs.
P1.2: Insurers make no profit.
P1.3: No Ls and all Hs buy insurance.

Result 1: In three sessions of the one-policy experiment, the market premium converges towards the average fair premium for the total population. In one session, it converges towards the fair premium of *L*s. And in one session only, it converges towards the fair premium of *H*s as the theory predicts.

Result 1, shown on Figure 4, largely contradicts the first theoretical prediction. In a majority of sessions, the market premium converges towards the average of *H*s' and *L*s' fair premiums in about 15 periods. This holds too when the five sessions are aggregated. A Wilcoxon signed-rank test then reveals that the insurance premium offered per session does not significantly differ from the mean fair premium for the total population ($z=-0.674$; Prob $>|z|=0.5002$).

The first two scenarios are surprising as they seem to invalidate the theoretical prediction (see section "The theoretical predictions to be tested") that, in the present experimental conditions, adverse selection would restrain the supply of insurance to a contract offering full insurance at a fair price for *H*s. An immediate answer to this finding is that insurers might be predominantly naïve, and target the whole population if they don't observe their clients' risk type on an individual basis. However, by condition (3), only *H*s should get insurance at this price, so that profits should be negative under these scenarios. Therefore, we would expect boundedly rational insurers to be naïve in the first trading periods and revise their strategy after experiencing repeated losses. However, such interpretation is not supported by the data. The insurance premium in the first period has a mean value of 80, well above the average fair premium of 40, and shows considerable variation across sessions.[24] Moreover, premiums do not converge towards the high-risk fair premium value of 60, but towards the average fair premium value of 40. Dividing the 60-period interval in two 30-period intervals I1 and I2, the premium remains stable and does not significantly diverge from the average fair premium of the two risk types, both on interval I1 ($z=-0.674$; p-value=0.5002) and I2 ($z=-0.405$; p-value=0.6858). Thus, we are confronted with a puzzle: insurers lack information on the risk type of their clients but they are not particularly naïve; yet, they offer in the long run a "low" premium that should take them into repeated losses.

Result 2: The profits earned by insurers who cannot offer more than one policy are never significantly different from zero.

Result 2 solves the puzzle that we just raised by showing that insurers effectively maximise their expected profit and, under perfect competition, earn zero profit. The latter hypothesis cannot be rejected by a Wilcoxon signed-rank test ($z=-0.098$; p-value=0.9221). Moreover, mean profits per period were

[24] The first-period premiums observed in the five sessions were respectively: 50, 40, 10, 150 and 150.

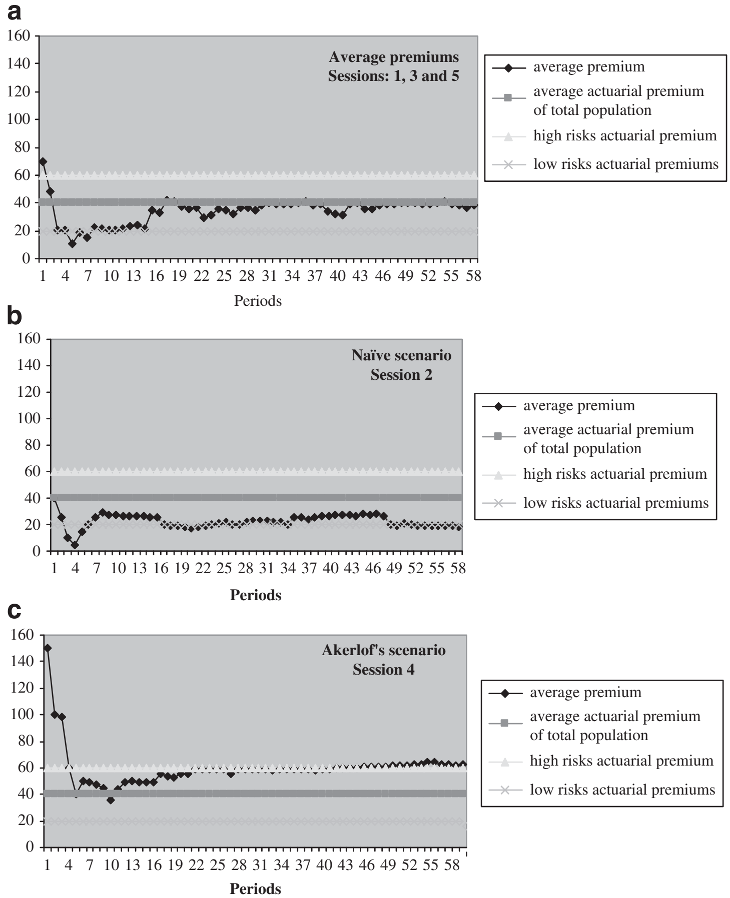

Figure 4. Three scenarios of convergence of the market premium: (a) Average fair premium of total population; (b) Fair premium of *L*s; (c) Fair premium of *H*s.

non-significantly different from zero in the five sessions.[25] Thus, markets were competitive in all the sessions and the second theoretical prediction is verified.

In order to verify the third theoretical prediction in the context of the first experiment, we compare the average frequencies of insurance purchasing

[25] The mean profits observed in the five sessions were respectively: −13, −29, −31, +3, −25. These values are to be compared with an initial endowment of +5,000.

during each of the intervals I1 and I2. *L*s would be "crowded out" of the insurance market if they purchase coverage less frequently in I2 than in I1, and crowding-out would be "total" if their frequency of coverage in I2 is not significantly different from zero.

Result 3: When insurers cannot offer more than one policy, *L*s are crowded out of the insurance market under adverse selection. However, some *L*s do not leave the market and some *H*s do not enter the market.

An application of the Wilcoxon test to the percentage of insurance policies purchased by low risks in each interval I1 and I2 reveals that, while the latter are crowded out of the insurance market (z=2.023; p-value=0.0431), the mean proportion of low risks insured in each session during the final 30 periods (I2) is significantly different from zero (z=2.023; p-value=0.0431).

Looking now at high risks, Wilcoxon signed-rank tests show that they buy insurance as much in I2 as in I1 (z=0.944; p-value=0.3452) and they purchase coverage more frequently than low risks (z=2.023; p-value=0.0431). The last result confirms that adverse selection reduced the opportunities for insurance available to *L*s compared with those available to *H*s.

A question remains: In four out of the five sessions, insurers charged a premium lower than the fair premium of *H*s although *L*s were crowded out and *H*s outnumbered *L*s on the market. How can insurers not suffer losses under such conditions? The answer to this question lies in a simple fact: in any period, some *H*s do not purchase full insurance at lower than fair price and some *L*s purchase insurance at a price higher than their WTP. Indeed, a Wilcoxon signed-rank test shows that a significant proportion of *H*s did not purchase insurance when the market premium was lower than WTP^H (z=−2.023; p-value=0.0431). Conversely, a significant proportion of *L*s bought insurance when the market premium was higher than WTP^L (z=2.023; p-value=0.0431). These two results do not change if the 15 first periods—that is, before the stationary equilibrium is reached—are taken out of the sample.

Since the use of the binary lottery procedure effectively controls for risk aversion (see subsection "The trading periods"), such observation is inconsistent with the maintained assumption that our experimental clients are EU maximisers. We may further say that subjects violated EU by distorting objective probabilities of loss. It strikes us that EU theory was violated in spite of the large experience that our subjects had the opportunity to acquire on their experimental market. On average, high risks perceived less than 30 per cent risk of loss and low risks perceived more than 10 per cent risk of loss, which resulted in a partial homogenisation of risk types. Consequently, insurers were able to reduce the price of insurance below the fair price of *H*s.

Figure 5 illustrates all these results in more detail by showing how the demand for insurance evolves over time for *H*s and for *L*s in the three types of sessions.

The picture described in the majority of sessions (Figure 5(a)) is a reflection of the aggregate results previously discussed. Figures 5(b) and 5(c) are of special interest. In session 2 (5.b), the premium converged towards the fair premium of *L*s because *H*s were particularly reluctant to buy full insurance in that session. Consequently, insurers were able to cut prices in order to attract *L*s. Figure 5(b) shows that the proportion of *L*s buying insurance in that session was about as high as that of *H*s. Session 4 (5.c) is the only one for which the premium converges towards the fair premium of *H*s, as EU theory would predict here. Obviously, *H*s were particularly prone to buy insurance in that session, which led insurers to raise prices. Figure 5(c) shows then that *L*s were crowded out of the market.

Results of the second experiment

Assuming that individuals only differ by their risk type, Rothschild and Stiglitz[2] suggested that introducing a partial insurance policy in addition to the full insurance policy would circumvent the crowding-out of low risks in a competitive insurance market if the proportion of high risks is large enough. Our second experiment respects the latter condition and tests the following theoretical predictions delineated in section "The theoretical predictions to be tested":

P2.1: A separating equilibrium obtains at fair prices, with Hs purchasing the full insurance contract and Ls purchasing the partial insurance contract;
P2.2: Insurers make no profit;
P2.3: low risks are not crowded out of the insurance market.

Result 4: A pooling equilibrium can be observed in four sessions out of six on the two insurance contracts. Full insurance is offered at the average fair premium of the total population and purchased by both risk types; partial insurance is offered at a price which lies between the fair premium of *L*s and the average fair premium and purchased by both risk types as well.

Two partially separating equilibria are also observed in the two remaining sessions. In one session, full insurance is purchased by the two risk types and partial insurance is purchased exclusively by *L*s. In another session, the full insurance policy is bought exclusively by *H*s and the partial insurance policy is shared by the two risk types.

Result 4 can be visualised on Figure 5. It means that most of the observed equilibria are not separating but rather pooling equilibria, which contradicts

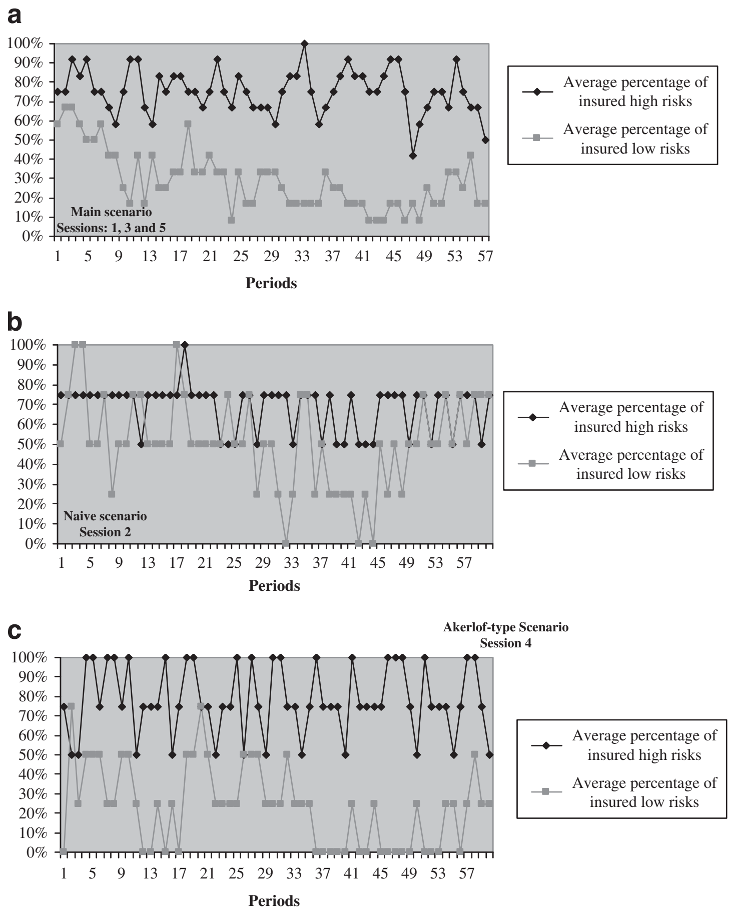

Figure 5. Partial crowding-out of low risks and retention of high risks: (a) Sessions in which the premium converges towards the average fair premium of total population; (b) Session in which the premium converges towards the fair premium of *L*s; (c) Session in which the premium converges towards the fair premium of *H*s.

the theoretical prediction. Although recent contributions to the theory predict similar possibilities of separating, partially separating, and pooling equilibria when two sources of heterogeneity coexist, both on the level of risk and on risk aversion,[26] controlling for risk aversion as we did should have ruled out

[26] (Landsberger and Meilijson, 1994; Smart, 2000; and Wambach, 2000).

such possibilities. Of course, other equilibrium concepts[3] have also been introduced with a single source of heterogeneity (risk level). However, the pooling equilibrium is only predicted by Wilson's[27] model when the proportion of high risks on the insurance market is small, so that it should not be observed here given the great proportion of high risks in our experiments. Moreover, the two contracts that would have been predicted by the RS model conditional on the (controlled) risk aversion of clients and proportion of *H*s were imposed on the data;[28] and this also seems likely to favour the emergence of the RS equilibrium.

Finally, notice that we do not observe the separating equilibria with cross-subsidisation between risk types predicted by Miyazaki,[29] but not by the RS model, although insurers were free to set the premiums at their preferred level. This may be the result of coordination failure among insurers when the whole supply of each insurance policy is attributed competitively in each period to the lowest bidder (Figure 6).

The equilibrium obtained in the majority of sessions also emerges when all sessions are aggregated. The full insurance premium then converges towards the average fair premium of the total population ($z=-1.153$; p-value=0.2489). The supply of full insurance is not targeted at *H*s but based on a pooling of risks. Similarly, the supply of partial insurance is not exclusively targeted at *L*s: a Wilcoxon signed-rank test reveals that the average premiums of deductible-based policies offered between sessions are higher than the fair premium of *L*s ($z=2.201$; p-value=0.0277) and lower than the mean fair premium of the total population ($z=-2.201$; p-value=0.0277). Nonetheless, a greater proportion of *L*s than *H*s purchase the partial insurance policy. Convergence towards the two stationary values is fast since market premiums required for full coverage (I1 vs. I2: $z=0.314$; p-value=0.7532) and for partial coverage (I1 vs. I2: $z=0.734$; p-value=0.4631) appear to be stable over time.

In conclusion, data from the second experiment refute Prediction *P2.1*, according to which each insurance policy is tailored to a risk type. Instead, they reflect a strategy of pooling by insurers.

Result 5: The profits earned by insurers on each contract are not significantly different from zero.

Application of the Wilcoxon signed-rank test reveals that we cannot reject the null hypothesis, according to which the profits earned both on the

[27] Wilson's (1977).
[28] As in Posey and Yavas (2007).
[29] Miyazaki (1977).

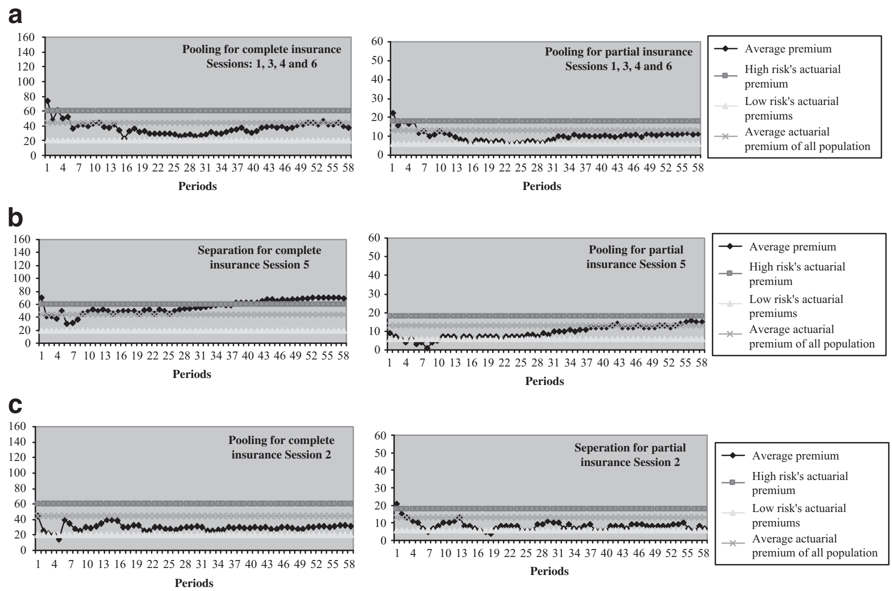

Figure 6. Three scenarios of equilibrium for partial and full insurance: (a) Pooling for partial and full insurance; (b) Separation for full insurance and pooling for partial insurance; (c) Pooling for full insurance and separation for partial insurance.

full insurance policy and on the partial insurance policy are nil (F policy: z=−1.414; p-value=0.1574. D policy: z=−1.241; p-value=0.2144). Thus, insurers behave as expected profit maximisers under perfect competition. Furthermore, they manage to pool risks and avoid losses.

Result 6: Hs prefer full coverage and Ls are indifferent between full coverage and a deductible. Ls are still crowded out of the market when they have a choice between two insurance policies.

A Wilcoxon signed-rank test on the mean number of insurance policies purchased during each session reveals that Hs acquired more F than D policies (z=2.201; p-value=0.0277) while Ls acquired an equal number of F and D policies (z=−1 363; p-value=0.1730). These behaviours remained stable over time.

Thus, self-selection of Hs on full insurance yields some support to the RS predictions while the weakness of self-selection of Ls on partial insurance invalidates them, as Figures 7 and 8 demonstrate. Another result shown by Figure 8 is even more striking: Ls purchase no insurance at all half of the time. More precisely, Ls are crowded out of the insurance market since they buy

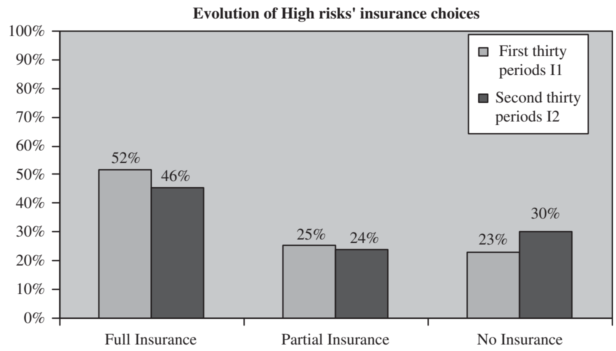

Figure 7. The distribution of insurance choices of high risks over time.

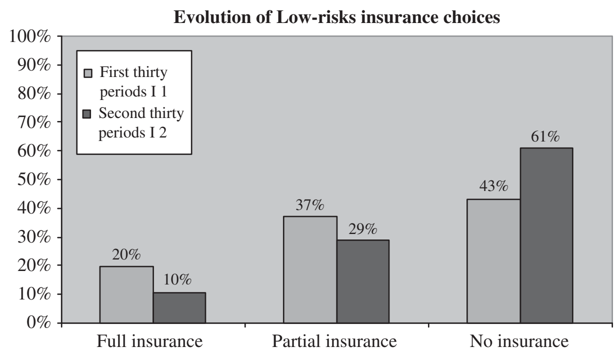

Figure 8. The distribution of insurance choices of low risks over time.

more insurance in I1 than in I2 (z=2.201; p-value=0.0277). This last result concerns both insurance policies. A higher proportion of Ls chose full insurance in I1 than in I2 (z=1.782; p-value=0.0747), and the same goes for the deductible policy (z=2.201; p-value=0.0277). Thus, low risks learn to shun both insurance contracts, as Figure 8 reveals.

In conclusion, the introduction of deductible contracts only gave rise to partial self-selection of individuals and, above all, it didn't stop the crowding-out of low risks. By offering differentiated policies, insurers allow low risks to buy insurance at fair prices.

Thus, even though low risks have fewer opportunities to buy insurance than they would under symmetry, policies with a deductible should allow them to remain on the insurance market. Our experimental results refute this

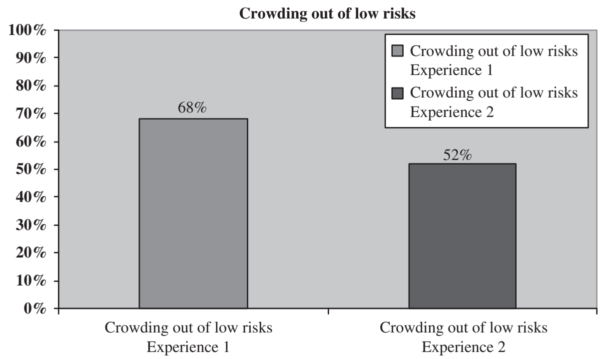

Figure 9. The crowding-out of low risks in the two experiments.

proposition: the (per session) average percentage of insured *H*s is significantly above that of insured *L*s (z=2.201, p-value=0.0277). Overall, 73 per cent *H*s get some kind of insurance vs. 48 per cent *L*s only.

Result 7: The rate at which *L*s are crowded out of the insurance market has not been significantly reduced by the RS therapy.

The crucial test yielding this result is based on a direct comparison of our two experiments in which all equilibrium-relevant parameters were given the same value. The rate of crowding-out of *L*s reaches a high of 68 per cent in the first experiment and a low of 52 per cent in the second. However, the difference is not significant by a Mann-Whitney U test (z=1.464; p-value=0.1432). This finding is illustrated by Figure 9.

General discussion and conclusion

This paper has presented an experimental analysis of competitive insurance markets with adverse selection focusing on the canonical models of Akerlof[1] and Rothschild and Stiglitz.[2] The first experiment was designed such that low-risk agents would be crowded out when a single full insurance contract can be offered but insurers cannot observe the risk type of their clients. The second experiment allowed the supply of the two levels of coverage predicted by the RS model while leaving competition set the market prices. Repeated experimental spot markets are especially suited to observe a disappearing "market for lemons" and to control for exposure to risk, adverse selection, the number and type of insurance contracts, the absence of loading, and perfect competition. Our experiments offer the closest experimental description of competitive insurance markets so far in the literature. In addition, they present two unique features worth mentioning. First, the binary lottery procedure was used to (successfully) control for the risk neutrality of insurers and the common risk aversion of clients. Second, the parameters of both experiments were matched in order to provide a clean test of the RS therapy of supplying two specific contracts instead of one for stopping the crowding-out of low risks.

The results reveal a partial crowding-out of low risks when a single full insurance contract can be offered (experiment 1). Crowding-out is not eliminated and it is not even significantly reduced by the introduction of deductible contracts (experiment 2). Finally, in contrast to the predicted separating equilibrium, we find pooling equilibria (experiment 2).

These results are intriguing because they seem to contradict a well-established economic theory which had been mostly confirmed by previous experiments.[30] Several technical objections arise first that we must dispel:

(i) Did subjects have enough incentives to play rationally?
This question arises because the biggest proportion of the subjects' gains comes from their initial endowment. However, we showed that insurers did maximise their expected profit and mean profits were null in all sessions. As for insureds, their potential loss represents one-fifth of their endowment which is a realistic share on insurance markets. More importantly, with the CARA utility function that we used, as did Posey and Yavas,[12] the initial endowment of subjects can have no impact on behaviour. Finally, the binary lottery procedure generates discrete and attractive gains that should give strong incentives to behave rationally.

(ii) Would the choice of other parameters modify the conclusions?
This question is natural since we chose a parameterised version of the lemons' model and the RS model. However, the theoretical predictions that we test are not restricted to some kind of parameters and utility functions as long as insurers are risk neutral, insureds are risk averse and incentive-compatible constraints are respected. On the basis of these criteria, our parameters are valid with a substantial margin of safety. Further, the value chosen for the constant absolute risk aversion would be considered "reasonable" by Shapira and Venezia (1999) and smaller than the one adopted by Posey and Yavas.[12] This should have favoured the crowding-out of low risks in our first experiment.

[30] (Shapira and Venezia, 1999; Asparouhova, 2006; Posey and Yavas, 2007).

(iii) Was the binary lottery procedure effective to control for risk attitudes?
We tested this assumption in subsection "Does the binary lottery procedure control for risk aversion?" and showed that we could not reject this claim.

(iv) Do we offer a valid test of the lemons' model and the RS model?
By matching the relevant parameters of our two experiments, we can measure the true impact of the RS proposition on the crowding-out of low risks through a direct comparison of outcomes in both experiments. Moreover, the partial crowding-out of low risks in the first experiment may signal why a pooling equilibrium is obtained in the second experiment. Some of the low risks who purchase full insurance in the first experiment are likely to do the same in the second and thereby to contribute to the pooling equilibrium.

Having dispelled these objections, it appears that the present experiments provide a stronger test of the theoretical predictions than previous attempts because we observed repeated and incentivised decisions, effectively controlled for risk attitudes and perfect competition in all sessions, provided no feedback information to the insurers about the risk type of the policyholders, and implemented a full interaction between the supply of and demand for insurance. The main reason for our negative result, we think, was revealed by the data: the maintained assumption of expected utility underlying classical models does not appear to obtain for participants in their choice of insurance.[31] Thus, our experiment does not invalidate the lemons' model but raises a concern regarding its implication for competitive insurance markets. A significant proportion of *Hs* do not purchase insurance when the market premium is lower than their *WTP* and even when it is lower than *L*s' fair premium. Conversely, a significant proportion of *L*s buy insurance when the market premium is higher than their *WTP* and even when it is higher than *H*s' fair premium. Since this behaviour can be observed in both experiments, it cannot depend solely on the presence of a deductible and, therefore, cannot be merely explained by an aversion to deductibles[32] or a cognitive bias towards high deductibles.[33] Since we effectively controlled for risk attitudes, we may further say that subjects violated EU by distorting objective probabilities of loss. On average, high risks perceived less than 30 per cent risk of loss and low risks perceived more than 10 per cent risk of loss, which resulted in a partial homogenisation of risk types. Pooling equilibria can be sustained because insureds who objectively differ in their risk level do not perceive themselves as being so much different.

[31] It should be noticed that Asparouhova[13] has validated the RS model in the context of credit markets, not insurance markets.
[32] Schoemaker and Kunreuther (1979).
[33] Tversky and Kahneman (1974).

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