Exchange Economies and Loss Exposure: Experiments Exploring Prospect Theory and Competitive Equilibria in Market Environments

By MIKHAIL MYAGKOV AND CHARLES R. PLOTT*

Exchange economies were created in which individuals faced losses. If people are risk seeking in the losses, as predicted by prospect theory, then due to the nonconvexity, the competitive equilibria are all on the boundaries of the Edgeworth Box. The experimental results are that risk-seeking behavior is observed in many people and appears in markets as predicted. In addition, market behavior is consistent with answers to hypothetical questionnaires. Contrary to prospect theory, risk seeking seems to diminish with experience; preferences in the market setting are not labile; and risk-seeking preferences are not simply a result of framing effects. (*JEL* C91, C92, D50, D80)

Recent years have found attempts to integrate ideas from a psychology research tradition with ideas from economics. The integration is difficult because the purposes of the two scientific enterprises differ and the methodologies differ. Nevertheless, the lessons from one approach can sometimes find applications in the other. This paper is an attempt to accomplish such an intellectual arbitrage by merging experimental methods from economics with theory suggested by psychology.

The central focus of the experiments reported below is a psychological theory, called prospect theory (Daniel Kahneman and Amos Tversky, 1979), which has received substantial attention in the decision literature (Colin Camerer, 1995). The substance of prospect theory is the process of individual decision-making as opposed to market activity and price formation typical of economics. For the most part, economists have not been interested in the process of individual decisions. Instead, economics has proceeded on the assumption that the consequences of the individual decision-making process, whatever they might be, will become manifest in the form of an individual preference relation. Thus, individual choices will be reflections of the attitudes that are summarized by the concept of a preference.

The individual in economics is captured by a preference relation over states of the world. By contrast, the individual in psychology is a complex of processes that might be subject to any number of influences that are sometimes summarized by a concept of framing. Consistency such as transitivity does not follow from psychological theory. Individuals can order things if asked to do so, but the ordering is labile and may bear no relationship to choices. In fact, it is not even clear if the concept of a preference is relevant from the point of view of prospect theory. Tversky et al. (1988 p. 383) put the issue well—"If different elicitation procedures produce different orderings of options, how can preferences and values be defined? And in what sense do they exist?" In summary, the substance of research from psychology is that preferences are labile (Tversky

* Myagkov: Department of Political Science, University of Oregon, Eugene, Oregon 97403; Plott: Division of the Humanities and Social Sciences, California Institute of Technology, M/C 228-77, Pasadena, California 91125. The research funding of the National Science Foundation is gratefully acknowledged, as is the support by the Caltech Laboratory for Experimental Economics and Political Science. The authors wish to thank Donald Brown, whose insights lead to the designing of these experiments. In addition, the author wishes to thank Colin Camerer, Timothy Cason, David Grether, Daniel Kahneman, Richard Thaler, and Amos Tversky for their comments on this, and many closely related subjects.

and Kahneman, 1986, 1981), because the process used by individuals to make decisions is subject to subtle framing effects. Thus, while the processes used by individuals may be stable, the existence of a summarizing characteristic of an individual such as a relatively stable or unchanging (nonlabile) preference is denied.

The apparent differences between the psychological view of the individual and the economic view of the individual seem to emerge from three sources. First, prospect theory is about a process of decision-making and not necessarily about a preference that exists as some stable or constant property of an individual. The principles of the psychological model address the nature of the steps that occur when a process of decision is evoked. Second, the theory addresses one-time decisions as opposed to repeated decisions or perhaps even ''substantially considered'' decisions that might take place in markets. Third, the sources of data are questionnaires and interviews as opposed to the market choices that are typical of data in economics. Furthermore, the purpose of the questionnaires is not to measure some property of an individual (such as the slope of an indifference curve) as would be the case in economics; the purpose is to demonstrate properties of a decision-making process that might produce substantially different decisions under slightly altered conditions. Thus, a tension between the two disciplines can easily result from a lack of realization that they are focused on different aspects of behavior and different sources of data.

The purpose of the research reported here is to ask if prospect theory and the methods used to support it can be employed to produce a model that captures data in a purely economic context. The research cannot be viewed as a test of prospect theory as developed by psychologists because it is being applied to a context and in a manner that differs substantially from what the originators of the theory intended. The differences are so dramatic that it might be more appropriate to refer to the theory that is to be applied here as ''extended prospect theory,'' rather than prospect theory, in order to emphasize that the liberties taken with the theory reside entirely with the present authors and not with the psychologists that are proponents of the theory.[1] The ''extended prospect theory'' is a theory of preferences, as opposed to prospect theory, which is a theory of decision-making process.

Exchange economies were created in which only losses can occur. If the principles of prospect theory are assumed to dictate properties of a stable individual preference, as opposed to a property of the process used to make decisions, then the (extended and modified) theory has definite consequences for what should be observed. More precisely, prospect theory implies concavity of indifference curves in the loss domain as opposed to the usual convexity assumption of economics. With the usual convexity assumptions violated, the competitive equilibria in an exchange economy have distinct properties if the equilibria exist. The research reported here investigates whether or not those properties are observed.

The first section of the paper outlines relevant aspects of extended prospect theory and the questions to be posed by the research. The second section details the experimental environments. The third section specifies the models that are needed to produce predictions about market behavior. The fourth section contains the results. The fifth section contains the results of some special experiments that were conducted to check the theoretical coherence (or robustness) of the results reported in the body of the text. These experiments help eliminate some obvious alternative hypotheses that might be used to explain the pattern of observed results. The final section summarizes and concludes the paper. The Appendices contain

[1] Several involved e-mail conversations serve to emphasize that the psychologists claim that the theory, as they use it, makes no clear predications under the conditions of the experiments reported in this paper. Examples of a lack of consensus is revealed by the following objections to the application of prospect theory to the markets studied here. (1) The incentives are such that subjects participate to earn money so all lotteries could be viewed as gains and no asymmetries in behavior would be observed. (2) Prospect theory is a theory of choice and not a theory of exchange. Exchange involves a procedural invariance that is not part of prospect theory. (3) The exchange environment is complex and with each trade a different reference point can be established. Prospect theory has yet to deal with the problem of multiple reference points.

experimental instructions and the statements and proofs of theorems used in the theory.

I. Research Questions

A fundamental difference exists between prospect theory and the traditional expected utility hypothesis, as found in economics. The expected utility hypothesis rests on the proposition that choices are made as if there exists a preference relation over lotteries over final states. It is as if the final outcome is the source of value and, in turn, the choices reflect a process of optimization modulated by attitudes toward risk. By contrast, prospect theory does not proceed on the presumption that a preference exists for final states. Individual decisions reflect optimization based on values but these values rest upon changes of states from some reference point, which for purposes of discussion could be viewed as a status quo. Furthermore, the value function is postulated to have a very distinct shape.

Briefly put, prospect theory rests on four axioms.

(i) *Decision utilities.* Decisions reflect a maximization based upon decision utilities.
(ii) *Reference dependence.* The carriers of decision utilities are changes in states (prospects) as opposed to outcomes or final states. These changes are relative to some outcome called the reference point.
(iii) *Loss aversion.* The decision utility function is steeper in the losses than in the gains. That is, the negative of a given movement in the loss direction from the reference point outweighs a positive of an equal movement in the gain direction.
(iv) *Diminishing sensitivity.* The decision utility function is convex in the loss domain and concave in the gain domain.

Prospect theory is an alternative to the expected utility hypothesis as a descriptive theory of decisions, but it has not been systematically applied to market environments. By implication, since the expected utility hypothesis is routinely used in economics, prospect theory might serve as an alternative foundation for market models. Exactly how one might apply the theory is not clear since the concept of a reference point in a rapidly moving market situation is itself not clear, and to date there is no substantial evidence that prospect theory, as articulated by psychologists, is applicable to markets. However, the literature contains reports (Tversky and Kahneman, 1986; Kahneman et al., 1990; Kahneman and Tversky, 1991) that traces of phenomena predicted by the theory have been detected.

The approach taken in this research is to create a market in which only ''losses'' can be realized and to study the resulting market behavior. Subjects were paid a flat amount of money ($60) in cash before the experiment began, which they kept during the course of the experiment. Once in the experiment they could only lose. Literally, subjects paid money to the experimenter. The amount of loss depended upon the decisions they made to buy and to sell lotteries, which were the functional equivalent of insurance.

Each individual was given an initial endowment of units of lottery (insurance) which could be sold for cash. Or, if the individual wished (s)he could use cash to buy units of lottery (insurance) from other individuals. The setting was that of an exchange economy to which a standard competitive model might be applied. If individuals were risk averse then the indifference curves would take the usual convex properties and the competitive equilibria would necessarily be of one class. If individuals were risk seeking then the indifference curves would take a concave property and the competitive equilibria would have a boundary property of a different class. Intuitively speaking, if the indifference curves of the Edgeworth Box are convex then the competitive equilibria tend to have an interior property, and if the indifference curves are concave then the competitive equilibria tend to take a boundary property. The following sections of the paper make these properties precise.

A day or two prior to the experiment, subjects were given a classroom questionnaire to complete. This questionnaire contained choices between lotteries similar to those that were used in Kahneman and Tversky (1979) to demonstrate a risk-seeking propensity in the loss domain. Thus, a measurement similar to the ones used by psychologists was taken. The purpose was to compare behavior as revealed in the questionnaire with behavior revealed in the markets.

The following four general questions are posed for research.

(1) Is there any consistent equilibration behavior observed within and across experimental markets? Unlike many previous market studies, the preferences explored in the experiments reported here have not been induced. If the reference point changes depending upon the context of the decision, then preferences might exhibit labile properties and, as a result, the markets might be erratic.

(2) Can market adjustments be associated with the equilibrium predications of the competitive model? As will be discussed later, the competitive model contains reasonably precise predictions about market behavior. However, there are very few studies in which the underlying parameters might not be convex. How the markets might behave under such circumstances is a question of general interest.

(3) If patterns of equilibration are observed do they imply the existence of risk-averse people, do they imply the existence of risk-seeking people, or do they imply the existence of both? The standard model typically assumes that people will be risk averse while a reasonable application of prospect theory would produce people that are risk seeking. Is risk seeking in the losses a property of individual preferences? Such a discovery would be of special interest because subjects in market experiments are generally observed exhibiting risk-avoiding behavior (sealed bid experiments and speculation experiments are typical).

(4) Is there any relationship between answers to the questionnaires and the behavior exhibited in the markets? Do the questionnaires produce measurements that predict behavior in the context of operating markets? Do questionnaires capture a property of an individual as opposed to a process of decision? Psychologists typically do not view the questionnaire as measuring a property of an individual and instead view it as a demonstration of the operation of certain aspects of a decision process. Economists are typically skeptical of any methodology in which questionnaires are used, so the question is of relevance along at least two dimensions.

II. Experimental Environment, Design, and Procedures

A total of ten experiments were conducted. The first nine of them (as summarized in Table 1) were held under identical economic and incentive environments. Experiments are indexed by the date of the experiment. The tenth one was a "control" experiment conducted on 0516. Its purpose and design will be discussed in Section V of this paper. Until then we discuss only the first nine experiments. Each experiment involved six to ten subjects. Subjects for some experiments were recruited from the California Institute of Technology and the experiments were conducted at the Caltech Laboratory for Experimental Economics and Political Science. Other subjects were recruited from classes at the University of Southern California and the experiments were conducted at the USC Experimental Economics Laboratory.

Subjects participated in one or two identical experiments. In all but 0324 and 0509 experiments, the subjects were first-time participants. We call them "inexperienced subjects" (see Table 1). All of the subjects who were used in 0324 and 0509 experiments were second-time participants ("experienced subjects") recruited from subject pools of one of the previous experiments with the first-time participants. None of the subjects had experience in experiments prior to the experiments reported here.

The economic and incentive environments were as follows. Subjects were given \$60 before the beginning of the experiment (they were handed the money in cash).[2] They were

[2] The instructions say: "For your agreement to participate you will be paid \$60." This was handed to them in cash. Then subjects were informed that participation involved the possibility of losing a portion of their money. The experiment was designed in such a way that no one could lose more than the \$60 that they had in their hand. No one could sell more than the inventory they had and no one could spend more than the cash on hand that they were allocated. The parameters chosen guarantee limitation on possible losses.

TABLE 1—TRANSACTION PRICES (WITH STANDARD DEVIATIONS) AND TOTAL NET VOLUMES

	Experiment								
Date	0228	0316	0317	0324	0428	0501	0502	0505	0509
Location	USC	USC	USC	USC	CIT	CIT	CIT	CIT	CIT
Experience	No	No	No	Yes	No	No	No	No	Yes
Period #	Average transaction prices (standard deviations)								
0	**50.35**	**23.29**	**33.01**	**32.82**	**38.19**	**55.21**	**41.15**	**98.18**	**48.85**
	(48.4)	**(15.9)**	**(19.5)**	**(18.3)**	**(14.3)**	**(10.1)**	**(17.1)**	**(59.4)**	**(3.51)**
1	**51.44**	**21.97**	**43.54**	**34.49**	**47.53**	51.45	44.53	49.54	42.91
	(26.6)	**(5.61)**	**(7.74)**	**(6.77)**	**(4.21)**	(6.31)	(8.16)	(4.81)	(3.38)
2	**64.12**	**24.05**	**43.18**	**39.33**	**48.17**	51.85	49.41	48.81	41.98
	(15.7)	**(7.48)**	**(7.09)**	**(29.2)**	**(1.21)**	(4.28)	(2.34)	(6.90)	(7.53)
3	56.14	26.34	44.21	39.48	48.37	50.57	48.18	46.90	43.35
	(15.8)	(10.9)	(4.75)	(9.44)	(5.64)	(1.01)	(3.38)	(3.43)	(10.3)
4	43.33	24.17	44.83	41.27	49.15	51.20	49.20	45.70	40.77
	(11.4)	(10.3)	(3.48)	(9.46)	(0.73)	(0.77)	(5.14)	(1.59)	(2.04)
5	42.75	—	45.12	43.69	48.41	49.65	49.63	44.24	41.58
	(9.2)	—	(3.81)	(2.36)	(5.23)	(1.25)	(1.10)	(0.83)	(2.28)
6	39.61	—	48.36	44.88	49.04	50.67	49.84	46.92	41.51
	(9.5)	—	(1.31)	(3.92)	(1.05)	(0.93)	(1.23)	(1.27)	(1.19)
7	—	—	—	46.03	—	50.42	49.17	47.57	42.47
	—	—	—	(1.73)	—	(0.64)	(0.46)	(0.94)	(1.36)
8	—	—	—	47.37	—	—	—	47.18	—
	—	—	—	(0.72)	—	—	—	(0.73)	—
	Competitive equilibrium predictions about total net volumes								
	100	100	100	100	80	100	80	60	100
	Actual total net volumes								
0	**34**	**66**	**81**	**54**	**60**	**54**	**38**	**28**	**42**
1	**48**	**46**	**62**	**60**	**52**	67	42	23	87
2	**67**	**52**	**67**	**58**	**37**	101	55	48	95
3	38	32	64	55	54	54	71	23	80
4	54	34	62	55	55	62	70	50	90
5	26	—	60	48	60	67	53	43	88
6	42	—	56	51	55	76	60	40	93
7	—	—	—	52	—	78	73	40	83
8	—	—	—	50	—	—	—	40	—

Note: Boldface denotes practice periods.

told that the money was theirs but as a result of the experiment they could lose some of it. They were told that the amount of the loss would depend upon the decisions they would make during the market and on the outcome of a roll of dice. The word "loss" was used in the instructions in much the same way as it is used in these paragraphs.

In the economic environment there were two goods that could be traded. Each individual was given an initial endowment of variable M and X. M is the notation of the numeraire (instructively, M stands for money). The initial endowment of M was $m_0 = 1000$ and m is the quantity of M held at the end of a period. X is the notation of the commodity (intuitively, X stands for lottery). The initial endowment of X was $x_0 = 20$ units and x equals the quantity of X held at the end of a period. Each subject was told that (s)he faced two possible losses: Loss A and Loss B. That is, Total Loss = Loss A + Loss B. The final loss exposure for a period of trading was

$$\text{Loss A} = \langle \$20 - (1/100)m \rangle \text{ and}$$

$$\text{Loss B} = \langle 0\{\text{Prob } 1/2\} \text{ or } \$40 - x\{\text{Prob } 1/2\}\rangle.$$

As can be seen, the variable M is literally money embedded in a loss framework and the variable X is a quantity of insurance. The expected value of Loss B offset from a one-unit increase in X is \$0.50. Since the value of one unit of M is \$0.01, the trade-off that leaves total expected loss unchanged is 50 units of M for one unit of X. That is, the risk-neutral price of X should be \$0.50.

In order to keep the losses as losses, the amounts A and B were constrained to be nonnegative. Therefore, subject's marginal utilities became zero beyond final holdings 40 units of X and beyond 2000 units of M.

Subjects were trained to participate in a multiple-unit double auction (MUDA) as implemented through a computerized market. Standard training procedures were followed. The variable M as defined appeared as cash on hand and X was inventory.

Subjects in USC participated in three (and one in Caltech) practice market periods without payoff or exposure. These were used to test and train subjects about the accounting and how the markets functioned. The practice periods were followed by real periods in which the outcomes or final holdings (m and x) represented actual loss exposures. Each period the endowments were reset to the initial levels and no carryovers were allowed. At the end of several real periods one period was chosen at random (one of the subjects rolled dice), and the lotteries that resulted from the trading during that period were actually played (once again a subject rolled the dice.). The losses were collected from the subjects and they were allowed to go.[3]

The instructions and accounting forms are included in Appendix A. Subjects first read the instructions and then were asked to answer the questions in an exercise that in essence tested their understanding of the content of the instructions. After the first two experiments a subject selection procedure was implemented. More subjects were recruited than were necessary—typically four or five extras. The first ten subjects who correctly answered all questions were allowed to participate. All other subjects were paid \$5 and were dismissed. This procedure was introduced to save time in the administration of the experiment and thereby have the opportunity to conduct more periods.

A questionnaire was administered to the entire classes from which subjects were later recruited. No reference to the questionnaire was made during the experiment or was it associated with the experiment in any other way. The questions themselves include the relevant questions from Kahneman and Tversky (1979). They are of the form:

"What would you choose: to lose \$50 for sure or \$100 with probability = 1/2?"

"What would you choose: to win \$200 for sure or \$400 with probability = 1/2?"

An individual that prefers a lottery to the expected values of the lottery is exhibiting risk-seeking type of answers. The stylized fact that has emerged from the Kahneman and Tversky research is that people are risk seeking in the losses. The data in support of this

[3] Under conditions of the expected utility hypothesis, this compound lottery has no influence on behavior. The implications of such a compound lottery for various forms of prospect theory or even extended prospect theory are only a matter of speculation at this time. The hypothesis maintained throughout the analysis in this paper is that the compound lottery does not influence the revealed preference for the lotteries at each period.

stylized fact are almost exclusively answers to questionnaires.

III. Model

The model that will be used to guide the analysis will be the general competitive equilibrium for an exchange economy. However, the use of the model will be a step beyond the usual applications in experimental markets. With the traditional use, preferences are induced and therefore known, and the reliability of the theory is tested. In the application at hand the preferences are not known, the reliability of the theory is assumed, and the observed market behavior is used to determine the nature of the preferences that must have existed in the experiment.

It is well known that that the general competitive equilibrium model is reasonably accurate under conditions in which preferences are induced and, thus, can be assumed to be known and fixed (Charles N. Noussair et al., 1995; Peng Lian and Plott, 1998). Furthermore, it is known that the predictions of the model are also accurate under preference conditions that produce market instability (Plott and Glen George, 1992). Thus, the analysis at hand will rest on a general assumption that, regardless of the preferences that may be present in the economies, the market will seek the competitive equilibrium as long as one exists. Of course, under the conditions of the experiments reported here, the preferences are not known and, according to the psychology literature, might not be fixed, or might not even exist. However, the key feature of extended prospect theory considered in this research is that preferences will exist and are of a form that can cause market instability in the sense that individuals will want to move towards a "boundary" of an opportunity set. The analysis will address the nature of equilibrium in cases in which different numbers of individuals might be risk averse (RA), risk seeking (RS) and risk neutral (RN).

The first proposition to be established is the relationships among assumptions about risk-seeking propensities, risk aversion, and the shapes of indifference curves. From the point of view of the model, the individual must choose a combination of two commodities, M and X. Preferences over these two commodities reflect the fact that different combinations determine different lotteries over monetary losses. The individual is assumed to be an expected utility maximizer over lotteries, but the indifference curves for m and x (the final holdings of M and X, respectively) will differ according to the individual's attitude toward risk.

The outcome for an individual is Loss A plus Loss B. Loss A is a loss for sure and Loss B occurs with a 0.5 probability. Thus, the Total Loss can be recombined into a choice of lotteries dictated by a choice of x and m, and are of the form: 0.5 probability of either loss = $\{\$(20 - m/100\}$ or loss = $\{\$(60 - m/100 - x)\}$. Thus, the expected value of the loss is $E(\text{loss}) = 40 - m/100 - 0.5x$. Notice that $E(\text{loss})'_x = 0.5$, where F'_y denotes the derivative of the function $F(\cdot)$ with respect to the variable y. In other words, in the range of $0 \leq m \leq 2000$, $0 \leq x \leq 40$, the expected loss reduction of a unit increase in x is \$0.50. That is, the actuarially fair market price of a unit of X is 50 units of M.

Three general background assumptions will be used throughout:

(a) The commodity space is two dimensional as characterized by the variables M and X, which characterize exposure to lotteries of monetary losses or changes in wealth from some current value of w. The important part of the commodity space is where M and X take the respective values $0 \leq m \leq 2000$, $0 \leq x \leq 40$, but individual choices are not restricted to these intervals, other than quantities meet the nonnegativity conditions.

(b) An individual's preferences over lotteries are as if the individual wished to maximize the expected value of a (twice differentiable) utility function of money.

(c) The relevant reference point for purposes of application of prospect theory is w, the wealth of the individual before making lottery choices.

Assumptions (a) and (b) can be summarized by an assumption that the individuals choose m and x to maximize $EU(w, m, x) = 0.5U(w, w + m/100 - 20) + 0.5U(w, w + m/100 + x - 60)$. The analysis will suppress

w since it assumed to be the same throughout the experiment.[4]

Figure 1 can be used to illustrate the fundamental implications of expended prospect theory within the environment of the experimental markets. That is, the outcomes involve losses as defined above and the initial endowments are $(m_0, x_0) = (1000, 20)$. All properties used are proved in Proposition B1, which appears in Appendix B.

If individuals are risk averse the indifference curves would be as shown in the upper panel of the figure. At a price of 50 or below, a risk-averse individual (RA) would spend all M on X. Intuitively, if the price of insurance is lower than (or equal to) 50, then the expected value of the loss is lower than (or equal to) a fair bet and a risk-averse individual would prefer to spend the money to avoid the exposure to risk, until fully insured. In other words, all RA individuals would be willing to buy as much insurance as is possible up to 20 units (point D). After 20 units, the individual is perfectly insured and additional units have no value, as shown by the horizontal indifference curves. As the price goes higher than 50, the RA individual's demand would fall continuously (point E). At some point, if the price gets sufficiently high, the RA individual might even start selling X (the insurance). The vertical parts of the indifference curves indicate that above 2000 additional M has no value since the loss for certain is completely offset. Thus, the excess demand functions of RA individuals are exactly 20 at prices at or below 50, but at prices above 50 the excess demands continuously drop and eventually would become excess supplies.

The lower part of Figure 1 contains indifference curves for a risk-seeking individual (RS). The fact of concavity of indifference curves as a consequence of convexity of the utility function is demonstrated by Proposition B1 (see Appendix B). The initial endowments are $(m_0, x_0) = (1000, 20)$ and the maximum amount of X the individual would want to hold is 40 and the maximum M is 2000. Beyond these limits the individual is fully insured, as shown by the horizontal (vertical) indifference curves. At any price of X of 50 or above, the RS individual will always be on the seller side of the market. The individual would sell X, insurance, and move to the points at a level of 2000 M. At a price slightly below 50, the RS would continue doing this. However, there is a sufficiently low price at which a RS individual is indifferent between buying and selling 20 units. In other words, the individual is indifferent between points B and B′. At a price below this critical value the RS individual will only demand 20 units of X. The insurance is so cheap that the RS would prefer to buy rather than sell. Thus the resulting demand function of a RS individual must be discontinuous. An important thing to notice is that under any price below (or equal to) 50, a RS always wants to have final holdings at the boundaries (of the positive marginal utility ranges). Thus, the excess demand function would jump by 40 units as the individual switches from a position of selling 20 units to a position of buying 20 units.

Risk-neutral individuals (RN) will buy 20 units at any price below 50 and sell units at any price above 50. At a price of 50 they are indifferent between buying and selling (up to the 20 units). Thus, the RN have excess demand similar to the RA at prices below 50 and similar to RS at prices above 50.

With the properties of individual excess demand functions established, the analysis can focus on the properties of equilibrium that can emerge from an exchange economy. Proposition B2 (see Appendix B) establishes the important results that in an exchange economy with the conditions of the experimental environment and with an even number of individuals: (i) a competitive equilibrium necessarily exists; (ii) if the price is above 50 then the number of risk-averse (RA) plus the number of risk-neutral (RN) is at least as large as the number of risk-seeking (RS) individuals; and (iii) if the price is less than 50 then the number of RS is no smaller than the number of RA plus the number of RN.

The intuition for properties (ii) and (iii) is easy to establish. Suppose the price has equil-

[4] Ordinarily, applications of the expected utility hypothesis would assume that the function was of the form $U(w + \Delta w)$.

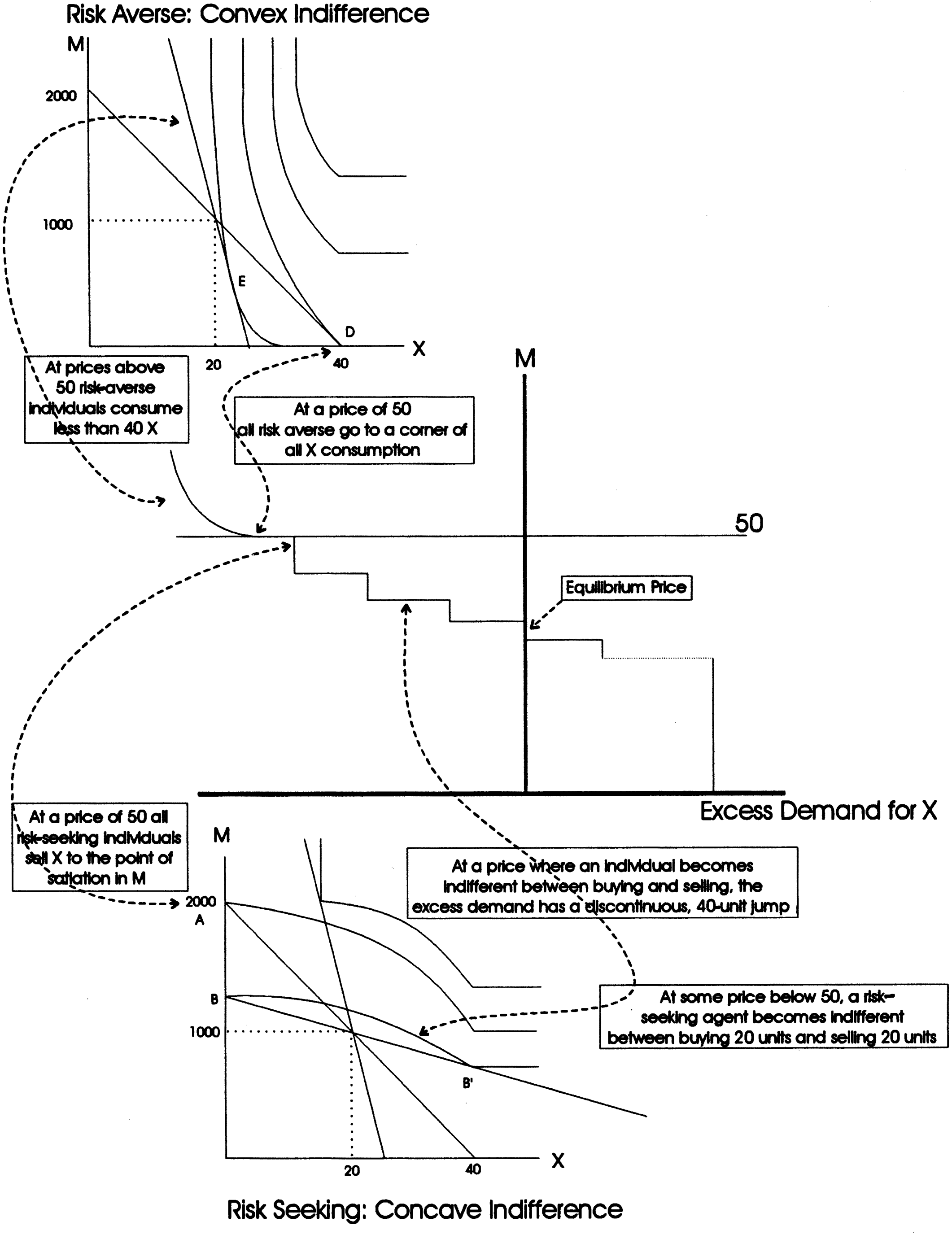

FIGURE 1. EXCESS DEMAND FUNCTION AND INDIFFERENCE CURVES FOR RISK-AVERSE AND RISK-SEEKING INDIVIDUALS

ibrated at above 50. All RS and all RN are necessarily sellers of X.[5] The RA are buyers of $x \leq 20$ units each. Since at equilibrium the quantity supplied equals the quantity demanded and since there is an even number of agents, the number of RS can be no greater than the number of RA and RN combined. Suppose the price is below 50. All RA and all RN are buyers of 20 units each. Some of the RS may be buyers of 20 each and all others will be sellers of 20. Since at equilibrium the quantity supplied equals the quantity demanded and since there is an even number of agents, the number of RS must be at least as large as the number of RA and RN combined.

Figure 1 will help develop an intuition for existence. Only the case of an equilibrium below 50 will be considered. (For the general case see Proposition B2 in Appendix B). Assume that the number of RS exceeds the number of RA. For convenience, assume there are no RN. As shown in the figure, an excess supply exists. The magnitude of this excess supply is 20 times the excess number of RS. As the price falls, some RS will shift discontinuously from a position of net seller of 20 units to a position of net buyer of 20 units. The excess supply will fall by 40 units each time an RS individual switches. The excess demand must become exactly zero at some point.[6] Thus, equilibrium existence is established. Such an equilibrium is illustrated in the figure.

[5] The reader should be warned that the parameter we used in this portion of the argument is delicate because of satiation. Since the price is above fifty, and since the individuals become satiated in M at 2000, sellers will sell less than 20 units.

[6] The intuition of the proof can be seen in the following argument. Let B be the number of buyers and S be the number of sellers and let the number of individuals $(B + S)$ equal $2k$ for some $k > 0$ (recall that the number of individuals is even). Excess supply $= 20B - 20S = 20B - 20(2k - B) = 40(B - k)$. Note that the excess supply is necessarily divisible by 40. Now, recall that a switch of a RS from a seller to a buyer as prices fall results in a drop in total excess supply of 40. (Assume, for convenience, that all preferences differ so only one person switches at a time.) Since 40 necessarily divides excess supply by $(B - k)$, the zero of the excess supply function (equilibrium) will necessarily be reached in $B - k$ steps.

The nature of the equilibrium has immediate consequences for the volume. The important ones are summarized by the next observation:

OBSERVATION: *If the price is lower than* 50 *then all individuals should trade* 20 *units. Furthermore, the number of buyers should equal the number of sellers and the volume should be* 20 *times one-half the number of individuals in the market.*

Thus, in an environment in which there is an even number of people, each of whom follows the expected utility hypotheses and is either risk avoiding, risk neutral, or risk seeking, the major results can be summarized as follows. If, and only if, there are as many risk-seeking individuals as there are risk-averse and risk-neutral individuals, then the competitive equilibrium price will be less than the "fair bet value" of $50M$ per unit of X. Furthermore, at the equilibrium all agents will be either buying or selling 20 units of X. The number of buyers will equal the number of sellers and total volume will be 20 times the number of individuals divided by two. If someone does not participate, or if an individual has preferences that are substantially different from those postulated, then the dynamics of the markets still could be similar because of the limited influence one individual might have by virtue of the constraints on the budget set. Of course, existence of equilibrium in the model is another thing and the presence of such individuals could force the system into an environment in which the competitive equilibrium does not exist.

IV. Results

The time series of all periods of three of nine loss-condition experiments are shown in Figures 2A, 2B, and 2C. Shown there are the contract prices as they occurred in time. The vertical bars represent the change of periods. A large black vertical bar represents the change from the practice periods to the periods for which the consequences would result in actual losses. While the figures show all data including the practice periods, only the real payoff periods are considered in the data anal-

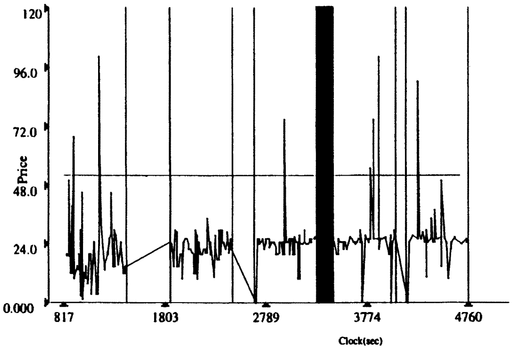

FIGURE 2A. EXPERIMENT 0316

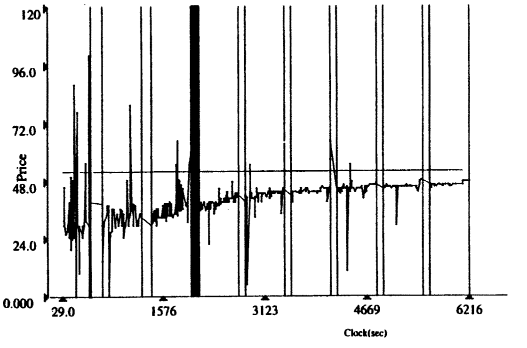

FIGURE 2B. EXPERIMENT 0324

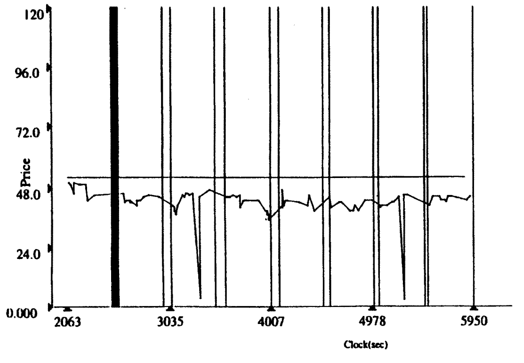

FIGURE 2C. EXPERIMENT 0509

ysis discussed in this section. The practice session is included only for illustrative purposes. The horizontal line is the actuarially fair price of 50.

The impression from the figures is that transaction prices tend to be lower than 50 and that in most cases prices settled to some sort of an "asymptote." The impression is supported by the first result. The importance of the result is that according to the model, the implication of such prices is that at least one-half of the subjects in the experiments were risk seeking.

RESULT 1: *The transaction prices tend to be no higher than the risk-neutral level of* 50. *The estimated asymptotes of such movements were lower than* 50.

SUPPORT:

The first claim of the result relies on the data presented in Table 1. The numbers in the upper part of the table are average transaction prices across actual payoff periods and experiments. Notice that there are only seven exceptions to the statement of the result, and six of these exceptions exist only in experiment 0501. In many periods of several experiments the average prices were within one cent of the risk-neutral price of 50, thereby suggesting the hypothesis that subjects were risk neutral and that subjective transaction costs would account for the difference. This possibility is discussed later in the paper. For now, it must be remembered that virtually all transactions were made below the risk-neutral level of 50 (see Figures 2A, 2B, and 2C). (Figure 2D for 0516 is a control experiment that will be used for comparisons and is discussed in detail later.)

For the second claim of the result, the destination and the direction of the equilibration process must be determined. The destination and the direction of the price convergence was evaluated by the application of a simple dynamic model (Noussair et al., 1995). The model assumes that price (dependent variable) may start from a different origin for each experiment, but the convergence is assumed to be to a common asymptote in all experiments. Formally the model is as follows:

$$P_{it} = B_{11}D_1(1/t) + \cdots + B_{1K}D_K(1/t)$$
$$+ B_2((t-1)/t) + u_{it},$$

where i is the index of the experiment; D_j are dummy variables that take value 1 if $i = j$ and value 0 otherwise; t is time measured in terms of experimental period number; K is number of experiments; P_{it} is the average price in period t of the experiment i; and u is a random variable, distributed normally with 0 mean. B_{1i} measures origin of the price convergence process, and B_2 is an asymptote.

Data in Table 2A show ordinary least-squares estimation of the model. The estimated asymptote was 46.11 and the risk-neutral equilibrium price was at 50. Thus, the statistical model suggests that the price equilibration was to the price lower than the risk-neutral level of 50.

The next result is focused on the convergence process and the degree to which it can be described as being toward the competitive equilibrium. It is important to note that the result addresses a convergence process because none of the processes could be said to have perfectly equilibrated.

RESULT 2: *Market movement toward a competitive equilibrium was observed across experiments. The propensity for movement toward competitive equilibrium quantities is more pronounced as subjects have experience in more than one experiment, while the evidence is mixed for inexperienced subjects.*

SUPPORT:

The first step of the support is to show that a tendency towards price equilibration was observed across experiments in a sense of a falling variance of price. Data in Table 1 show that the standard deviations of the prices were lower in the final periods of every experiment, compared to earlier periods, thus suggesting price equilibration.

The next step is to determine if one of several patterns of competitive equilibria predicted by the model was observed across experiments. The competitive model predicts a pattern of prices and closely related final holdings. We know from Result 1 that prices as well as the asymptotes of the process were no higher than 50 in all but one experiment. Thus, the equilibrium final holdings should be at the boundaries of the positive marginal utilities and the number of sellers should equal the number of buyers (Observation). In equilibrium each subject should have bought or sold 20 units of inventory, thus making final holdings equal to 40 or 0.

Data on final holdings are less decisive than on prices, but relevant statistics are in Table 2B. Shown there are the numbers of individuals who increased or decreased their holding of X by various levels. The last two periods of an experiment were averaged for each individual and used as the measure to indicate the individual's position. The numbers of buyers are approximately equal to the numbers of sellers (40 vs. 38), and 57 out of 78 people have moved halfway (at least nine units) or more toward the boundaries. This is more than 73 percent of the individuals.

The fact that not all of the individuals have moved to the extremes shows up again in the volume numbers. Data in the lower part of Table 1 show the time series of net trade volumes across experiments. In five out of nine experiments the volumes were substantially lower than the predictions of the competitive model and there were no clear signs of volume convergence to the predicted quantities.[7]

[7] The relevance of this phenomena will be discussed later in the paper where individual behavior of subjects will be considered.

TABLE 2A—ORDINARY LEAST-SQUARES ESTIMATION OF THE CONVERGENCE PROCESS

Equation: $P_{it} = B_{11}D_1(1/t) + \ldots + B_{1K}D_K(1/t) + B_2((t-1)/t) + u_{it}$.
i—index of the experiment; t—period number; P_{it}—average transaction price in period t of experiment i. $D_j = 1$ if $i = j$, 0 otherwise. $u_{it} \sim N(0, s^2)$. Dependent variable—P_{it}.

Experiment	Independent variable	Estimated coefficient	Standard error	t-statistics
022894	B_{11}	50.32	2.86	17.58
031694	B_{12}	21.07	3.03	6.95
031794	B_{13}	44.35	2.86	15.50
032494	B_{14}	39.02	2.82	13.82
042894	B_{15}	49.57	2.87	17.32
050195	B_{16}	54.74	2.81	19.43
050295	B_{17}	48.33	2.81	17.16
050595	B_{18}	49.47	2.84	17.57
050995	B_{19}	39.68	2.77	14.08
	B_2	46.11	0.84	54.28

Notes: Number of observations—49; R^2—0.71. Standard error of the regression—3.38; Durbin-Watson statistics—1.78. Mean of dependent variable—45.66.

The effects of experience are reflected by the decisions of the 20 subjects who participated in 0324 and 0509. The relevant data are in Table 3. All of these subjects had participated as inexperienced subjects in earlier experiments. For each of these subjects the average of the final holdings of the last two periods (when inexperienced) was compared to the last two periods (when experienced). Six of the seven subjects who came close to the "boundaries" (bought or sold more than two-thirds of the theoretically predicted quantities) when inexperienced, kept that tendency when experienced. Secondly, 15 of 20 subjects under consideration increased the absolute values of their final-holding changes the second time of participation. On average, the net change in holdings was 10.6 when inexperienced, and 15.3 when experienced. Thus, the evidence for movement toward a competitive equilibrium allocation is stronger in markets in which subjects were experienced.

In summary, price convergence receives substantial support, while allocation data are less supportive of movement toward the competitive equilibria. Movement toward the extremes occurs, but in the USC experiments the movement is incomplete, resulting in volumes that are less than the competitive prediction. While the evidence is thus mixed, we conclude that a tendency of convergence toward a competitive equilibrium was observed across experiments.

The next result states the implications of the particular competitive equilibrium observed, as related to the numbers of different types of preferences. It is here that observed market behavior and the theory of markets are used together to deduce the type of preference that must have existed in the subjects.

RESULT 3: *The number of risk-seeking subjects in the experiments was no less then the number of risk-averse and risk-neutral subjects combined.*

SUPPORT:

Proposition B2 states that only in the cases in which the number of risk-seeking subjects is no less than the number of non-risk-seeking subjects can the competitive equilibrium price be at some level which is strictly lower than 50. Result 1 says that prices are below 50. Result 2 states that the convergence was toward a

TABLE 2B—NUMBERS OF INDIVIDUALS WITH VARIOUS LEVELS OF PURCHASES AND SALES: AVERAGE OF LAST TWO PERIODS, ALL EXPERIMENTS

	All experiments combined						
Final holdings	0–0.4	0.5–4	5–8	9–12	13–16	17–20	Total numbers
BUYERS	4	2	5	7	8	14	40
SELLERS		6	4	5	7	16	38

competitive equilibrium. Thus, it is possible to apply Proposition B2 to the experimental data and conclude that the number of risk-seeking subjects in the experiments was no lower then the number of non-risk-seeking subjects.

The conclusion is consistent with the diminishing sensitivity axiom of prospect theory, which predicts such a behavior in losses. However, the price equilibration across experiments, identified in the previous paragraphs, has one major implication, which is very important for the discussion of the relevance of prospect theory for economics from a methodological point of view. Namely, equilibration suggests that, contrary to prospect theory as advanced by psychologists, preferences exist and do not exhibit labile properties that might result from multiple reference points or changes in reference points in the complex markets. This issue will be pursued toward the end of the results section.

The next result evolves from an inquiry that has two forms. First, do the questionnaires used extensively in psychological studies lead to measurements of properties of people that will be manifest in market behavior? The second is a corollary to the first. Is risk seeking in the negatives a property of individual preferences or is it a property of the way that people think about things? Is it a property of preference or is it a property of the process of preference formation? As it turns out, the questionnaires have a biased property as a prediction of market behavior but, nevertheless, provide strong predictive powers about such behavior. Thus, one cannot reject the notion that the questionnaires measured a property of preference as opposed to a feature of cognition.

The analysis will consist of three steps. First, the subjects will be classified as RA or RS according to their behavior in the experiments. Secondly, the same classification will be completed according to their answers to the questionnaires. Comparison of two classifications will provide support for the statement of results.

A classification of the subjects by their behavior in the experiments is developed by using the equilibrium patterns suggested by the model. Subjects can be classified into three different categories, according to their final holdings. Only two last periods of every experiment were used in the analysis. Data in Table 4A show the results of such a classification.

1. Risk seeking (RS)—This class contains subjects who satisfy the following condition: They moved at least halfway toward the ''sellers' boundary'' on average; i.e., they sold at least ten units of X on average in the last two periods of the experiment.

2. Possibly risk averse (RA)—This class contains subjects who satisfy the following condition: They moved at least halfway toward the ''buyers' boundary'' on average; i.e., they bought at least ten units of X on average in the last two periods of the experiment.

The competitive model predicts that in equilibrium, when the prices are sufficiently lower than the risk-neutral price, risk-seeking people can demonstrate the same behavior as risk-averse people: buying units of inventory. On the other hand, if a subject is on the seller's side of the market and prices are below 50, then that subject is exhibiting risk-seeking behavior. Thus, formally, the numbers in Table 4A represent lower bounds of the numbers of the risk-seeking people in the experiments and the upper bounds of the numbers of the risk-averse subjects.

TABLE 3—COMPARISON OF THE NET CHANGES OF FINAL HOLDINGS (AVERAGE OF THE LAST TWO PERIODS) AND CLASSIFICATION RESULTS FOR THE SUBJECTS WHO PARTICIPATED IN TWO EXPERIMENTS

	Inexperienced			Experienced		
Subject #	Experiment	Net changes of final holdings of inventory	Classification	Experiment	Net changes of final holdings of inventory	Classification
1	0316	6.5	"?"	0324	8.5	"?"
2	0316	0.5	"?"	0324	0	"?"
3	0316	10.5	RA	0324	12	RA
4	0316	−5	"?"	0324	−19	RS
5	0316	−3.5	"?"	0324	9.5	"?"
6	0316	−3	"?"	0324	−15	RS
7	0316	−1	"?"	0324	0	"?"
8	0317	−13.5	RS	0324	−17	RS
9	0317	−3	"?"	0324	11	RA
10	0317	0	"?"	0324	10	RA
11	0501	−13.5	RS	0509	20	RA
12	0501	−12	RS	0509	31.5	RA
13	0501	−12.5	RS	0509	−20	RS
14	0501	−14	RS	0509	−20	RS
15	0502	−17	RS	0509	20	RA
16	0502	−20	RS	0509	20	RA
17	0502	−19.5	RS	0509	−20	RS
18	0502	20	RA	0509	19.5	RA
19	0505	−20	RS	0509	−12.5	RS
20	0505	−17.5	RS	0509	−18	RS

3. "?"—It is hard to say about subjects. This class contains subjects who did not demonstrate a "consistent pattern" of behavior. In other words, these were subjects who:

(i) May have been moving in a direction of the boundaries, but did not demonstrate any pattern of consistency.
(ii) Were trading around the status quo, instead of moving toward some boundary, but showed no consistent behavior.
(iii) Were not buying or selling anything at all.
(iv) Demonstrated a mix of (i), (ii), and (iii).

Notice that approximately two-thirds of all subjects (53 out of 82) were classified as RS or RA and the other one-third was classified as "?." Since, as discussed in the previous paragraphs, those subjects who were classified as RA could in fact be RS if prices were sufficiently low, the results of such a classification could be interpreted to be that there was no less than 50 percent of the people in the experiments that were risk seeking. This classification is consistent

TABLE 4A—CLASSIFICATION OF THE SUBJECTS ACCORDING TO THEIR BEHAVIOR

Experiment	RA*	RS**	"?"
0228	3	3	4
0316	2	1	7
0317	3	3	4
0324	3	3	4
0428	2	2	4
0501	4	4	2
0502	3	3	2
0505	2	2	2
0509	5	5	0
Totals	27	26	29

* These measures are upper bounds.
** These measures are lower bounds.

with the claim of Result 3 that risk seeking accounts for a substantial proportion of behavior.

The classification provides a possible insight about the weaknesses in the support for equilibration. Recall from the support of Result 2 that the total net volumes of trades were lower than predicted by the competitive model. Now it becomes clear that such a phenomena is likely due to the great number of subjects who were classified as "?." The common feature of most of such subjects is that they did not move far from the status quo. In other words, they all had low net volumes across periods, or they were inconsistent across periods and, as a result, they could not be classified as RA or RS. Data in Table 1 show that the net volumes were approximately 10–50 percent lower than ones predicted by the model. On the other hand, one-third of subjects were classified as "?," thus providing support for the claim that the "?" subjects were responsible for low net volumes.

A classification of the subjects according to their answers to the questionnaires was done. All of the subjects were asked to answer the following questions—What would you prefer to lose:

(i) $500 for sure or $1,000 with probability 0.5.
(ii) $20 for sure or $40 with probability 0.5.
(iii) $3,000 for sure or $4,000 with probability 0.8.
(iv) $7.50 for sure or $15 with probability 0.5.
(v) $1 for sure or $2 with probability 0.5.

According to their answers they were qualified using two different types of classifications.

Type 1 classification: Risk averse—three or more answers "for sure"; risk seeking—three or more answers "with probability = 1/2."

Type 2 classification: (According to the answers to single question), which one would you choose—losing $20 for sure or losing $40 with a probability 1/2?

Risk seeking—Would prefer to lose $40 with probability = 1/2 instead of to lose $20 for sure.

Questionnaires were completed by all 82 subjects who participated in the experiments. According to the type 1 criteria, 66 (80 percent) were "risk seeking" and 16 (20 percent) were "risk averse." According to the type 2 criteria, 61 (74 percent) were "risk seeking" and 21 (26 percent) were "risk averse."

With the measurements above completed, the result can now be stated. The essence of the result is that the questionnaires have predictive power about behavior in markets.

RESULT 4: *There is strong consistency between answers to the questionnaires and experimental market behavior. However, the questionnaire may have a bias that overestimates the number of risk-seeking individuals relative to the number of risk-averse individuals.*

SUPPORT:

The numbers in Table 4B represent relationships between the experimental data and the data from the questionnaires. If only subjects who were classified as RA or RS are considered, then the probability that a subject who appears to be RS according to the questionnaires would demonstrate the same kind of behavior in the experiment ($p(RS_{exp} | RS_{quest})$) is equal to 0.65 (0.63 for type 2 classification). Similarly, $p(RA_{exp} | RS_{quest}) = 0.35$

(0.37), $p(RA_{exp}|RA_{quest}) = 0.87$ (0.80), $p(RS_{exp}|RA_{quest}) = 0.13$ (0.20). Two conclusions follow about relevance of the questionnaires for predicting market behavior. First, answers to the questionnaires do produce measurements that can be used as a rough prediction of the behavior in the context of operating markets, since the probability of consistent (with the answers) behavior is 0.73. Secondly, the likelihood of a deviation in the experiment from the answer given to the questionnaire is about three times for risk-seeking subjects (questionnaire) rather than for risk-averse ones (questionnaire). It is important to note that the results are the same for both types of classification. In other words, choice of either of the two different types of classification does not change the results. Finally, the fact that the questionnaire overestimated the number of RS-type behavior in the markets is consistent with the model, which claims that as prices fall below 50 the RS will begin to shift from selling to buying. However, this aspect of the data will be discussed again as Conjecture 3.

TABLE 4B—RELATIONSHIP BETWEEN ANSWERS TO THE QUESTIONNAIRES AND EXPERIMENTAL BEHAVIOR

Type 1 classification
More than two out of five answers of a particular type

Type 2 classification (in parentheses)
Based on the answer to the choice of loosing $20 for sure or $40 with $p = 1/2$

	Risk seeking in the questionnaires	Risk averse in the questionnaires
Risk seeking in the experiment	17 (16)	2 (3)
Risk averse in the experiment	9 (10)	13 (12)
"?" in the experiment	20 (17)	1 (4)

V. Results and Theoretical Coherence: Three Tests

The results as reported go beyond a simple reporting of statistics. They embody an attempt to weave a sense in which the statistics are consistent with the principles that support "extended prospect theory" as integrated with the competitive model. Since the data do not perfectly fit the competitive model, as modified to include the possibility of risk-seeking behavior in the negatives, there might be alternative explanations. In this section we discuss additional experiments that explore three possible alternative explanations of the data. Space limitations prevent any detailed reporting but these additional experiments can be used as some indication of the robustness of the major results reported in the body of the paper. These additional experiments will be referenced as "additional controls."

The motivation for the first additional control experiment was the fact that transaction prices in most experiments tend to be very close (a penny below) to the risk-neutral level of 50. In view of such data, a possibility exists that the subjects were risk neutral and that transaction costs accounted for the observed lack of accuracy of the model. To test this hypothesis (risk neutrality) an additional control experiment (0509) was conducted. This experiment involved a special selection of subjects from those that had participated previously. Subjects were chosen that had previously demonstrated risk-seeking behavior according to the model. Aside from the selection of subjects, the experiment was an exact replica of all previous experiments. All subjects who participated in experiment 0509 had already participated in one of the previous California Institute of Technology experiments: 0501, 0502, or 0505. All but one of the subjects chosen for 0509 were those that could be classified as risk seeking as a result of their previous participation. Data in Table 1 show that in the three previous experiments (0501, 0502, and 0505) prices were close to the risk-neutral level of 50. Thus, if the subjects were risk neutral then the transaction prices in the experiment 0509 should be also near 50. On the other hand, if the existence of risk-seeking individuals interpretation of the data is correct, then, as the model implies, the prices in experiment 0509 should be significantly below 50.

The last column in Table 1 presents transaction prices for the additional control experiment 0509. It is clear that the prices were not only below 50 but are far below (about 20 percent) the prices in the experiments 0501, 0502, and 0505. Thus the prices are out of the range of any previously observed transactions costs deviation from equilibrium. Since market prices were substantially below the risk-neutral equilibrium, the model implies that there are at least as many risk-seeking subjects as there are risk-averse and risk-neutral subjects combined, so the hypothesis about general risk neutrality can be rejected.

A second additional control experiment (0516) was conducted to explore the idea that the observed risk-seeking behavior could be explained as a property of general risk-seeking preference, as opposed to simply risk seeking in losses. If subjects change their risk-seeking behavior to risk-averse behavior when the experimental conditions are formulated in terms of gains as opposed to losses, then the hypothesis of general risk-seeking preference can be rejected. Does the risk-seeking behavior observed simply reflect the attitudes of individuals that prefer risk taking in general, or is it the case that preferences are different for gains as opposed to losses? The test was performed using an experiment with a translation of the origin of the payoffs to a "gains" environment.

First, subjects were paid \$10 up front and were given 1000 units of money (M) and 20 units of inventory (X) as initial holdings. Secondly, their incentives to trade were formulated in terms of potential gains:

Total Gain = Gain A + Gain B

Gain A = $\langle (1/100)m \rangle$ and

Gain B = $\langle 0\{\text{Prob } 1/2\}$ or $(100 \text{ cents})\{\text{Prob } 1/2\}\rangle$.

Thus, the purchase of a unit of X is simply the purchase of a lottery that yields a 50:50 chance between 100 cents and 0. Note that for both types of design (losses and gains) the *ex ante* expected amounts of money a subject could earn were the same. Thus, since the final states of the world are the same under both conditions, stable preferences over final states of the world should produce behavior that is the same for both types of experiments. The

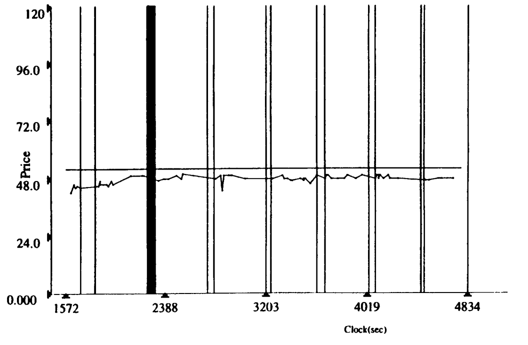

FIGURE 2D. EXPERIMENT 0516

nine subjects who were used in this second control experiment had participated in the first additional control experiment 0509. (One of the ten subjects that participated in 0509 could not return for the experiment 0516). Recall, these subjects when participating in experiment 0509 demonstrated clear risk-seeking behavior in losses as they had done in the previous experiments. Therefore, if no differences exist for the subjects between losses and gains, one would also expect to observe risk-seeking behavior in the "gains" and thus prices should be above the "expected value." Prices above the risk-neutral level of 50 would reflect the buying efforts of risk-seeking individuals who drive the price up because they enjoy the variance in wealth. On the other hand, if the subjects have asymmetric risk attitudes in the gains and losses, then the subjects would switch to the risk-averse behavior when the lotteries are formulated in terms of gains. As a consequence, the transaction prices in the second additional control experiment (0516) would be below the risk-neutral level of 50.

Figure 2D presents time series of transaction prices for the second additional control experiment (0516). The horizontal line corresponds to the risk-neutral level of 50 cents. Notice that all transaction prices are below 50.[8] There are

[8] (Period, average price, standard deviation, volume): (0, 45, 2.15, 51), (1, 47, 1.34, 81), (2, 48, 0.83, 70), (3, 48, 1.28, 80), (4, 48, 0.83, 80), (5, 48, 0.5, 80), (6, 48, 0.46, 80), (7, 48, 0.48, 80).

an odd number of agents and if more than half are risk seeking then the prices must necessarily be above the fair lottery price of 50. Thus, the market measure suggests risk aversion on the part of subjects as opposed to risk seeking. This asymmetry in behavior is supported at the individual level. Three of the four subjects who demonstrated risk-averse behavior in 0516 (the gains) by selling the lottery at prices below the risk-neutral price had exhibited strong risk-seeking tendencies by selling insurance at a price below the risk-neutral prices, when participating in 0509 (the loss). These individuals exhibited clear asymmetric behavior by switching to risk-averse behavior when the market consists of the same lotteries with the expected loss now being a gain.[9] Thus, the hypothesis that the subjects were risk seeking in general and exhibited no asymmetric behavior, can be rejected.

A glance at the time series of all experiments suggests the motivation for a third set of additional control experiments. Notice that prices in all experiments tend to be below the equilibrium value of the model. This suggests the hypothesis that something about the experiments, unrelated to risk preferences, caused the markets to converge from below. A third set of four additional control experiments were performed but are not reviewed here in detail. The purpose of the experiments was to control for the hypothesis that the ''natural path'' of convergence of any market in these environments is from ''below.'' These experiments were identical to the other experiments in the loss domain except the numeraire was switched from money to the lottery and the units were changed to accommodate the switch.[10] If risk-seeking behavior is present then prices should be *above* the equilibrium price of 200. Thus, the same theory of risk seeking that predicted below risk-neutral prices now predicts prices above the risk-neutral equilibrium price level.

Four experiments were conducted with inexperienced and then experienced subjects. Because this switch in numeraire was evidently difficult for subjects, the processing and analysis of the data require more space than is available in this paper. However, the conclusion from analysis is that with experienced subjects some support exists for the presence of risk-preferring subjects in this ''inverted'' environment. These data are not conclusive but they do help to reject any presumption that for some reason prices are always below risk-neutral levels whether in the gains or losses. Prices of money in terms of the ''insurance,'' when experienced people were used, tended to be above the risk-neutral levels.

A paradox can be observed in the data. On one hand, the individuals selected for experiment 0509 continued to exhibit risk-seeking behavior throughout the second experience. On the other hand, the data suggest an evolution of risk attitudes when experience becomes a factor. In other words, for many subjects, the risk attitudes after experience might be different from those initially. For example, Figures 2A, 2B, and 2C show that in most of the experiments price convergence was occurring in the training periods. The early prices were consistently lower, suggesting that people were becoming more risk averse as they gained experience (and also faced actual payoffs). The following two conjectures represent an attempt to approach the problem of changing behavior with experience. The conjectures should not be interpreted as results but rather as a starting point of a discussion about this complex issue.

[9] Because prices are endogenous, the model itself indicates that market experiments of the type studied here can only yield limited opportunities to classify individuals according to preferences. Three individuals who were sellers in the loss and sellers in the gain clearly exhibited the asymmetry of preferences suggested by extended prospect theory. One individual, a buyer in loss and a buyer in gain, exhibited behavior that was consistent with asymmetric preferences but, of course, could also have been consistently risk averse. Two individuals who were sellers in the loss and buyers in the gain were consistent with asymmetric preferences but are also consistent with general risk seeking. Three individuals were buyers in the loss and buyers in the gains and thus cannot be classified at all since they are consistent with all modes of preferences.

[10] $m_0 = 2000$, $x_0 = 10$; Loss A = $\langle 0\{\text{Prob } 1/2\}$ or $\$40 - (1/100)m\{\text{Prob } 1/2\}\rangle$, Loss B = $\$20 - x$. The risk-neutral price of x in terms of m is 200.

CONJECTURE 1: *Support of specific implications of the loss-aversion axiom of prospect theory, such as an "endowment effect," "status quo bias," or "trade-off vs. improvement" is stronger in the experiments involving inexperienced subjects and disappears with experience.*

SUPPORT:

The conjecture is a direct implication of the data presented in Table 3. The source of support is a comparison of the behavior of the subjects who participated in the experiments 0316, 0317, 0501, 0502, and 0505 as inexperienced subjects, with their behavior when they participated in the experiments 0324 and 0509. The latter behavior was substantially different from the former. Such a difference in behavior of the same people participating in the same experiment suggests that experience matters.

As was discussed in the support of Result 2, in the first set of experiments (subjects were inexperienced) the final holdings of eight of 20 subjects were near the origin (less than 10 units were traded), implying status quo bias. In other words, the status quo was the chosen option for the subjects. At the same time, however, the phenomena cannot be due to the status quo bias as derived from prospect theory. At the prices that existed in these markets, if people are risk seeking (as they must be under the conditions of prospect theory from which the status quo bias is derived), the competitive equilibrium has individuals only on the "boundaries." Thus, while a status quo bias is observed it cannot be due to prospect theory. At the same time, in the second set of experiments (subjects were experienced) the final holdings of only four of 20 subjects were near the origin, implying "boundary" final holdings as predicted by the competitive model and in agreement with other experiments. Moreover, 15 of the 20 subjects increased the absolute values of their final holdings during their second experiment. The conclusion is that inexperienced subjects in the experiments demonstrated a tendency to make very few changes in their holdings. With experience and understanding, their behavior changed. Thus, degree of experience and not a status quo bias derived from prospect theory accounts for their behavior.

The conjecture above suggests that when people do not feel confident about their understanding of a situation they will be conservative and choose inaction over action. It is possible to use extended prospect theory to explain such phenomena. The explanation could go as follows. A natural feature of uncertainty, as opposed to risk, is the imagined existence of negative prospects that are possibly weighted so high that inaction results. With exposure to the decision environment comes a better understanding and as a consequence the imagined, possibly negative prospects disappear and the other features of the decision process emerge. While this explanation is crude, it appears that a modification of extended prospect theory is necessary for the last result to be explained.

The discussion and results above hold implications for the nature of circumstances under which real prospect theory can be applied. The real prospect theory (and not the extended prospect theory examined here) is about a decision process. A natural question to pose is if the axioms/laws of the decision process have a change in nature, or evolve to take different forms as experience and understanding takes place. The conjecture developed next suggests that some of the central phenomena identified by prospect theory are not stable features of human choice behavior. They diminish with experience and, perhaps, with reflection.

CONJECTURE 2: *With experience, risk seeking in the losses evolves into either risk-neutral or risk-averse behavior.*

SUPPORT:

Price convergence from below in most experiments (Table 1) suggests that the incidence of risk-seeking behavior is getting weaker as the experiment continues. The competitive model implies (Propositions 4–6), that the more RS subjects are in the system the less will be the equilibrium price and the more RA subjects are in the system the higher will be the equilibrium. Table 1 shows that the prices were consistently increasing in seven out of nine experiments.

Although it is impossible to claim that risk-seeking behavior always disappears with experience, obvious tendencies towards the diminution of risk seeking were observed in four experiments.

The above conjectures are of potential importance because they help isolate the nature of the decision process and its possible relationship to properties of an individual. Convergence in economic environments seems to occur at many different levels. Clearly, prices and quantities have a convergence property. However, individual decision rules seem to evolve and individual understanding of a situation and the attitudes of other individuals seem to undergo a transformation during the course of decisions and market activity.

A hypothesis/philosophy has been advanced to describe this evolution, called the discovered preference hypothesis (Plott, 1996), and while that hypothesis is so simple that it is not likely to survive close examination, the above two conjectures seem to be part of a pattern that the discovered preference hypothesis was advanced to capture. The idea is that the individuals have a consistent set of preferences over states but such preferences only become known to the individual with thought and experience. Individuals at first exhibit a type of myopia, choosing in a somewhat impulsive way reflecting their immediate perceptions of their interests. With experience, behavior moves toward patterns of choice behavior typical of the predictions of classical preference theory. Thus, when individuals are first given questions, they are characterized by a type of confusion. As they begin to formulate decisions in this state they are influenced by "frames" in much the way that prospect theory asserts. As an understanding of the context evolves, the manifestation of the underlying preferences becomes more clearly observable in the data and decisions approach those predicted by the classical theory of choice and preference.

A final conjecture is offered about the relationship between the methodology of questionnaires as a research tool and the creation of experimental markets. It rests on the fundamental assumption that preferences do exist in the classical sense of economics, and that the preferences are reflected in individual choice behavior.

CONJECTURE 3: *The questionnaires have a bias that overstate the number of risk-seeking individuals relative to the number of risk-averse individuals.*

The observation that motivates this conjecture is the nature of the error rate of risk seeking as measured by the questionnaire. A total of 62 people participated as inexperienced subjects. Of these, 46 were RS according to the questionnaire and 16 were RA. Subjects responding as RA in the questionnaire (15) were more likely to behave RA in the experiment (12/15 inexperienced) than were subjects responding as RS in the questionnaire (46) likely to behave RS in the experiment (17/46 inexperienced). The asymmetry is clear. Of course, as was mentioned in the discussion of Result 4, the model suggests that at low prices some of the RS will turn to behavior that cannot be distinguished from RA behavior so these statistics alone might not be so supportive of the conjecture. However, additional support comes from the asymmetry of the behavior of those who could not be classified in the experiments (designated as "?"). The subjects who were RS in the questionnaire exhibited a much greater tendency to be "?" in the markets (20/46 inexperienced) than did the subjects that were RA according to the questionnaire (1/15 inexperienced). Thus, the bias exists in the form of the ability to connect subjects that answered the questionnaire as RS with subsequent behavior that would be difficult to classify. That difficulty does not exist with subjects that were RA, according to the questionnaire.

Of course, the idea of bias of the questionnaire approach is only a conjecture. The explanation could reside in the nature of this particular questionnaire (see Camerer, 1995) for references to the literature in which the properties of such instruments are studied. Or, the asymmetries could be due to the method of classification based on behavior in the experimental markets. The data reported here from these experiments do not seem to have the capacity to resolve the issues.

VI. Conclusions

This research began with questions motivated by psychological research. Prospect theory has had a considerable impact on the decision literature. The question posed by the research reported here was whether or not the predictions of an ''extended prospect theory'' could find support in markets.

Exchange economies were created in which only losses could occur. Preferences over losses were not controlled by the unusual methodology in which preferences are induced. Instead, the objective was to determine if the ''preferences revealed'' by market actions had properties that one might expect from having studied the psychological-based literature.

Risk-seeking behavior in the loss domain was observed in the markets studied. Its existence lends support to two fundamental properties of prospect theory. First, since risk-averse behavior has been widely documented in the positive domain in experimental markets, we can conclude that there is an asymmetry between gains and losses. A single control experiment reported in the paper further supports a pattern of asymmetry and that asymmetry is a fundamental property of prospect theory. As a corollary, we can conclude that there are such things as ''gains'' and ''losses,'' as opposed to only ''final states of the world,'' the existence of which implies the existence of another fundamental feature of prospect theory, a reference point. Finally, we can conclude that risk seeking in the losses is a frequent occurrence. It was a property of over one-third of the total of all people observed in these markets.

The patterns of results lend strong support to features of prospect theory as a description of a decision process. The more fundamental question to be posed is whether individuals are ONLY a bundle of decision processes: rules of thumb that have no necessary relationship to an underlying attitude or coherence of an underlying preference. First, it should be emphasized that a pattern of coherence is evident in the markets. Convergence toward competitive equilibria occurred. It follows that the ''reference point'' was not so subject to moment-to-moment ''framing'' that preferences became so labile that they had no coherence. These markets behaved as if a large proportion of individuals had reasonably coherent and stable preferences. Of course, a large proportion of these preferences were exactly of the form that one would have expected from a reading of prospect theory, as stated by the ''extended prospect theory.'' Psychologists have long maintained that a relevant domain of prospect theory is ''one-time decisions.'' The results reported here question whether or not that is the only circumstance in which the theory applies. The conjectures reported here suggest that the first impulses experienced by a decision maker would seem to be described by the theory. Features of prospect theory are present when people are confused. The support for the status quo bias is an example. The difference in behavior of those that give a risk-seeking response to a questionnaire as opposed to those that give a risk-averse response is another body of evidence that conservatism is a consequence of incomplete understanding. After all, the theory is about a process of decision, so it is not particularly surprising that its features are most evident in situations in which individuals are involved in a process of decision.

Whether or not ''considered opinions'' are governed by the same processes as are immediate impulses involves deeper and more complex experiments than have been performed to date. The final conjecture of the paper is that some of the features of prospect theory will disappear with practice or perhaps even with reflection. In particular, the conjecture is that risk seeking in the losses is a property of inexperience that will give way to risk-averse behavior. Of course, one implication of the conjecture is that the concept and importance of a reference point will also fade. The idea that the evolution of attitudes has a direction toward the more classical lines of preference theory has been vigorously criticized (Kahneman, 1996). Nevertheless, the data presented here provide additional support for such a presumption.

APPENDIX A

INSTRUCTIONS

You are about to participate in an experiment. For your agreement to participate you will be paid \$60. The structure of the experiment is such that you will be exposed to a possible money loss.

The amount of loss will depend upon your decisions and the outcome of the lottery as will be explained in the following paragraphs.

Your total money loss will consist of two different types of losses:

Total Loss = Loss A + Loss B.

Loss A will be determined as \$20 minus 1/100 times your A-Cent holdings.

Loss B will be determined by the outcome of a lottery. The outcome of the lottery is determined by a single draw from an urn that contains an equal number of RED and BLACK balls.

If the drawn ball is a RED one then your Loss B is zero.

If the drawn ball is a BLACK one then your Loss B will be determined as \$40 minus your B-Dollar holdings.

The experiment will consist of a series of periods. At the beginning of each period you will be given 1000 A-Cents and 20 B-Dollars. The A-Cents reduce your money Loss A. The B-Dollars reduce your money Loss B should a BLACK ball be drawn, but of course B-Dollars are worth nothing to you should a RED ball be drawn. During the period you will be able to change the nature of your Losses by exchanging A-Cents for B-Dollars and B-Dollars for A-Cents.

Each 1 B-Dollar held at the end of a period reduces your B Loss by \$1 should a BLACK ball be drawn, and each 100 A-Cents reduces your A Loss by \$1.

As you may have noticed, the chance that the drawn ball is BLACK is 1/2 or 50 percent and the chance that the drawn ball is RED is also 1/2 or 50 percent. You may also have noticed that A-Cents are always worth something to you (100 A-Cents reduces \$1 of A Loss not depending on the outcome of the lottery) and that you need B-Dollars only in 50 percent of cases (1 B-Dollar reduces \$1 of B Loss only if a BLACK ball is drawn).

As described above, the maximum possible A Loss is \$20 (happens if you have no A-Cents at all), and the maximum possible B Loss is \$40 (happens if you have no B-Dollars at all and the BLACK ball is drawn). That implies that the maximum amount of A-Cents you may want to have is 2000 A-Cents and B-Dollars is 40 B-Dollars.

The A-Cents that you have at any time are found in the CASH ON HAND space on your computer screen. The B-Dollars that you have are found in the INVENTORY space on your computer screen. So if you buy one unit of INVENTORY at a price *P*, you give up *P* A-Cents and you acquire 1 B-Dollar. If you sell one unit of INVENTORY at a price *P* you acquire *P* A-Cents and you give up 1 B-Dollar.

The CASH ON HAND (A-Cents) and INVENTORY (B-Dollars) held at the end of a period will dictate the terms of your lottery that resulted from the trades you made during the period. These dictate the nature of your loss. Nothing can be transferred from one period to another. The trading in each period yields the terms of a specific lottery.

The results of only one period will be used to determine your Loss. At the end of the experiment a special lottery will be held to determine which of several periods it will be. In this special lottery each period will be given equal weight.

EXAMPLE 1

Suppose for example that you made no trades at all during the period. So your final holdings are the same as initial holdings: 1000 A-Cents (CASH ON HAND) and 20 B-Dollars INVENTORY).

If a BLACK ball is drawn you would have lost:

-------- **A Loss** -------------------------

\$20 − 1/100 × 1000 (the A-Cent held)

plus

--------- **B Loss** ------

\$40 − \$20 (the B-Dollars held) = \$30.

If a RED ball is drawn you would have lost:

-------- **A Loss** -------------------------

\$20 − 1/100 × 1000 (the A-Cent held)

plus

--------- **B Loss** ---------

\$0 = \$10.

After each period you will have to fill out the RECORD OF LOSSES enclosed in your instruction folder. For example if in some period you acted as described in Example 1, your RECORD OF LOSSES should be as follows.

Period #		Your B-Dollar holding (Inventory)	Your A-Cent holding (Cash on Hand)	Your B Loss $40 minus #B-Dollars	Your A Loss $20 minus #A-Cents 100	Total Loss if the ball is BLACK (A + B)	Total Loss if the ball is RED (A)	Real Total Loss
0	Beginning	20	1000	$20	$10	$30	$10	
0	End	20	1000	$20	$10	$30	$10	

EXAMPLE 2

Suppose now that during the period you have sold 15 B-dollars at price 60 each. That means that your final holdings are: 5 B-Dollars (20 − 15) and 1900 A-Cents (1000 + 15 × 60).

If a BLACK ball is drawn then you would have lost:

$$\$20 - 19\text{ (A Loss)} + \$40 - 5\text{ (B Loss)}$$

$$= \$36\text{ (Total Loss)}.$$

If a RED ball is drawn then you would have lost:

$$\$20 - 19\text{ (A Loss)} + \$0\text{ (B Loss)}$$

$$= \$1\text{ (Total Loss)}.$$

Your RECORD OF LOSSES in this case should be filled out as follows.

Period #		Your B-Dollar holding (Inventory)	Your A-Cent holding (Cash on Hand)	Your B Loss $40 minus #B-Dollars	Your A Loss $20 minus #A-Cents 100	Total Loss if the ball is BLACK (A + B)	Total Loss if the ball is RED (A)	Real Total Loss
0	Beginning	20	1000	$20	$10	$30	$10	
0	End	5	1900	$35	$1	$36	$1	

The above the example shows how you may change the nature of your losses by selling B-Dollars compared to making no actions at all (Example 1). Namely, in the Example 1 your gains were the following:
50% chance of losing $30 (a BLACK ball is drawn);
50% chance of losing $10 (a RED ball is drawn).

After selling 15 B-Dollars at the price of 50 each (Example 2) your losses are determined as:
50% chance of losing $36 (a BLACK ball is drawn);
50% chance of losing $1 (a RED ball is drawn).

Now you can see how your actions during the experiment may change the nature of your losses.

EXAMPLE 3

Suppose that during the period you bought 20 B-Dollars at a price 40 each. That means that your final holdings are: 200 A-Cents (1000 − 20 × 40) and 40 B-Dollars (20 + 20).

If a BLACK ball is drawn you would have lost:

$$\$20 - 2\text{ (A Loss)} + \$40 - 40\text{ (B Loss)}$$

$$= \$18\text{ (Total Loss)}.$$

If a RED ball is drawn you would have lost:

$$\$20 - 2\text{ (A Loss)} + \$0\text{ (B Loss)}$$

$$= \$18\text{ (Total Loss)}.$$

So your losses in this example are the following:

50% chance of losing \$18 (a BLACK ball is drawn);

50% chance of losing \$18 (a RED ball is drawn).

Your RECORD OF LOSSES should be filled out as follows.

Period #		Your B-Dollar holding (Inventory)	Your A-Cent holding (Cash on Hand)	Your B Loss \$40 minus #B-Dollars	Your A Loss \$20 minus #A-Cents 100	Total Loss if the ball is BLACK (A + B)	Total Loss if the ball is RED (A)	Real Total Loss
0	Beginning	20	1000	\$20	\$10	\$30	\$10	
0	End	40	200	\$0	\$18	\$18	\$18	

Compare it to the losses from Examples 1 and 2.

Exercise 1

Suppose that during the period you sold 18 B-Dollars at the price of 55 each.

Compute:

(i) Your final B-Dollar holding ________.

(ii) Your final A-Cent holding ________.

(iii) Your A Loss ____________________.

(iv) Your B Loss ____________________.

(v) Your Total Loss if a BLACK ball is drawn ________________________________.

(vi) Your Total Loss if a RED ball is drawn ________________________________.

So your final lottery is:

50% chance of losing _____;

50% chance of losing _____.

(vii) Fill out the RECORD OF LOSSES for the above case.

Exercise 2

Repeat Exercise 1 for the case when during a period you bought 10 B-Dollars at the price of 45 each.

(i) Your final B-Dollar holding ________.

(ii) Your final A-Cent holding ________.

(iii) Your A Loss ____________________.

(iv) Your B Loss ____________________.

(v) Your Total Loss if a BLACK ball is drawn ________________________________.

(vi) Your Total Loss if a RED ball is drawn ________________________________.

So your final lottery is:

50% chance of losing _____;

50% chance of losing _____.

(vii) Fill out the RECORD OF LOSSES for the above case.

APPENDIX B

PROPOSITION B1: *Consider a utility function satisfying the general assumptions (a), (b), and (c) in the text (page 807). If*

1. $U'(z) > 0$ *for any* z;
2. $U''(z) < 0$ *for any* $z < 0$ *if a subject is risk averse in losses*;
3. $U''(z) > 0$ *for any* $z < 0$ *if a subject is risk seeking in losses;*
4. $U'(z) = 1$ *and* $U''(z) = 0$ *if a subject is risk neutral*,

then the indifference curves of the final holdings of M and X satisfy the following properties (where subscripts represent derivatives):

1. $x'_m < 0$ *for any* m: $0 < m < 20$;
2. $x''_{mm} > 0$ *(Convex) if a subject is risk averse in negatives*;
3. $x''_m < 0$ *(Concave) if a subject is risk seeking in negatives*;
4. $x'_m = -0.02$ *and* $x''_{mm} = 0$ *if a subject is risk neutral.*

PROOF:

The indifference curves are determined by the following equation:

$$(B1)\quad 0.5U(m/100 - 20) + 0.5U(m/100 - 20 + x - 40) = C,$$

where $0 \leq m \leq 2000$ and $0 \leq x$ are the money M and the inventory X holdings, respectively, by the end of a period. Equation (B1) defines an implicit function $x = x(m, c)$ representing an indifference curve. To determine the shape of the indifference curves x'_m and x''_{mm} are to be computed. By differentiating both sides by m we get:

$$\text{(B2)} \quad 0.01U'(m/100 - 20) + U'(m/100 + x - 60)(x'_m + 0.01) = 0,$$

$$\text{(B3)} \quad x'_m = -0.01 - 0.01U'(m/100 - 20)/U'(x + m/100 - 60).$$

Differentiating both sides of (B2) by m implies:

$$\text{(B4)} \quad 0.01U''(m/100 - 20) + 100U''(m/100 + x - 60) \times (x'_m + 1)^2 + 100U'(m/100 + x - 60)x''_{mm} = 0.$$

Substitution of (B3) into (B4) gives:

$$\text{(B5)} \quad x''_{mm} = (-10^{-4})/U'(m/100 + x - 60) \times [U''(m/100 - 20) + U''(m/100 + x - 60) \times \{U'(m/100 - 20) \div U''(m/100 + x - 60)\}^2].$$

By substituting into (B5) the properties of the derivatives listed in the hypothesis of the proposition, the first three conclusions of the proposition follow immediately. One may also notice that for all types of subjects

$$\text{(B6)} \quad U'(x = 40, m = 0) = -0.02 \text{ and } -0.01 \leq U'(x, m = 20) \leq -0.02.$$

From this the fourth conclusion of the proposition follows.

LEMMA B1: *Let* A, S, *and* N *denote the numbers of risk-averse, risk-seeking, and risk-neutral subjects, respectively. If there are only risk-averse subjects in the experiment* (S = N = 0) *then under the conditions on the preferences and identical initial endowments a competitive equilibrium always exists at a price strictly higher than* 50.

PROOF:

Formally, a competitive equilibrium exists in the system if and only if there is a price p^e at which total excess demand $[D(p) = \Sigma Q_i(p)$, where $Q_i(p)$ is an individual excess demand$]$ has a value of 0, $D(p^e) = 0$. For every i, since all subjects are risk averse, $Q_i(50) = 20 > 0$ and $Q_i(+\infty) < 0$, and $D(50) > 0$ and $D(+\infty) < 0$.

The continuity of $Q_i(p)$ implies the continuity of $D(p)$, which in turn implies that there exists p^* such that $50 < p^* < +\infty$ and $D(p^*) = 0$.

LEMMA B2: (S = 0) *If there are no risk-seeking subjects in the system then under the conditions on the preferences and identical initial endowments a competitive equilibrium always exists. Equilibrium price is higher than* 50 *if* A > N *and equal to* 50 *otherwise.*

PROOF:

For the risk-neutral subjects the excess demand function takes values in the interval from −20 to +20 ($Q_i(50) = [-20; 20]$). For the risk-averse subjects $Q_i(50) = 20$. Thus at price $p = 50$ the total excess demand correspondence is equal to the interval $[d_1; d_2]$. That is $D(50) = [d_1; d_2]$, where $d_1 = -20\text{N} + 20\text{A}$ and $d_2 = 20(\text{A} + \text{N})$. If A > N then $0 < d_1 < d_2$ and the proposition is reduced to the Lemma B1. If A ≤ N then $d_1 \leq 0 \leq d_2$. The lemma is proved, since at the price of 50 the total excess demand function has a value of 0 ($0 \in D(50) = [d_1; d_2]$).

PROPOSITION B2: *Under the conditions on preferences, identical initial endowments and* *even number of subjects, a competitive equilibrium always exists. Equilibrium price is lower than or equal to* 50 *if* $S \geq A + N$ *and greater than or equal to* 50 *if* $S \leq A + N$. *Moreover, if* $S > A + N$ *then equilibrium price is strictly lower than* 50.

PROOF:

Notation:

$\Pi = \{p_1, \ldots, p_L\}$ – set points of discontinuity of $D(p)$ ($p_j < 50$ for any j and $L \leq S$) in increasing order. n_j is the number of the individuals whose demand is discontinuous at $p_j \in \Pi$. We need to prove that there exist a p^* such that $D(p^*) = 0$.

Let us note that $D(\infty) < 0$.

First, let us determine the total excess demand $D(p)$ at $p = 50$. By definition $D(p) = \Sigma Q_i(p)$. For the risk-neutral subjects $Q_i(50) \in [-20; 20]$. For the risk-averse subjects $Q_i(50) = 20$. For the risk-seeking subjects $Q_i(50) = -20$. Repeating the similar argument in Lemma B2, at $p = 50$ $D(50) = [d_1; d_2]$ where $d_1 = -20(N + S) + 20A$, $d_2 = -20S + 20(A + N)$.

If $d_2 > 0 (S < A + N)$ then for the two possible cases ($d_1 \leq 0 < d_2$ and $0 < d_1 \leq d_2$) the proof is similar to the proofs of the Lemmas B1 and B2. The equilibrium price is greater than or equal to 50.

If $d_2 = 0$ ($S = A + N$), then 50, there exist multiple equilibria. First, notice that 50 is an equilibrium price.

Second, if the price is above 50 then supply is always greater than demand. Therefore no equilibria exist. On the other hand, if the price falls a little below 50 then demand is still equal to supply. This continues until all risk-seeking people are willing to sell. Therefore there exists an interval $[a; 50]$ of equilibrium prices, where $0 < a < 50$.

Finally, let us consider the case when $d_2 < 0$; i.e., $S > A + N$.

The correspondence $D(p)$ is strictly positive at the price equal to 0 ($D(0) = 20(N + S + A)$), strictly negative at the price equal to 50 ($D(50) = [d_1; d_2]$ and $d_2 < 0$) and has L points of discontinuity at the interval $[0; 50]$. It will be shown that the set of the values of $D(p)$ on the above interval is a set of $S + 1$ consecutive integers from $40K_1$ to $40K_L$, where $K_1 = (N + A + S)/2$ (positive) and $K_L = (A + N - S)/2$ (negative).

Second, let us construct $D(p) = \Sigma Q_i(p)$ for $p \in [0, 50)$. For the risk-averse and risk-neutral subjects $Q_i(p) = 20$ if $p \in [0, 50)$. Thus, the only subjects whose excess demand functions have different values in the interval are risk-seeking ones. For a risk-seeking subject $Q_i(p) = \{20$ if $p < p_j$, -20 if $p > p_j$, 20 or -20 if $p = p_j\}$, where $p_j \in \Pi$. This implies that $D(p)$ is constant in any open interval $(p_j; p_{j+1})$. One may notice that there are $L + 1$ such intervals, since there are L points of discontinuity. Let us denote $D(p) = 40K_j$ if $p \in (p_{j-1}; p_j)$. At $p = p_j$, n_j of risk-seeking subjects are indifferent between +20 and −20. Thus, the total excess demand of those n_j subjects at the price p equal to p_j is the set of $n_j + 1$ integers: $\{20n_j, 20n_j - 40, \ldots, -20n_j\}$. Moreover, the total excess demand of the same n_j subjects is equal to $20n_j$ if p is less than p_j and is equal to $-20n_j$ if p is greater than p_j. The total excess demand of everybody else is constant near p_j. This implies that $D(p_j - \varepsilon) - D(p_j + \varepsilon) = 40(K_{j+1} - K_j) = 20n_j - (-20)n_j = 40n_j$. Thus all K_j can be determined by induction. Formally:

If $p \notin \Pi$; $p_{j-1}, p_j \in \Pi$, $p \in (p_{j-1}; p_j)$ then $D(p) = 40K_j, j = 1 \cdots L$,

where K_j is defined as follows:

$K_1 = (A + N + S)/2$ [Positive integer, since there is an even number of subjects]

$K_{j+1} = K_j - n_j$.

If $p \in \Pi$; $p = p_j$, then $D(p) = \{40K_j, 40(K_j - 1), \ldots, 40K_{j+1}\}$.

Thus at the interval $[0; 50)$ $D(p)$ has the following values:

$40K_1, 40(K_1 - 1), \ldots, 40K_L$, where $K_1 = (A + N + S)/2 > 0$ and $K_L = K_1 - \Sigma n_j = K_1 - S = (A + N - S)/2 < 0$. This implies that one of the values is zero. The proposition is proved.

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