Screening Equilibria In Experimental Markets

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1. Introduction

In their classic paper, Rothschild and Stiglitz (1976) analyze a competitive insurance market under asymmetric information with two policyholder risk types, or probabilities of having a fixed loss amount. Their model is a screening model where uninformed insurers move first offering a menu of contracts, defined as price-quantity pairs, to informed policyholders. They conclude that the only Nash equilibrium in this setting is a separating equilibrium, and that this equilibrium exists only if the proportion of high risk policyholders is sufficiently large. In this equilibrium the price-quantity pairs allow insurers to deduce policyholder risk types by their contract choices.

This paper by Rothschild and Stiglitz has spurred on a tremendous amount of additional research. This subsequent research is noteworthy in terms of the wide variety of fields to which the model has been applied. In addition to inspiring papers which directly apply the Rothschild-Stiglitz model, the paper has been cited several hundred times in the twenty-one years since its publication.[1]

One body of research which followed the paper's publication sought to develop alternative equilibrium concepts to be applied to the same type of problem studied by Rothschild and Stiglitz, the competitive insurance market with asymmetric information. These include most notably Wilson (1977), and Riley (1979). Wilson's equilibrium concept allowed for behavior by insurers called "Wilson foresight". Miyazaki (1977) and Spence (1978) established that under

[1]On the twentieth anniversary of the paper's publication, the European Group of Risk and Insurance Economists held a conference honoring this classic article. The conference featured Michael Rothchild, Joseph Stiglitz and others presenting papers inspired by the original work which were subsequently published in a special edition of the Geneva Papers on Risk and Insurance Theory (1997).

this new type of behavior an equilibrium always exists. It is either the Rothschild-Stiglitz equilibrium or a pooling equilibrium. Riley presented a model with “reactive” firms which always sustains an equilibrium. Both the Miyazaki-Wilson and Riley equilibria are non-Nash equilibria.

Another body of research has extended the Rothschild-Stiglitz model to analyze insurance markets with asymmetric information more extensively. This research includes studies on the efficiency implications of the Rothschild-Stiglitz model when compared to Miyazaki-Wilson and Riley (Crocker and Snow, 1985), studies of the efficiency of the use of categorical discrimination in insurance markets (Crocker and Snow, 1986; Hoy, 1982) and studies of the social value of hidden information (Crocker and Snow, 1992; Doherty and Thistle, 1996; and Doherty and Posey, 1998). It has also been used to study multi-period insurance contracts (Cooper and Hayes, 1987; Hosios and Peters, 1989), and has been extended to include uncertainty about the size of losses (Doherty and Schlesinger, 1995) and policyholder uncertainty about risk type (Ligon and Thistle, 1996). Numerous other issues in insurance markets have been analyzed with the Rothschild-Stiglitz model from supply restrictions in liability insurance markets (Berger and Cummins, 1992) to the financing of charitable hospital care (Posey, 1997).

This screening model of adverse selection has been applied to issues in many fields other than insurance. It has been applied to credit markets (Stiglitz and Weiss, 1992) including mortgage lending (Brueckner, 1992, 1994; Chari and Jagannathan, 1989; LeRoy, 1996) and lending to entrepreneurs (De Maza and Webb, 1990). In the law and economics literature, the model has been applied to attorney fee structures (Rubinfeld and Schtchmer, 1993) and in the conflict resolution literature it has been applied to arbitration (Curry and Pecorino, 1993).

Unemployment has been proposed as a screening device for worker productivity (Stiglitz, Rodriguez and Nalebuff , 1993). The wide variety of other applications is numerous.

Given the widespread application of this model in so many fields, empirical investigation would be particularly valuable. The empirical tests which focus on automobile insurance markets have provided mixed results. D'Arcy and Doherty (1990) and Dionne, Gourieroux and Vanasse (1998) have not found support for the Rothschild-Stiglitz adverse selection model in automobile insurance markets in the United States or Canada, while Dahbly (1983) and Puelz (1990) have found support. In the medical insurance and life insurance markets, the model is supported by the empirical evidence (Beliveau, 1981; Browne and Doerpinghaus (1993); Browne, 1992).

In this paper, we conduct an experimental test of the Rothschild-Stiglitz screening model of insurance markets with asymmetric information. Our focus is on the strategic behavior of firms with the option to offer menus of contracts to screen policyholders by risk type. Although a number of experiments have tested separating versus pooling equilibria in signaling models (e.g., Miller and Plott, 1985; Cadsby, Frank and Maksimovic, 1990), we have found only one other experimental test of a screening model (Berg, Dickhaut and Senkow, 1987). In that paper, to make the procedure more tractable for the subjects, the designers of the experiment limited the choice of sellers to four contracts (price-quantity pairs). This very strong restriction is necessary because of the complexity of the model. [2] In our experiment, we allow sellers to offer one or both of two quantities of insurance, full coverage or partial coverage, and effectively allow them to choose any price above zero in increments of .10 units. To make the procedure more tractable for

[2] Berg, Dickhaut and Senkow (1987) focus on discriminating between the Rothschild-Stiglitz, Wilson and Riley models which is not a focus of our experiments.

participants in our experiment, the buying decisions are made by a computer and we focus on the behavior of sellers and whether they indeed attempt to screen buyers by risk type in an environment where sellers have many contract options.

We develop a parameterized example of the Rothschild-Stiglitz screening model and utilize these parameters to design our experimental sessions. Our results provide striking evidence for screening behavior by sellers. We first conduct three sessions of our experiment in which the proportion of high risks is such that a Rothschild-Stiglitz separating equilibrium should exist. Each session involves 30 rounds, and in each round sellers compete for potential policyholders of two types, high and low risk. In each of these sessions, by the final round 100% of the markets have the Rothschild-Stiglitz separating equilibrium outcome, and 98.3% of markets have the Rothschild-Stiglitz separating equilibrium in the last 10 rounds. Not only are sellers in our experiment able to screen high risk and low risk buyers, they also price both full coverage and partial coverage contracts at their equilibrium levels. We then conduct three more sessions in which the only change we make is decreasing the proportion of high risks such that the Nash equilibrium is now a pooling equilibrium where the sellers offer only the full coverage contract. Once again, the observed behavior converges to the equilibrium prediction, although at a slower rate than it did in the three separating equilibrium sessions. In all but one of the last 10 rounds of each session, the observed outcome is a pooling outcome where only the full coverage contract is offered. However, there are some deviations from the equilibrium pricing. Approximately 13% of the full coverage contracts are sold at a price other than the equilibrium price (usually one increment above or one increment below).

Given the complexity of the Rothschild-Stiglitz model and the complexity of the resulting experimental design, the fact that the theory performed so well in our experiments is somewhat surprising. We believe the explanation lies in the simplicity of the competition involved in the model, the Bertrand type price competition. A price cut by one seller would capture the whole market for that seller. As a result, the other sellers have to match that price cut, otherwise they would not be able to sell any units. In our separating sessions, the price competition quickly results in both partial coverage and full coverage contracts being offered at their equilibrium prices. The convergence to the equilibrium in the pooling sessions is slower because it essentially involves two steps. In the first step, some sellers have to realize that instead of offering both contracts they could steal all the high risk and low risk buyers by offering the full coverage contract only. Realizing that they are losing their customers to a pooling contract, other sellers follow. Once all the sellers begin to offer the full coverage pooling contract, price competition eventually forces the price of the full coverage contract to its equilibrium level.

The next section presents the Rothschild and Stiglitz model and a parameterized example of it. These parameters are utilized in our experiment. Section 3 describes the design of the experiment. Experimental procedures are provided in Section 4. Section 5 reports the results of the experiment. Section 6 offers concluding remarks.

2. Rothschild-Stiglitz Model

Rothschild and Stiglitz (1977) develop a model of a competitive insurance market with asymmetric information. All potential policyholders are endowed with initial wealth W and each faces two possible states of nature, the loss state, with a reduction in wealth to W-X, and the no loss state where wealth remains at W. They assume two types of potential policyholders (or customers), high risk and low risk. The probability of the loss state is p_L for low risks and p_H for high risks, with $p_L < p_H$. The corresponding probability of the no loss state for type i is1- $p_{i,}$ $i=L,H$. The proportion of high risk individuals in the market is λ and 1- λ is the proportion of low risk individuals. All parties know W, λ, p_L, p_H, X and the utility function of potential policyholders U(·) defined over wealth. But each customer's probability of a loss is private information to that customer and the insurers know only the proportion of high and low risks, not which customers are which risk type. Potential policyholders are expected utility maximizers and it is assumed that $U' > 0$ and $U'' < 0$.

Rothchild-Stiglitz Equilibrium

The type of equilibrium considered by Rothchild and Stiglitz is a Nash equilibrium. The insurance premium paid in all states of nature is α and *I* is the payment made to the insured in the loss state. Therefore, an insurance contract can be defined as a pair (α, I). An equilibrium is defined as a set of contracts such that, when each customer chooses a contract to maximize his or her expected utility, no equilibrium contract yields negative profits and no insurer has an incentive to offer contracts outside the equilibrium set. The Rothschild-Stiglitz equilibrium is a screening equilibrium which induces individuals of each risk type to buy the policy or contract designed for them and, consequently, reveal their information. Let (α_i, I_i) represent a contract intended for a type *i* individual, $i=L,H$. The equilibrium consists of a low risk and high risk contract solving the following maximization problem:

$$\text{Max} \quad (1-p_L)U(W-\alpha_L)+p_LU(W-X-\alpha_L+I_L) \qquad (1)$$

subject to $(1-p_H)\, U(W-\alpha_H)+p_HU(W-X-\alpha_H+I_H)$

$$-(1-p_H)U(W-\alpha_L)-p_H U(W-X-\alpha_L+I_L)=0 \quad (2)$$

$$\alpha_H-p_H I_H=0 \quad (3)$$

and $$\alpha_L-p_L I_L=0. \quad (4)$$

The solution gives low risks the highest utility possible while ensuring that high risks do not choose the low risk policy, due to the self-selection constraint (2) and that the low and high risk policies each break even, or are actuarially fair, due to constraints (3) and (4).

Figure 1 depicts the R-S equilibrium. E is the initial endowment; wealth in the loss state is shifted from *W* to *W-X*. The line labeled p_H is the zero-profit line for high risk policies and has slope $-(1-p_H)/p_H$; the line labeled p_L is the zero-profit line for low risk policies having slope $-(1-p_L)/p_L$. The pooled price line, labeled p^*, gives the zero-profit policies for an average risk having a probability of loss of $p^*=(1-\lambda)\, p_L+\lambda\, p_H$. The R-S equilibrium contract for high risks is the full insurance contract labeled *H*. The equilibrium contract for low risks, *L*, gives high risks the same level of expected utility as *H*, as can be seen by the fact that the indifference curve C_H passes through both *H* and *L*.

Note that the indifference curve for risk type *i* is tangent to the zero profit line p_i at the full insurance line. The slope of the indifference curve for a type i individual at any point (Y_1, Y_2) is $-(1-p_i)U'(Y_1)/p_i U'(Y_2)$ which equals $-(1-p_i)/p_i$ at full insurance. Since $p_H > p_L$, the slope of a high risk indifference curve through any point is flatter than the slope of a low risk indifference curve through the same point. The Rothchild-Stiglitz equilibrium exists if and only if the indifference curve for a low risk through *L*, C_L, does not cross the pooled price line p^*. Consider Figure 2 where the indifference curve for a low risk through *L*, C_L, does cross the pooled price line p^*. Then an insurer can offer a contract in the region between C_L and the pooled price line which will attract both risk types away from the Rothschild-Stiglitz contracts and earn positive profits (because the contract is to the southwest of the pooled price line). In this case, no equilibrium exists for the following reason. Competition will drive the pooling contract to the zero-profit full insurance pooling contract F in Figure 3. But such a pooling equilibrium cannot be sustained because at that contract, the low risk indifference curve is steeper than the pooled price line while the high risk indifference curve is flatter. Therefore, a contract can be offered from the region between C'_L and the pooled price line which will attract only low risks away from the pooling contract F, making positive profits and causing *F* to make negative profits. Therefore, the proportion of high risks λ in the market (which determines p^*) is crucial to the question of whether the Rothschild-Stiglitz equilibrium or any equilibrium exists. If λ is sufficiently small, then no equilibrium will exist.

<u>Parameterized Version of Rothschild-Stiglitz Model</u>

In order to perform experiments to test the Rothschild-Stiglitz model, and, in particular, to test the equilibrium behavior of firms in the Rothschild-Stiglitz setting, the following assumptions are made. It is assumed that there are 120 consumers who have exponential utility functions, $U(Y) = -e^{-rY}$, and that $p_H = {}^1/_5$, $p_L = {}^1/_{15}$, $r = (\ln 4)/3$ and $X = 19.5$. Note that with exponential utility functions, initial wealth does not have an impact on the outcome. Two cases are considered, first $\lambda = ½$ and then $\lambda = {}^1/_4$.

First consider the case where $\lambda = ½$. The solution to the Rothschild-Stiglitz problem (1)-(4) is $(\alpha_H, I_H) = (p_H X, X) = (3.9, 19.5)$ and $(\alpha_L, I_L) = (p_L I_L, I_L) = (.9, 13.5)$. This is depicted in Figure 4. When $\lambda = ½$, the pooled price line does not cross the low risk indifference curve through L = (.9, 13.5) and the R-S equilibrium can be sustained.

The line I_H = 19.5 = Full insurance represents all contracts with coverage level 19.5, where the price increases along the line by moving to the northeast. Similarly, the line I_L = 13.5 represents all contracts with coverage level 13.5, where the price increases along the line by moving to the northeast. In order to make the experimental procedure tractable for subjects, the coverage options of the insurers are restricted to these two levels, 19.5 and 13.5, the two coverage levels which are the equilibrium levels for the Rothschild-Stiglitz model. These two coverage levels are denoted full coverage and partial coverage, respectively. Firms are able to compete on the basis of price to sell either or both of these two coverage levels. Note that the exponential utility function implies that the amount a consumer of a given risk type is willing to pay for full coverage over partial coverage is fixed rather than varying as prices vary. This is due to constant absolute risk aversion.[3] High risks are willing to pay up to 3 units more for full coverage over partial coverage since 3.9 and .9 are the premiums levels for full and partial coverage, respectively, which satisfy constraint (2). Low risks are willing to pay up to 1.5 units more for full coverage over partial coverage. This can be determined by finding the amount, π, that low risks will pay for full insurance which will leave them indifferent to the low risk R-S equilibrium contract (.9, 13.5):

$$U(w-\pi) = ({}^4/_{15})\, U(W-.9) + ({}^1/_{15})\, U(W-.9\ -6) \Rightarrow$$

$$e^{r\pi} = ({}^4/_{15})\, e^{r(.9)} + ({}^1/_{15})\, e^{r(.9+-6)} \qquad \Rightarrow$$

$$4^{(\pi - .9)/3} = ({}^4/_{15}) + ({}^1/_{15})\, 4^{6/3} \qquad (\text{since } e^r = 4^{1/3}) \qquad \Rightarrow$$

[3] Note that the slope of the indifference curve for a type i individual at any contract (α, I) is $-(1-p_i)U'(-\alpha)/p_iU'(-\alpha -X + I) = -(1-p_i)(-re^{r\alpha})/(p_i(-e^{-r(-\alpha -X + I)})) = -(1-p_i)/(p_i(-e^{-r(-X + I)}))$ which does not depend on α.

$\pi = 2.4$.

Therefore, a low risk will pay up to 2.4 - .9 = 1.5 more for full coverage over partial coverage.

When $\lambda = {}^{1}/_{4}$, the pooled price line does cross the low risk indifference curve through L = (.9, 13.5). The Rothschild-Stiglitz equilibrium does not exist in this case. In this stylized version of the model with the two coverage options 19.5 and 13.5, or full and partial, respectively, the equilibrium is a pooling equilibrium where both risk types purchase full coverage at the zero-profit pooling premium of $(\lambda\, p_H + (1\text{-}\lambda)p_L)\, X = ({}^{1}/_{10})\ 19.5 = 1.95$. Therefore, the equilibrium consists of a single contract (1.95, 19.5). This is represented in Figure 5 as contract F. Note that, unlike in Figure 3 for the general model, insurers cannot offer contracts in the area between C'_L and the pooled price line which will break the pooling equilibrium because such coverage levels are not available to them in our parameterized version of the model. This is only true if the low risk indifference curve through the R-S separating contract for low risks crosses the full insurance line to the southwest of F which is the case under our parameter assumptions. So a pooling equilibrium can be sustained.

The purpose of the experiment is to test if sellers in this parameterized version of the Rothschild-Stiglitz economy would separate when $\lambda = ½$ and pool when $\lambda = {}^{1}/_{4}$. In addition, the experiment will test whether sellers would offer the contracts at their equilibrium prices, i.e. whether they would offer the full coverage contract at a price of 3.9 and partial coverage contract at a price of .9 when $\lambda = ½$, and offer the pooled contract at a price of 1.95 when $\lambda = {}^{1}/_{4}$.

3. The Experimental Design

We conducted six experimental sessions. The first three sessions involved 60 high cost and 60 low cost buyers (λ = ½) with separating equilibrium as the predicted outcome. We will refer to these sessions as the *separating treatment* sessions. The last three sessions involved 90 high cost and 30 low cost buyers (λ = $^1/_4$) with pooling equilibrium as the predicted outcome. These sessions will be referred to as the *pooling treatment* sessions.

All 6 sessions of our experiment were divided into 35 identical trading periods. Given the lengthy nature of our instructions, we designated the first 5 rounds as practice rounds to give the subjects a chance to fully understand the game. In the following 30 rounds, the subjects played the same game for cash.

Each session involved a different set of 18 sellers, who sat at visually isolated terminals. Each seller had two types of services to sell: Service A and Service B. In each round, a seller was matched with two other sellers in the room. Thus, there were 6 groups of sellers in each round. Each seller was matched randomly with two different sellers in each of the 35 rounds. The three sellers in each group competed with each other to sell to a set of buyers. The identities of the sellers, including the identification numbers they were assigned to, were kept anonymous. The purpose of this was to prevent sellers from building reputations during the experiment, and thus to capture the one-shot nature of the theoretical model.

Each trading period consisted of the following steps. First, each seller chose which service, A or B or both, to offer and posted a unit price for these services. Service A represents full coverage (I=19.5) and Service B represents partial coverage (I=13.5) from the parameterized Rothschild-Stiglitz model of the previous section. Then, each buyer decided which service to purchase and from which seller to purchase it. After all the decisions were made, each seller was informed of the sale price for each service, number of units s/he sold of each service, which buyer type(s) purchased which of his/her service(s), and his/her earnings for the round.

A seller's point earnings from the sale of each unit equaled the sale price minus cost for that unit. Following the parameterized version of the Rothschild-Stiglitz model, the cost of selling a unit of Service A to a High Cost buyer was set at 3.9 points (the probability of a loss times the coverage level, 1/5 x 19.5) while the cost of selling a unit of Service A to a Low Cost buyer was set at 1.3 points (1/15 x 19.5). Similarly, the cost of selling a unit of Service B to a High Cost buyer was set at 2.7 points (1/5 x 13.5) while the cost of selling a unit of Service B to a Low Cost buyer was set at 0.9 points (1/15 x 13.5).

Unlike the sellers' decisions, the buyers' decisions did not involve any strategic considerations. Having observed the prices of the three sellers for each service, a buyer with the exponential utility function would simply pick the lowest price for the service that s/he decided to purchase. Given the purely mechanical nature of the buyers' decisions in our setup, and to better focus on the sellers' actions, we simplified the experiment by computerizing the buyers' choices. Sellers were informed that the computer would make the choices for the buyers according to the following rules.

Each buyer will purchase at most one unit of either Service A or B. As a first rule, each buyer compares the prices of the three sellers for the two services and identifies the seller that offers the lowest price for Service A and the seller that offers the lowest price for Service B. Then, the two buyer types use the following rules in their purchases:

> **High Cost Buyers:** They will never pay more than 16 points for Service A and more than 13 points for Service B. They are willing to pay up to 3 points more for Service A than

Service B. That is, if the lowest price for Service A does not exceed the lowest price for Service B by more than 3 points, they will purchase Service A (from the seller that offered the lowest price for Service A). Otherwise, they will purchase Service B from the seller that offered the lowest price for Service B.

Low Cost Buyers: They will never pay more than 13.7 points for Service A and more than 12.2 points for Service B. They are willing to pay up to 1.5 points more for Service A than Service B. That is, if the lowest price for Service A does not exceed the lowest price for Service B by more than 1.5 points, they will purchase Service A (from the seller that offered the lowest price for Service A). Otherwise, they will purchase Service B from the seller that offered the lowest price for Service B.

A seller's earnings in a round were determined by how many units of Service A and B he/she sold and to which type of buyers in that round. As a result, each seller's earnings in a round depended on his/her price choices and the price choices of the two sellers that s/he was matched with in that round. If it turned out that there was a tie for the lowest price between two or all three sellers for a service that buyers of either type decided to buy, then these buyers were shared equally among the sellers that charged the lowest price.

4. Experimental Procedures[4]

All six sessions were conducted in June 1998 at the Pennsylvania State University. Each treatment used 54 subjects, 18 in each of three sessions, who had signed up in response to fliers

[4] Instructions are included in an Appendix.

posted around campus. The fliers indicated that the average earnings for participants would be $23 for a session lasting less than 2 hours. Each subject participated in one session only. Subjects were seated in front of computer terminals, read aloud a set of instructions and given an opportunity to ask questions. We then conducted the 5 practice rounds in which earnings were hypothetical, and at the end of each practice round we gave subjects another opportunity to ask questions. No communication between subjects was permitted during any of the sessions.

Given the nature of the game subjects played, it was very difficult for us to predict the point earnings for the subjects. Point earnings for a subject could have been as high as 1420 points in the separating treatment sessions (selling A at 16 to high risks and B at 13 to low risks) and as low as 0 points (the theoretical prediction). Such extreme earnings predictions associated with each treatment made it difficult to assign a proper exchange rate for their point earnings. To make sure the average participant would earn a reasonable amount, we decided to calculate the exchange rate at the end of each session such that the average earnings in that session would be $20 per subject. The instructions informed the participants that their point earnings from rounds 6 through 35 would be multiplied by an exchange rate of [$20 / the average point earnings per participant]. It is important to note that this payoff structure does provide the subjects with monetary incentives to maximize their points earnings. The higher a subject's point earnings were, the greater his/her dollar earnings would be.[5] To ensure positive earnings for each subject, we also paid each subject an additional $3 for participating in the experiment. Thus, earnings averaged $23 in each session. The sessions averaged 110 minutes.

[5] Indeed, there was considerable variation across subjects' earnings. They ranged from $3 to $59.75 in the separating sessions, and from $3 to $101.75 in the pooling sessions.

Sellers chose prices by entering a number up to one decimal between 0 and 16 for Service A and between 0 and 13 for Service B.[6] They were told that if they choose not to offer a particular service, then they could type "x" rather than a price in the corresponding space. If a seller did not enter a price within 60 seconds of receiving the prompt, his/her prices for that round would be submitted as blank and sh/e would not sell any units in that round (this did not occur in any of the sessions). After all three sellers in each group posted their prices, the computer made the purchasing decisions for each type of buyer group according to the rules described earlier, and informed each seller the sale price for each service, the number of units that the seller sold of each service to each buyer type, and his/her earnings for the round.

Note that the restrictions on posted prices permit sellers to choose prices below cost. It is also possible that a seller could offer a price for a service with the expectation that it would be purchased by low cost buyers, but instead high cost buyers would purchase it and cause the seller to suffer a loss. Therefore, it was possible for a seller to have negative earnings in any round.

5. Experimental Results[7]

The results of the separating treatment sessions, Sessions S1, S2 and S3, are summarized in Figures 6, 7 and 8. These figures display the average posted price by sellers and the average transaction price for each service in each round. The equilibrium prediction was that both services would be offered at their zero-profit prices, Service A at 3.9 and Service B at 1.

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[6] Since no buyer is willing to pay more than 16 for Service A and more than 13 for Service B, the upper limits on prices did not constrain the sellers' strategy spaces.

[7] We exclude the data from the practice round from all calculations in this section. A complete set of the data is available from either author upon request.

However, since sellers are indifferent between earning zero profits and not selling, and since prices could be set up to one decimal point, price combinations of 4 and 1, and 3.9 and 0.9 were also Nash equilibrium outcomes. The tables below Figures 6-8 report the frequency of the equilibrium play: the proportion of seller trios (markets) in which the transaction prices of the two services were an equilibrium combination (any of the three equilibrium price combinations).

In spite of the complicated nature of the experiment, our results from the separating sessions are quite clear. Although less than half of the transaction prices were equilibrium prices in the first 5 rounds, the prices converged to an equilibrium quickly. In the last ten rounds, all the transaction prices in each session were equilibrium prices, except for round 27 in session S1 and rounds 26 and 27 in session S3. In the last three rounds of each session, every transaction took place at equilibrium prices.[8] Such a sharp outcome in a relatively complicated experiment illustrates the power of Bertrand competition. Even if some sellers had been slow to understand the game or resisted playing the equilibrium prices initially, the feedback that they received about the selling prices at the end of each round made it clear to them that they had to lower their prices in order to be able to sell any units. As the figures illustrate, not only the transaction prices converged, but also the posted price of each seller converged to the equilibrium prediction.

A comparison of the three separating treatment sessions indicates that there was not a statistically significant difference among the sessions, and thus among the cohort of players in these sessions. Table 1 presents statistics for testing the following hypotheses: H_{01}: $\mu_{s1} = \mu_{s2}$, H_{02}: $\mu_{s2} = \mu_{s3}$ and H_{03}: $\mu_{s1} = \mu_{s3}$ where μ_{si} is the proportion of transaction prices in session S_i, i=1,2,3,

[8] Almost all of the equilibrium transactions took place at a price of 4 for Service A and at a price of 1 for Service B.

that are equilibrium prices. The statistics are based on the final round, the last 15 rounds, and all 30 rounds. As the p-values in Table 1 indicate, there was no difference between any of the three separating treatment sessions at 10% significance level.

The posted prices and selling prices in the pooling treatment sessions, P1, P2 and P3, are summarized in Figures 9-11. A price of zero for a service in these figures represents the sellers' decision not to offer that service, ("x"). The equilibrium prediction is for Service A to be sold at 2 and Service B not to be offered at all. We anticipated that obtaining the equilibrium outcome in the pooling treatment sessions would be more complicated than the separating treatment sessions; in the separating treatment sessions the competition among the sellers forced them to price each service at its cost where the only critical question was whether they would be selling each service to the buyer type to which they intended to sell. The pooling equilibrium, on the other hand, requires at least one seller to realize that if all sellers offered both of the services, then s/he could profit from offering Service A only at such a price that would attract all buyers of both types. However, s/he also must realize that if s/he offers Service A only and prices it with the expectation that all buyer types would buy it, s/he runs the risk that some other seller's price for Service B may attract all the low cost buyers, and as a result s/he may end up selling to high cost buyers only and incurring a loss.

The more complicated nature of the pooling sessions can be seen in the posted prices in Figures 9-11. Since the average price for B is calculated using only prices at which B was offered (i.e., not including "x" choices by sellers) the average posted prices for B on the graphs capture only those which are not "x" choices (recall that if all prices in a round are "x"s, then the average price on the graphs appears as zero for that round). Note that not all the posted prices converged to the equilibrium.[9] However, a great majority of transactions were in line with the equilibrium prediction. As the last column under the figures indicates, in 6 of the last 10 rounds of Session P1 and in 7 of the last 10 rounds of Session P3, all the Service A units were sold at the equilibrium price of 2 and Service B was not sold at all. The results of Session P2 were weaker; in only 3 of the last 10 rounds, the observed behavior of transactions were entirely in line with the equilibrium prediction.

It is important to note that the divergence of some of the transactions from the equilibrium prediction in the pooling sessions were mostly with respect to the price of Service A, not with respect to "pooling." As the second column under Figures 9-11 shows, with the exception of a single round in Session P1, each transaction in each of the last 10 rounds of every session involved a pooling outcome where only Service A was sold. The discrepancy between the two columns is due to the fact that a few of the selling prices for Service A were different than 2. The typical deviation was to the price of 1.9, which indicates an attempt by some sellers to capture the whole market, albeit at a loss.

We attribute the high percentage of pooling equilibrium outcomes in sessions P1-P3, in spite of the complicated nature of the game, again to the power of Bertrand competition. It is not trivial for subjects to figure out that offering Service A only at a certain price will gain him/her the whole market. However, all it takes for a market to realize this is for one seller in that market

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[9] It should be pointed out that 87% of posted price pairs in the last 5 rounds were equilibrium prices. If a seller offers Service B at a high enough price at which no buyer type would buy it (e.g., if the difference between his/her price for Service A and Service B is less than 1.5 or if his/her price for B exceeds 13.7), then this would effectively mean that he/she did not want to sell Service B. Therefore, we include prices of 2 for A and >.5 for B as equilibrium posted prices.

to discover this opportunity. Once a seller in a market steals all the buyers by offering a pooling contract, the other sellers realize that they will have to offer a similar contract. Eventually, all sellers start offering the equilibrium contract.

There was a session effect between Session P2 and the sessions P1 and P3. As reported in Table 2, using the observed behavior in the last 15 rounds, and in all rounds, Session P2 was significantly different than Session P1 and P3 while Session P1 and P3 did not exhibit significant differences. The exception is with respect to the last round behavior where Session P3 exhibited a different behavior than Session P1 and P2 while Sessions P1 and P2 did not exhibit a significant difference.

Our last test deals with the main objective of the experiment: would a change in the proportion of high cost and low cost buyers induce a change in the pricing strategies of the sellers? The instructions we used for the separating and pooling sessions were identical except for the line where we changed the number of high cost buyers from 60 to 30 and the number of low cost buyers from 60 to 90. Table 3 confirms what has already become clear from Figures 6-11; there was a significant change in the proportion of times the observed prices were a separating equilibrium outcome as we changed the proportion of high risk buyers from ½ to ¼. The proportion of separating equilibrium outcomes dropped from around 1 in sessions S1, S2 and S3 to around 0 in sessions P1, P2 and P3.

6. Conclusion

In this paper, we conduct an experimental test of the Rothschild-Stiglitz screening model of insurance markets with asymmetric information. Our focus is on the strategic behavior of firms with the option to offer menus of contracts to screen policyholders by risk type. We develop a parameterized example of the Rothschild-Stiglitz screening model and utilize these parameters to design our experimental sessions. Our results provide striking evidence for screening behavior by sellers. In the first three sessions of our experiment the proportion of high risks is such that a Rothschild-Stiglitz separating equilibrium should exist. In each of these sessions, almost all of the markets have the Rothschild-Stiglitz separating equilibrium in the last 10 rounds. Sellers in our experiment screen high risk and low risk buyers as well as price both the full coverage and partial coverage contracts at their equilibrium levels. In the next three sessions the only change we make is decreasing the proportion of high risks such that the Nash equilibrium is now a pooling equilibrium with only the full coverage contract being offered. Again, the observed behavior converges to the equilibrium prediction, although at a slower rate than it did in the three separating equilibrium sessions.

Instructions

General Rules

This is an experiment in the economics of decision making. If you follow the instructions carefully and make good decisions, you can earn a considerable amount of money. You will be paid in private and in cash at the end of the experiment. The funding for this experiment has been provided by the Division of Research in the Smeal College of Business at Penn State.

The experiment will consist of 40 rounds. The first 5 rounds will be practice rounds. The purpose of the practice rounds is to familiarize you with the experimental procedures. Nothing that you do in the practice rounds will affect your earnings.

The rules for each round are identical. In each round you will have a chance to earn some points. How many points you earn will depend on your decisions and the decisions of the other people in this experiment. At the end of the instructions we will explain how your point earnings will be converted into dollars and cents. The more points you earn, the greater your earnings will be. It is in your interest to make as many points as you can in each and every round. You will be paid in private and in cash at the end of the experiment.

Description of Each Round

There are 18 of you in this experiment, and each of you is given the role of a seller. Each of you has two types of services to sell: Service A and Service B. The buyers in this game are hypothetical and the computer will make the purchasing decisions for the buyers. We will describe how the purchasing decisions are made shortly.

In each round, you will be matched with two other sellers in the room. You and the two sellers you are matched with will be competing to sell to the same buyers. Since there are a total of 18 sellers in the room, there will be 6 groups of sellers in each round. You will be matched randomly with two different sellers in each round. You will not know who is matched with you in any round. Similarly, the other sellers in this experiment will not know who they are matched with in any round.

Each round consists of the following simple steps: (i) you choose which services you would like to offer, A or B or both; (ii) you choose a unit price for the services that you offer and enter it on your terminal (as everything else, your prices will also be in points); (iii) the buyers decide which service to purchase and from which seller to purchase it; (iv) the buyers' purchase decisions and your earnings resulting from any sale appear on your screen, and (v) you record your prices, the sale prices, the number of units of each service you sold and your earnings on the record sheet that you have been provided. We will now describe how the buyers decide from which seller to purchase and how your earnings are determined.

How the buyers' decisions are determined

Each group of sellers, including you and the two sellers you are matched with face two groups of buyers; High Cost buyers and Low Cost buyers. As will be clear briefly, it will cost you more to sell to High Cost buyers than to Low Cost Buyers. Each group of sellers face 60 High Cost buyers and 60 Low Cost buyers in each round. A buyer of any type makes two choices: which of the two services, Service A or Service B, to purchase; and from which of the three sellers to purchase. A buyer can purchase only one unit of Service A or Service B, but not both, in each round.

As a first rule, each buyer compares the prices of the three sellers for the two services and identifies the seller that offers the lowest price for Service A and the seller that offers the lowest price for Service B. Then, the two buyer types use the following rules in their purchases.

High Cost Buyers:

1. High Cost buyers will never pay more than 16 points for Service A and more than 13 points for Service B. Thus, no Service A will be purchased by any High Cost buyers if the lowest price for Service A exceeds 16 points. Similarly, no Service B will be purchased by them if the lowest price for Service B exceeds 13 points.

2. High Cost buyers are willing to pay up to 3 points more for Service A than Service B. That is, if the lowest price for Service A does not exceed the lowest price for Service B by more than 3 points, they purchase Service A (from the seller that offered the lowest price for Service A). Otherwise, they purchase Service B from the seller that offered the lowest price for Service B.

Low Cost Buyers:

1. Low Cost buyers will never pay more than 13.7 points for Service A and more than 12.2 points for Service B. Thus, no Service A will be purchased by any Low Cost buyers if the lowest price for Service A exceeds 13.7 points. Similarly, no Service B will be purchased by them if the lowest price for Service B exceeds 12.2 points.

2. Low Cost buyers are willing to pay up to 1.5 points more for Service A than Service B. That is, if the lowest price for Service A does not exceed the lowest price for Service B by more than 1.5 points, they purchase Service A (from the seller that offered the lowest price for Service A). Otherwise, they purchase Service B from the seller that offered the lowest price for Service B.

Since each High Cost buyer follows the same rules, it should be clear that High Cost buyers will either all purchase Service A or all purchase Service B from the seller that offers the lowest price for the service chosen. Similarly, since each Low Cost buyer follows the same rules, Low Cost buyers will either all purchase Service A or all purchase Service B from the seller that offers the lowest price for the service chosen. If it turns out that there is a tie for the lowest price between two or all three sellers for a service that buyers of either type decide to buy, then these buyers will be shared equally among the sellers that charge the lowest price.

How your earnings are determined

Your earnings in a round will be determined by how many units of Service A and B you sell and to which type of buyers in that round. As a result, your earnings in a round depend on your price choices for the two services and the price choices of the two sellers you are matched with in that round.

. If you do not sell any units in a round, your earnings for that round will be zero points.

. If you make a sale in a round, then your **point** earnings from each unit will be equal to your price minus cost for that unit. Your cost of selling a unit of Service A is 3.9 points for a High Cost buyer and 1.3 points for a Low Cost buyer. Your cost of selling a unit of Service B is 2.7 points for a High Cost buyer and 0.9 points for a Low Cost buyer. Your earnings therefore are as follows:

For each unit of Service A that you sell to a High Cost Buyer you earn: Your price for Service A less 3.9 points
For each unit of Service B that you sell to a High Cost Buyer you earn: Your price for Service B less 2.7 points
For each unit of Service A that you sell to a Low Cost Buyer you earn: Your price for Service A less 1.3 points
For each unit of Service B that you sell to a Low Cost Buyer you earn: Your price for Service B less 0.9 points

The following table summarizes the buyers' decisions and how your earnings are determined:

	High Cost Buyer	**Low Cost Buyer**
The most the buyer is willing to pay		
for Service A:	16.0	13.7
for Service B:	13.0	12.2
How much more the buyer is willing to pay for Service A over Service B:	3.0	1.5
Cost of providing		
Service A:	3.9	1.3
Service B:	2.7	0.9

Profit per buyer is price minus *cost.*

Remember that each High Cost buyer and each Low Cost buyer purchases the same type of service and from the same seller (the seller that offers the lowest price for that service). Recall that there are 60 buyers of each type. Since each of 60 High Cost buyers purchases the same type of service, then there are four possibilities. a) Your price is lowest for the service that they purchase and you sell 60 units, b) You and one other seller charge the same lowest price and you each sell 30 units, c) All three of you charge the same price and you each sell 20 units or d) Your price is higher than the lowest price and you sell zero units. Similarly, you either sell 60, or 30, or 20, or 0 units of a service type to Low Cost buyers.

At the end of each round, the computer will inform you how many, if any, units of each service you sold to which buyer types and your earnings resulting from any sale. You will also be informed of which service High Cost buyers purchased and the lowest price for that service, and which service Low Cost buyers purchased and the lowest price for that service. We ask that you record the prices you offered, the sale price for each service, and the buyer type that purchased that service as well as the number of units each service you sold and your earnings.

At the end of the experiment your point earnings from rounds 6-40 will be summed and converted into dollars and cents as follows. Your point earnings will be multiplied by an exchange rate which equals [$20 divided by the average point earnings per seller]. This will insure that the average seller will earn $20. However, note that the more points you earn, the greater your dollar earnings will be. You may earn more or less than $20 depending on how your points compare to the average. It is thus in your interest to make as many points as you can in each and every round. Each person will be paid an additional $3 for participating in the experiment.

<u>Entering Your Price</u>

At the beginning of each round you will see the following prompt on your screen:

PLEASE SELECT A PRICE FOR EITHER SERVICE A OR SERVICE B OR BOTH. IF YOU CHOOSE NOT TO OFFER A PARTICULAR SERVICE, TYPE X RATHER THAN A PRICE IN THE CORRESPONDING SPACE. PRESS THE ENTER KEY AFTER EACH SELECTION.

SERVICE TYPE:	A	B
MIN-MAX:	(0-16)	(0-13)
PRICE (IN POINTS)	_______	______

After you make your selections, you will be asked to confirm them. You can change your selection by typing N(o) when you are asked to confirm your selections. This will take you back to the lines to retype your new selections. Once you are satisfied with your selection, you should type Y(es) when asked to confirm; once you have typed Y you will have made your choice.

After you and the two sellers you are matched with have made your choices, the computer makes the purchasing decisions for each type of buyer group according to the rules that we described above.

You will have 1 minute in each round to choose your prices from the time you receive the prompt. If you do not make a decision within 1 minute, your prices for that round will be submitted as blank and you will not sell any units in that round.

Are there any questions?

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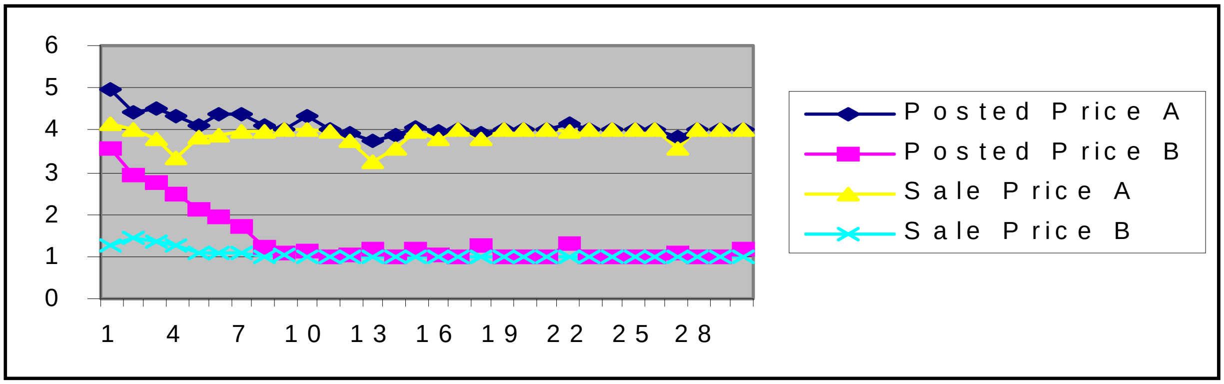
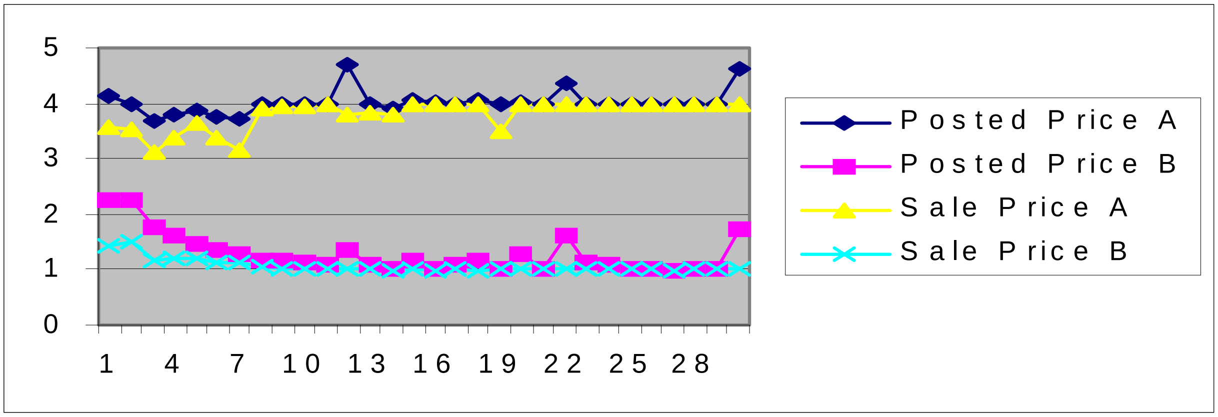
FIGURE 6



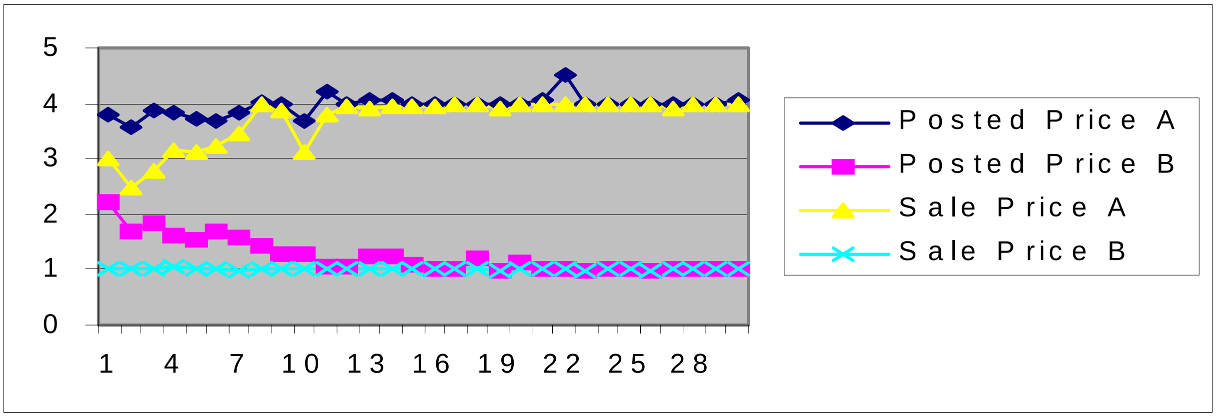
Rounds	Proportion Of Markets With Separating Equilibrium
1	0
2	0
3	0.17
4	0.17
5	0.39
6	0.5
7	0.67
8	0.83
9	0.83
10	1
11	0.83
12	0.83
13	0.67
14	0.67
15	1
16	0.83
17	1
18	0.67
19	1
20	1
21	1
22	1
23	1
24	1
25	1
26	1
27	0.83
28	1
29	1
30	1

FIGURE 7



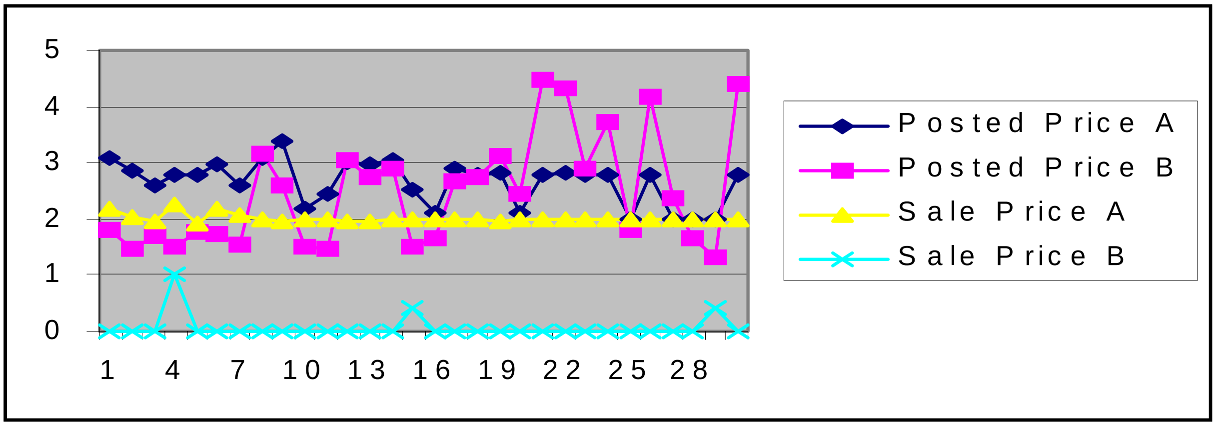
Rounds	Proportion Of Markets With Separating Equilibrium
1	0
2	0
3	0
4	0
5	0.39
6	0.17
7	0.17
8	0.28
9	0.67
10	1
11	1
12	0.83
13	0.89
14	0.72
15	1
16	0.83
17	1
18	0.83
19	0.83
20	1
21	1
22	1
23	1
24	1
25	1
26	1
27	1
28	1
29	1
30	1

FIGURE 8



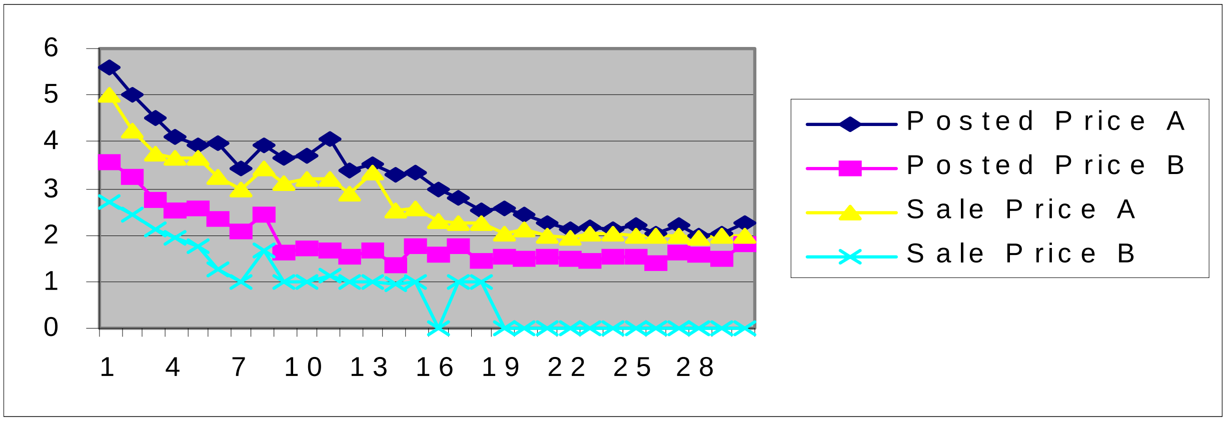
Rounds	Proportion Of Markets With Separating Equilibrium
1	0.33
2	0
3	0.17
4	0.17
5	0.33
6	0.17
7	0.39
8	0.78
9	0.5
10	0.5
11	0.67
12	0.83
13	0.83
14	1
15	1
16	1
17	1
18	1
19	0.83
20	1
21	1
22	1
23	1
24	1
25	1
26	0.83
27	0.83
28	1
29	1
30	1

FIGURE 9



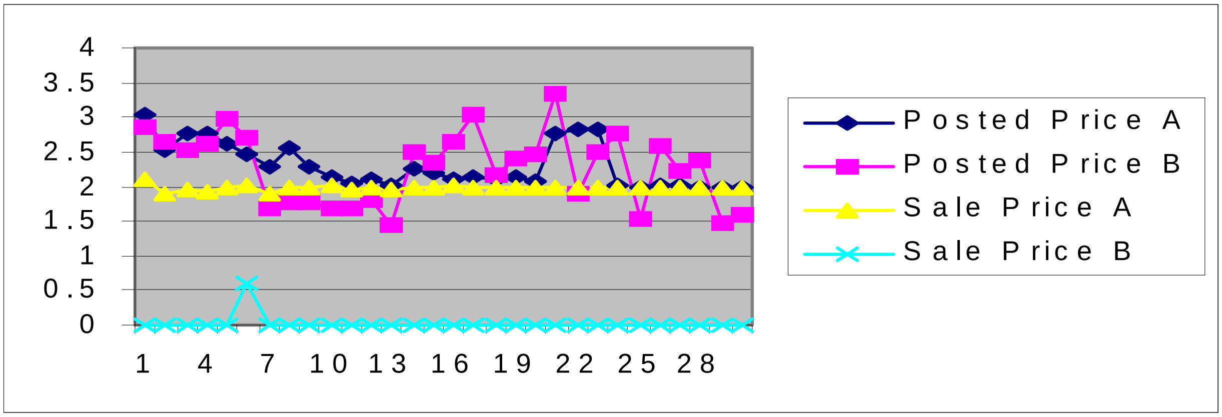
Rounds	Proportion Of Markets With Pooling Outcomes	Proportion Of Markets With Pooling Equilibrium Outcomes
1	1	0.17
2	1	0.22
3	1	0.67
4	0.83	0.17
5	1	0.5
6	1	0.83
7	1	0.5
8	1	0.67
9	1	0.5
10	1	1
11	1	1
12	1	0.72
13	1	0.83
14	1	1
15	0.83	0.67
16	1	0.83
17	1	1
18	1	1
19	1	0.83
20	1	0.83
21	1	1
22	1	1
23	1	0.83
24	1	0.89
25	1	0.83
26	1	1
27	1	1
28	1	1
29	0.83	0.83
30	1	1

FIGURE 10



Rounds	Proportion Of Markets With Pooling Outcomes	Proportion Of Markets With Pooling Equilibrium Outcomes
1	0	0
2	0.33	0.17
3	0.33	0
4	0.5	0
5	0.33	0
6	0.5	0.17
7	0.67	0.17
8	0.17	0
9	0.17	0
10	0.33	0.17
11	0.33	0.17
12	0.67	0
13	0.33	0.17
14	0.67	0
15	0.83	0
15	1	0
17	0.83	0.17
18	0.83	0.22
19	1	0.33
20	1	0.33
21	1	0.5
22	1	0.39
23	1	0.67
24	1	0.83
25	1	1
26	1	1
27	1	0.67
28	1	0.67
29	1	1
30	1	0.72

FIGURE 11



Rounds	Proportion Of Markets With Pooling Outcomes	Proportion Of Markets With Pooling Equilibrium Outcomes
1	1	0.17
2	1	0.33
3	1	0.17
4	1	0.5
5	1	0.5
6	0.83	0.5
7	1	0.39
8	1	1
9	1	1
10	1	0.83
11	1	0.5
12	1	0.83
13	1	0.5
14	1	0.83
15	1	1
16	1	0.94
17	1	1
18	1	0.83
19	1	1
20	1	1
21	1	1
22	1	0.83
23	1	1
24	1	1
25	1	1
26	1	1
27	1	1
28	1	1
29	1	0.83
30	1	0.83

Table 1. Statistical Tests For Session Effects for the Separating Treatment[1]			
Using Data From Final Round ***Using Data From the last 15 Rounds*** *Using Data From the All Rounds*			
Dependent Variable	Observations	Proportion of equilibrium outcomes	p-value[2]
Proportion of markets with Separating Equilibrium in Session S1	**18** ***270*** *540*	**1** ***.956*** *.763*	
Proportion of markets with Separating Equilibrium in Session S2	**18** ***270*** *540*	**1** ***.967*** *.720*	
Proportion of markets with Separating Equilibrium in Session S3	**18** ***270*** *540*	**1** ***.967*** *.734*	
Difference in Proportions (Session S1 - Session S2)			**1** ***.504*** *.109*
Difference in Proportions (Session S1 - Session S3)			**1** ***.504*** *.36*
Difference in Proportions (Session S2 - Session S3)			**1** **1** *.493*

1 The null hypothesis is that the Proportion of equilibrium prices is the same in both sessions.

2 The reported p-value is the probability under the null hypothesis of getting a statistic as large as the one observed.

Table 2. Statistical Tests For Session Effects for the Pooling Treatment[1]

Using Data From Final Round
Using Data From the last 15 Rounds
Using Data From the All Rounds

Dependent Variable	Observations	Proportion of equilibrium outcomes	p-value[2]
Proportion of markets with Pooling Equilibrium in Session P1	**18** ***270*** *540*	**1** ***.926*** *.783*	
Proportion of markets with Pooling Equilibrium in Session P2	**18** ***270*** *540*	**.722** ***.567*** *.317*	
Proportion of markets with Pooling Equilibrium in Session P3	**18** ***270*** *540*	**.833** ***.952*** *.778*	
Difference in Proportions (Session P1 - Session P2)			**.009** ***.000*** *.000*
Difference in Proportions (Session P1 - Session P3)			**.058** ***.208*** *.825*
Difference in Proportions (Session P2 - Session P3)			**.418** **.000** *.000*

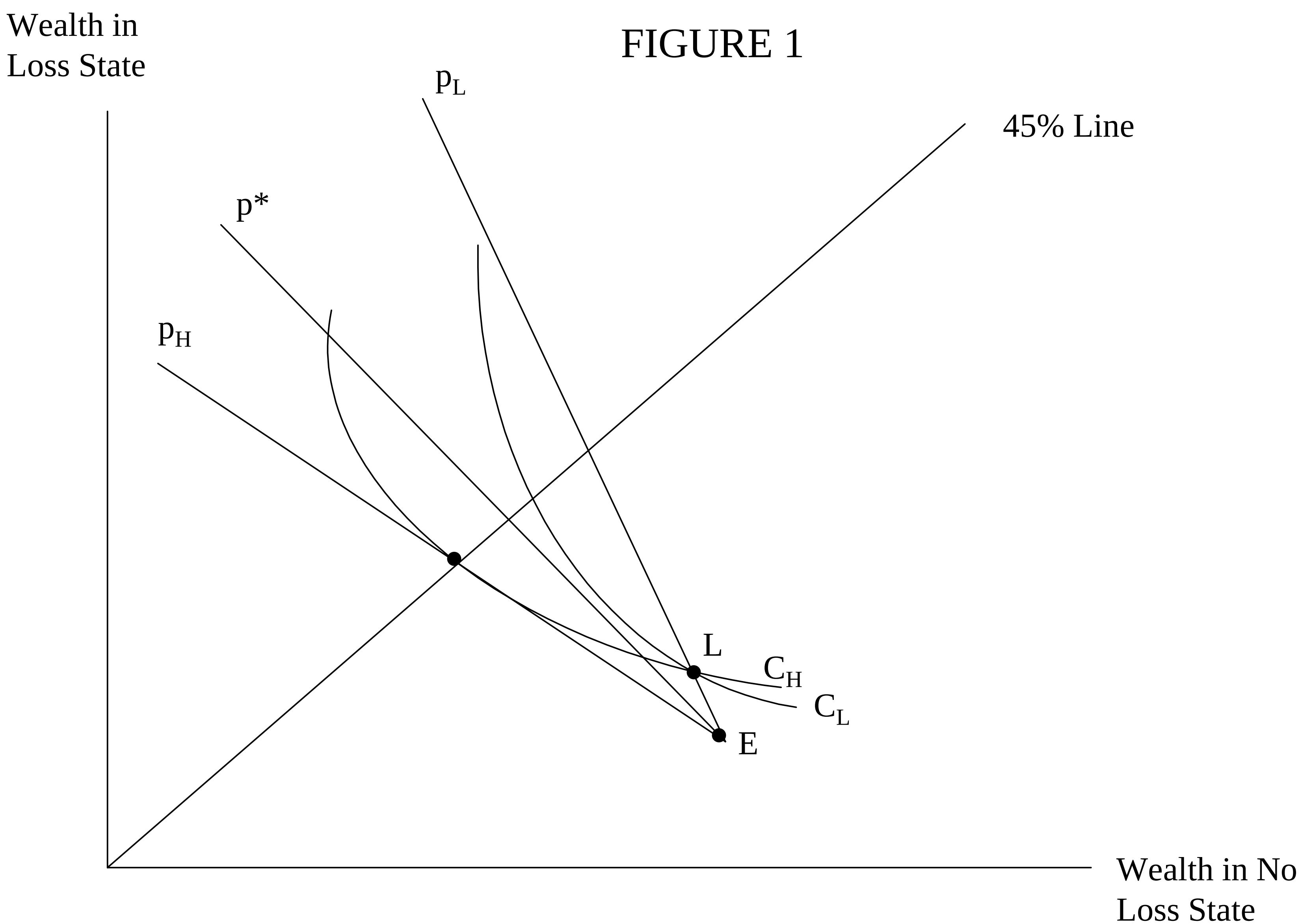
1 The null hypothesis is that the Proportion of equilibrium prices is the same in both sessions.
2 The reported p-value is the probability under the null hypothesis of getting a statistic as large as the one observed.

Table 3. A Comparison of the Separating and Pooling Sessions[1]				
Round(s)	Observations	Number (proportion) of Separating Equilibrium Outcomes in P1+P2+P3	Number (proportion) of Separating Equilibrium Outcomes S1+S2+S3	p-value[2]
1-5	270	3 (.01)	38 (.14)	0
6-10	270	18 (.07)	152 (.56)	0
11-15	270	24 (.09)	230 (.85)	0
16-20	270	0 (0.0)	249 (.92)	0
21-25	270	0 (0.0)	270 (1.0))	0
26-30	270	0 (0.0)	261 (.97)	0
16-30	810	0 (0.0)	780 (.96)	0
1-30	1610	45 (.03)	1200 (.74)	0
30	54	0 (0.0)	54 (1.0)	0

1 The null hypothesis is that the Proportion of separating equilibrium prices is the same in sessions S1+S2+S3 and P1+P2+P3.

2 The reported p-value is the probability under the null hypothesis of getting a statistic as large as the one observed.

FIGURE 1



Wealth in
Loss State
p_L
45% Line
p*
p_H
L
C_H
C_L
E
Wealth in No
Loss State

FIGURE 2

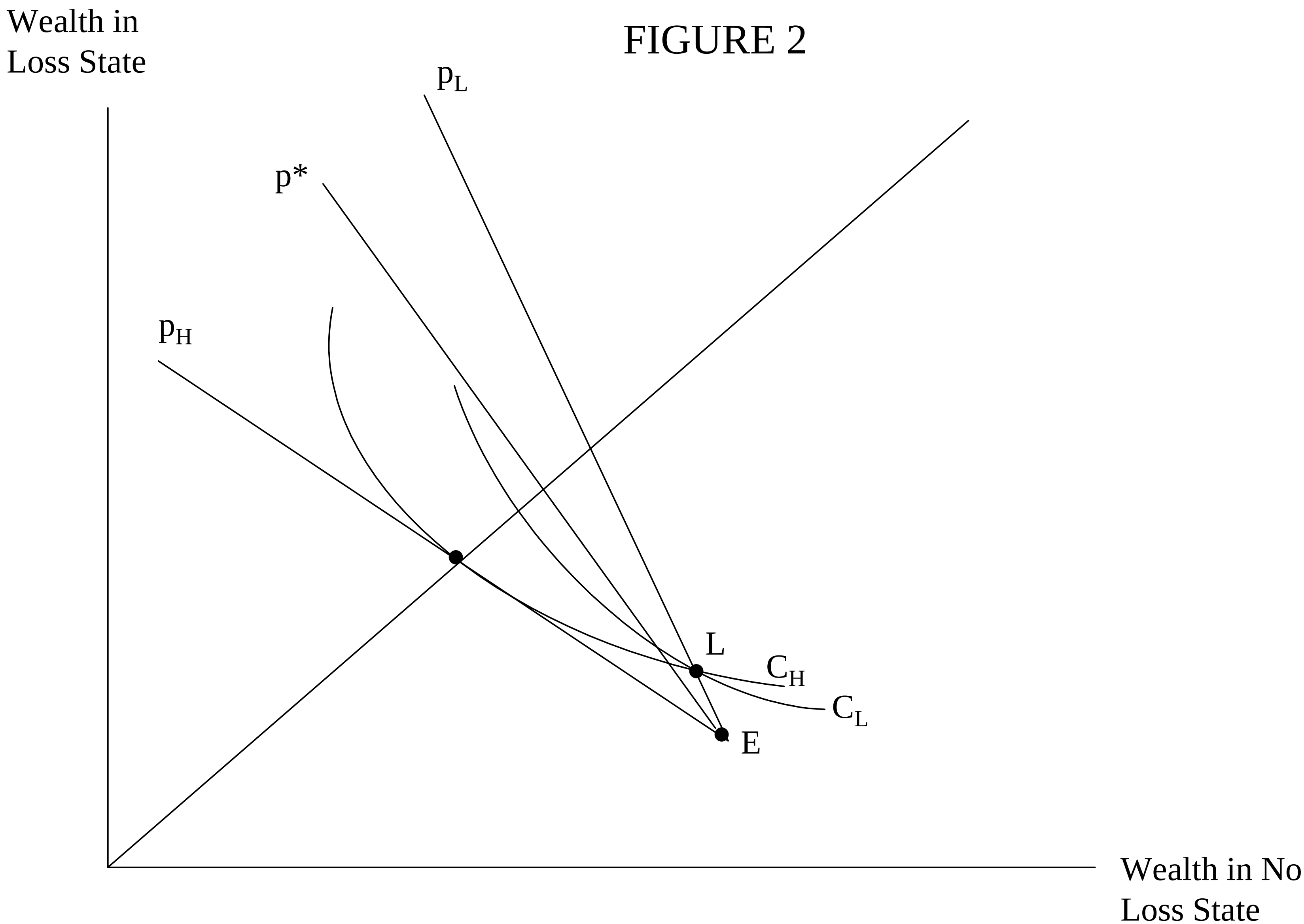


FIGURE 3

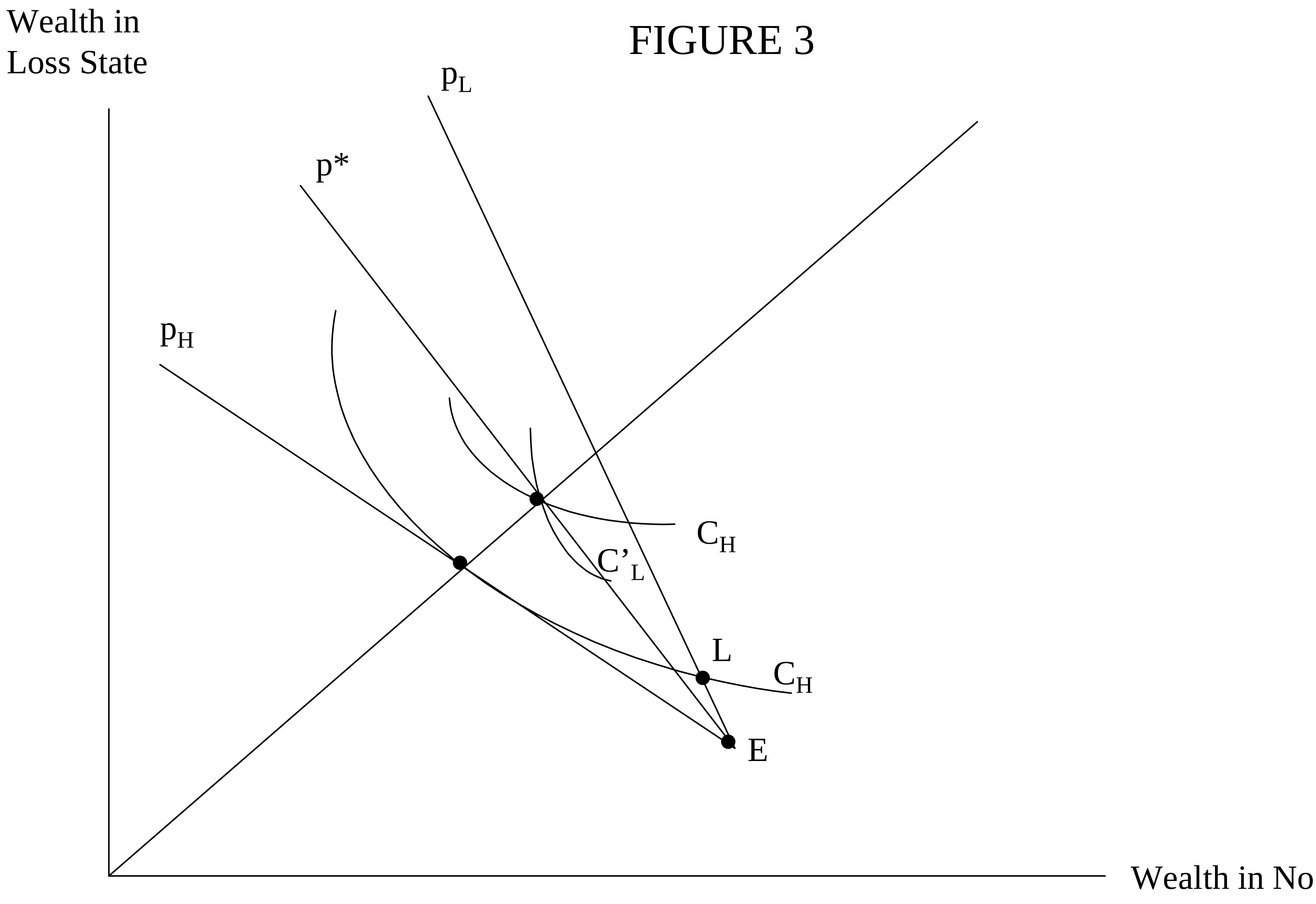
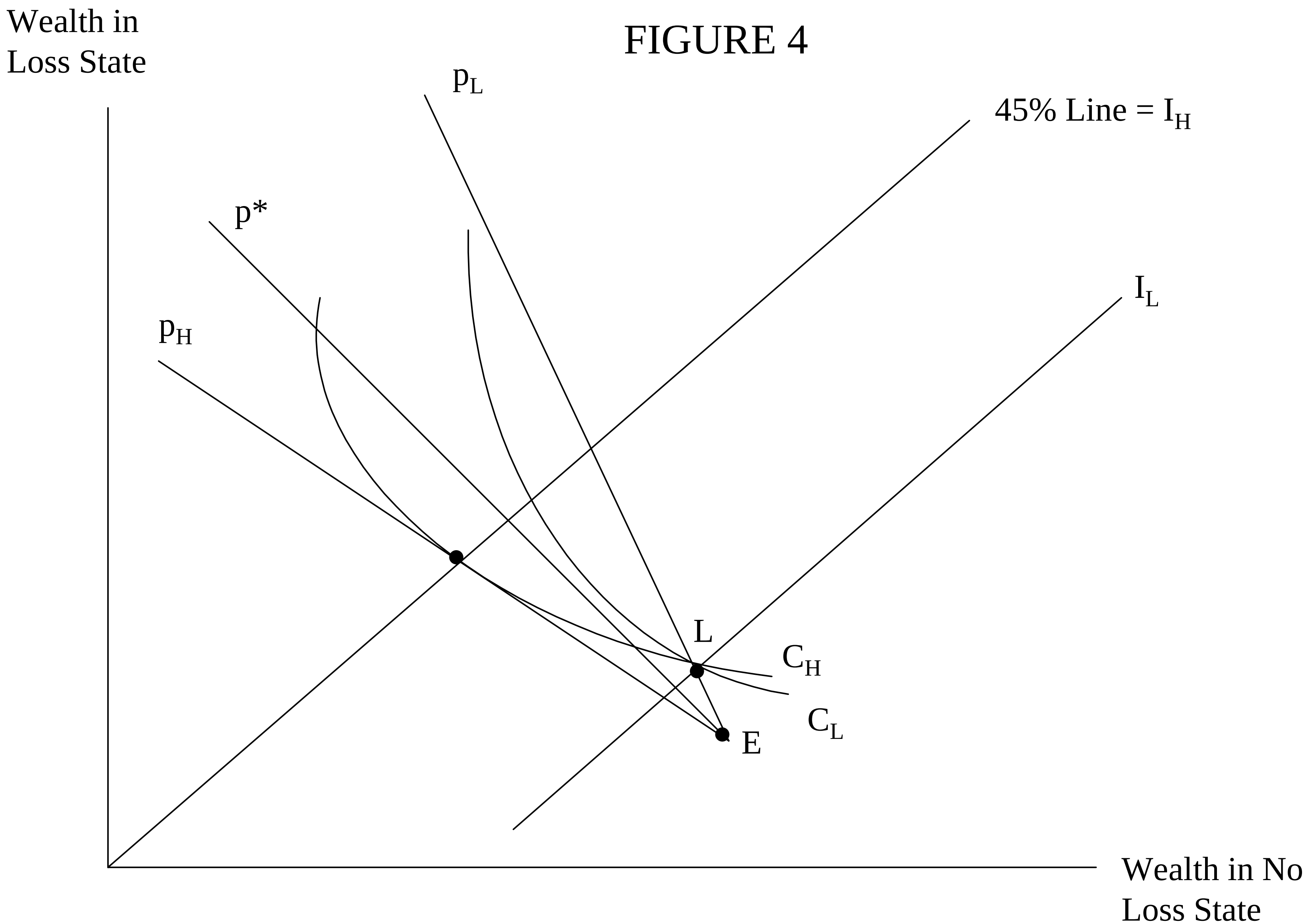
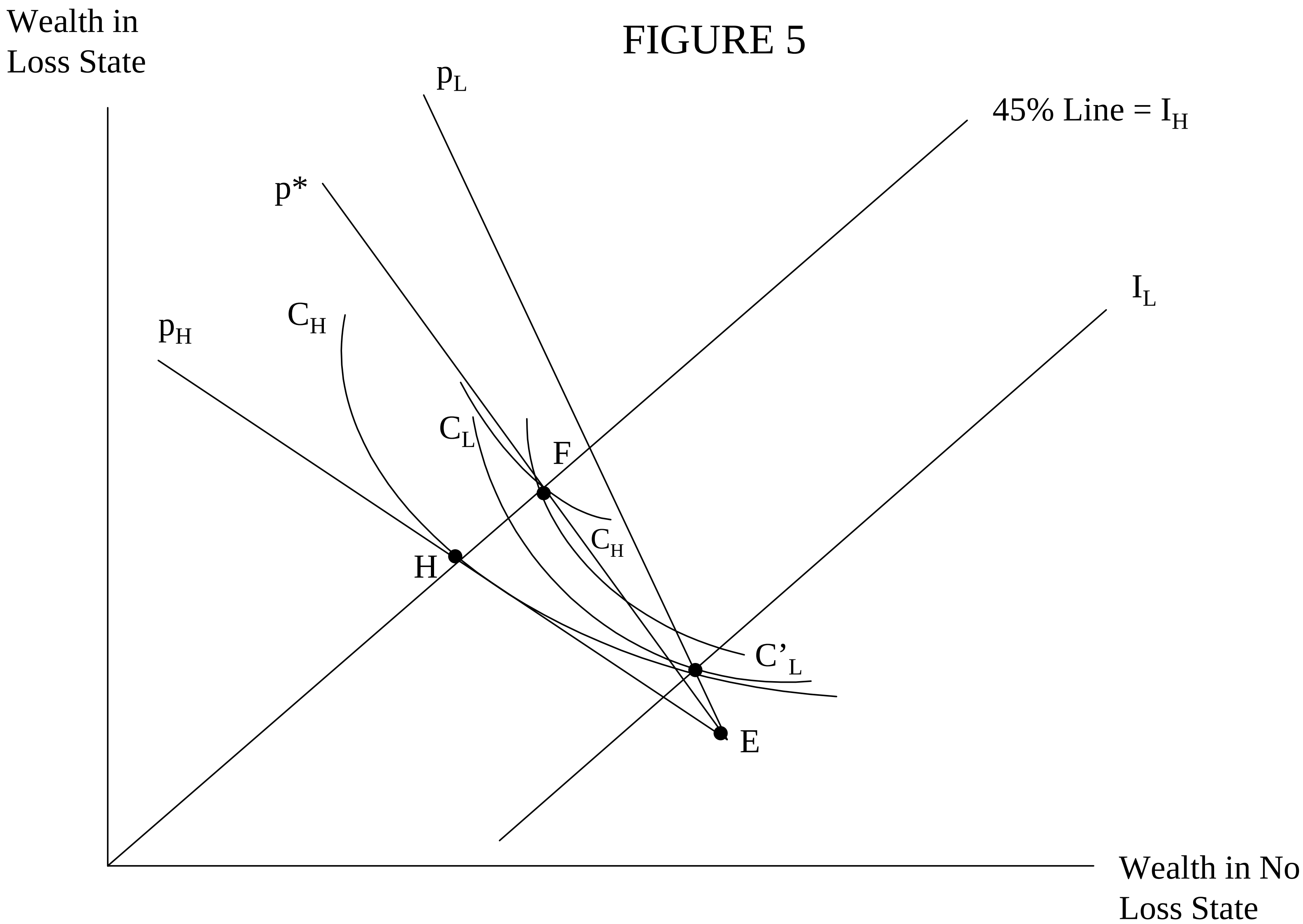


FIGURE 4



Wealth in Loss State
p_L
45% Line = I_H
p*
I_L
p_H
L
C_H
C_L
E
Wealth in No Loss State

FIGURE 5


Wealth in
Loss State
pL
45% Line = IH
p*
IL
CH
pH
CL
F
CH
H
C'L
E
Wealth in No
Loss State