5-2011

Stuffing the Mattress: An Experiment on Risk and Bank Runs

Taylor Kaye Porter
College of William and Mary

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A thesis submitted in partial fulfillment of the requirement
for the degree of Bachelor of Arts in the Department of Economics from
The College of William and Mary

by

Taylor Kaye Porter

Accepted for HONORS
(Honors)

Lisa R. Anderson (Economics), Director

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In some aspect, every person you meet shapes the work you do and the milestones you complete. Understanding that this list could be endless, I respectfully acknowledge:

- Professor Lisa R. Anderson, the single most important person throughout this endeavor and my academic career. My lessons from you far exceed the classroom. Thank you for accepting me as a student, research assistant, and occasional dinner guest.
- Charles G. Koch Charitable Foundation, whose generous financial support allowed this project to be carried out to its full capacity. Words cannot express the gratitude I have.
- James Monroe Scholar Program, whose initial grant investment was the catalyst for an idea to become a three year (or more!) academic research topic.
- Mr. and Mrs. Peter Atwater, Mr. Samuel Ozeck, and Reverend James Pratt, for believing in the possibility of this project and financially supporting its continuation.
- Kitty Rubertus, for telling me that I was always right, even when I most certainly was not. Thank you for the thousands (read: millions) of supportive calls and hugs.
- DP and Charlyn Porter, for helping to raise one tough girl with an insatiable desire to travel and a (growing) attempt at style. You encourage me to only ever accept "no" after exploring all other options.
- My sister, longest friend, and fellow New Yorker, Kelli Anne Porter. "Going 'round the world in a [Red Nissan] pickup truck…[We] ain't goin' down 'til the sun comes up." *Garth Brooks*
- My grandmother, [Nana] Kaye Julian, for living a life that proves every successful businesswoman must have a little "Julia Sugarbaker" in them.
- Professor Beth Freeborn and Professor Katherine Guthrie, two amazing readers whose insightful and thought provoking commentary is much appreciated.
- Ms. Jennifer Bryn Hetrick, there are no words. "For all the times you [stand] by me…for all the joy you [bring] to my life…you [see] the best there [is] in me." *Celine Dion*
- Ms. Alexandra Hoge and Papa Hoge, who each remind me (in their own distinct way) that "if you really want something, you can figure out how to make it happen." *Cher*
- Ms. Hilary Whelan and Ms. Zara Stasi, for keeping me honest and sane. "Before I can live with other folks, I've got to live with myself. The one thing that doesn't abide by majority rule is a person's conscience." *Harper Lee*

- Ms. K. Bailey Thomson and Mr. Brian Focarino, for always holding their heads up and consistently striving for more. “I ain't choose to rhyme, rhymin' chose me.” *Bubba Sparxxx*
- Ms. Katherine Covino, for reminding me daily to “Be who you are and say what you feel because those who mind don't matter and those who matter don't mind.” *Dr. Seuss*
- Mr. John “JZ” Zachary, your work as a research assistant was unparalleled. Thank you for your impeccable work ethic and great sense of humor.

I. Introduction

Economic tumultuousness has been experienced worldwide as a direct result of bank runs. The occurrence of bank runs depends on complex interactions between people and their expectations, as individuals gain information not only through their own private information, but also through the informal observation of others. The interdependent relationship between investors and institutions in a bank run scenario has regained global attention with the ongoing worldwide recession and is exemplified by traditional commercial bank failures, spanning from the U.S. banking crisis during the 1930's to more recent examples today. For example, in July 2008, the Federal Reserve seized California-based IndyMac Bank and closed the $32 billion institution temporarily to prevent a complete run on deposits.

Others events in modern financial history that do not have direct ties to commercial banks have been described as fundamentally similar to a bank run. The weekend failure and subsequent acquisition of the U.S. investment bank Bear Stearns is one of several examples. Bear Stearns lost all immediate liquidity when investors feared its ability to meet its short term debt covenants, including overnight repurchase agreements. The 2007 run on the United Kingdom's Northern Rock, repurchased by Bank of England, is an international example of the same phenomenon.

This experiment, based on the Diamond and Dybvig (1983) model, distinguishes individuals' expectations about other participants' behavior from individuals' expectations about the health of the banking institution. Experimental results suggest that investors, on average, converge to a socially optimal equilibrium. However, some individuals deviate from optimal behavior by withdrawing funds too early. We find that subjects are more sensitive to information around the stability of the banking institution rather than to other participants' behavior. The next section reviews the literature on conformity and bank runs. Sections III and IV describe the model and the experimental design. Section V presents our results and Section VI concludes.

II. Literature Review

Theory

There exists a plethora of literature aimed to address and explain bank runs, nearly all of it stemming from the nucleus, multiple equilibria model that Diamond and Dybvig (hereafter, DD; 1983) created. One feature of interest in the model is that there are two types of investors. One type of investor is impatient in the sense that they gain utility only from withdrawing their assets and consuming immediately. Another type of investor does not have an immediate need for funds and thus may leave assets invested. In one equilibrium, bank runs never occur because depositors withdraw funds only if they need to. In a second equilibrium, bank runs always occur because depositors assume that all others will withdraw their deposits and the bank will become insolvent. This fear perpetuates the run on the bank.

From this core model, research on bank runs has expanded in many directions. Researchers have worked to answer questions around the prevalence, severity, and causes of bank runs, as well as address the policy implications of the effectiveness of deposit insurance in preventing them. Alternatively, other theorists have chosen to focus on the creation and duration of information cascades and herd mentality. Though less specific in context, information cascades examine the tendency of agents to follow an established public pattern, even if their private information conflicts.

Bickhchandani, Hirshleifer, and Welch (hereafter, BHW; 1992) create a model in which agents have private and imperfect information about an event and are required to make public sequential decisions regarding it. BHW (1992) stress the volatility of information cascades by finding that social equilibria can radically shift not only with the arrival of new information, but also if individuals suspect that underlying circumstances may have changed. Cipriani and Guarino (2005) support BHW's findings. They argue that the heightened sensitivity of information cascades to any exogenous variable make it the ideal model for herd behavior as an explanation for excess price precariousness and financial system fragility. Anderson and Holt (1997) also find that cascades occur consistently in the laboratory when other incentives to follow the crowd are minimized.

Building a model closer in form to that of DD (1983), Deng, Yu, and Li (2010) investigate the frequency of bank runs by analyzing three specific interaction factors; the most unique is the interaction neighborhood of agents. By assuming a communication lattice in which one agent is able to communicate openly with four of his cardinally located neighbors, Deng et al. (2010) find that large interactions of neighborhoods could prevent bank runs.

An interesting subset of research withholds the distribution of types from agents. Wallace (1988) extends DD's model with sequential decision making. In doing so, he creates a model in which agents' propensity to consume or invest (more commonly defined as the distribution of types) is withheld from the group of agents. Under such aggregate uncertainty, creating a program to battle such crises of confidence (i.e. deposit insurance) becomes much more complicated and ultimately limits Wallace's conclusions. Wallace concludes that deposit insurance is insufficient in preventing a bank run should individuals be absolutely isolated from one another during the period (1988). Though the isolation restriction limits the significance of Wallace's statistical findings, he argues that isolation must be retained because the alternative does not resemble banking and agents would simply not want to participate in the credit market.

Within existing bank run theory, some models address the determinants of what would make an agent choose to withdraw from a bank. These decisions are oftentimes presented as either a function of other agents' decisions or as a function of asymmetric information about the stability of the banking institution itself. Chen and Hasan (2008) examine the prevalence of panic runs, a phenomenon they define as a bank run triggered by changes in depositors' expectations. They find that the probability of a panic run increases when the prospects of the banking industry are poor and that suspension of convertibility may increase welfare. Dwyer and Hasan (2006) reach the same conclusion using historical bank balance sheet data from a large number of banks in Wisconsin and Illinois; these states exhibit some of the highest bank closure rates due to insolvency. They conclude that suspension of convertibility reduces the probability of a bank run, specifically by 21%.

Experimental Research

Garratt and Keister (2009) base their model off of DD (1983), though their analysis focuses on multiple opportunities for their experimental agents to withdraw assets. Garratt and Keister (2009) argue that multiple opportunities to withdraw more realistically models the decisions investors face daily, namely that depositors will always have a period of time during which they can do so. Garratt and Keister's (2009) model differs from DD (1983) in that agents play a simultaneous-move coordination game, rather than our sequential-move game. This is a crucial difference, as DD (1983) presumes that agents are able to gain information from two sources. The first is their own private information and the second is the observance of the public and sequential decisions of other agents. They find that the possibility for multiple withdrawals are statistically significant in predicting an agent's decision and ultimately leads to a quicker breakdown of trust among agents, creating a run on the bank.

Madies (2006) studies the prevalence of panic-based bank runs; however, also does so using a simultaneous move game, as opposed to a sequential decision game used in our model and others. Madies (2006) does not address information-based bank runs. He finds that a pure-panic run, defined as the equilibrium in DD's (1983) model in which all agents choose to withdraw their assets, is an unusual phenomenon in practice (i.e. there are always some agents who will choose to not withdraw or not-run). Madies (2006) finds no-run agents interesting because, on average, these agents earn no payment over a guaranteed fixed, albeit lower payment, for withdrawing immediately. Two possible explanations from these no-run agents are revealed in post-experiment questionnaire answers. No-run agents admit one of two things: (1) that they did not factor other agents into their decision making process or (2) that they consciously forfeited payment in some rounds in an attempt to show goodwill and prompt others to make a choice that may benefit everyone. Madies (2006) also tests the effect of full and partial deposit insurance and finds that it is easier to stop bank runs than it is to prevent them.

Schotter and Yorulmazer (2008) study the variables that affect the severity of a bank run. By creating a default insolvent bank (i.e. a run is certain to occur), Schotter and Yorulmazer (2008) analyze the effects that specific factors such as private information and deposit insurance have on the outflow of funds. They find that agents with inside information into the quality of the bank tend to withdraw their money later than agents without this inside information. Agents in our model are not informed of the binary "goodness" of the bank, but rather a publicly known probability of failure.

Our model is a hybrid of previous literature, aimed to distinguish the effects of agents' expectations about other agents and agents' expectations about the health of the banking institution. Since information and expectations cannot be controlled with naturally occurring data, the laboratory provides an ideal environment to test this type of model.

III. A Parameterized Bank Run Model

Consider a simple model with two types of agents who have invested money in a bank and must choose when to withdraw it to purchase consumption goods. There are three Type I investors, and they are impatient in the sense that they may get utility from consuming during a particular period, but get nothing from consuming at the end of the period. There are seven Type II investors, and they may get utility from consuming during the period or at the end of the period. Each investor's type is his or her private information. Payoffs are determined by an investor's decision (withdraw funds during the period or wait until the end), by the decisions of other investors, and in some cases by the condition of the bank, which may be good or bad. Decisions are announced publicly and are made in a randomly determined sequence. A run on the bank is defined to be six investors choosing to withdraw funds during the period. Any investors who have not yet made decisions after the 6^{th} withdraw decision necessarily earn nothing.

Payoffs for Type I investors are simple. Given that the bank does not fail, these investors earn $1 for consuming during the period and nothing if they defer consumption to the end of the period or if they cannot withdraw before a bank run occurs. Type II agents also earn $1 by consuming during the period given that a bank run does not occur. As noted above, it takes six withdrawals during a period to render a bank insolvent (i.e. for a bank run to occur).

If a bank run does not occur, Type II players have the potential to earn more money if they defer consumption to the end of the period. This payoff amount depends on the fundamental condition of the bank. In the absence of a bank run, all Type II investors who defer consumption to the end of the period earn $3 if the condition of the bank is good and $0 if the condition of the bank is bad. It is common knowledge that the condition of the bank is good with probability (1-p), and bad with probability (p). This probability is unaffected by the decisions of agents. Hence, the only private information in this model is an agent's type.

The bank may fail in one of two ways in this model: If the condition of the bank is bad, this constitutes a bank failure and all investors who choose to defer consumption earn less money than if they had withdrawn it for consumption during the period. The probability that the bank's condition is good is common knowledge and is independent of investor decisions. Hence, no information about this type of failure is gained by observing the decisions of other investors. However, the second type of bank failure occurs when there is a bank run. This is entirely determined by the decisions of other investors, namely six withdraw decisions in any given period.

Following DD's (1983) analysis, we limit our focus to two interesting equilibria for this experiment: one in which all players expect others to choose according to their type (the socially optimal equilibrium) and one in which all players expect others to withdraw for consumption during the period (the panic run equilibrium). In the socially optimal equilibrium, all three Type I agents consume in period 1 and earn $1, and all seven Type II agents consume in period 2 and earn $3 or $0, depending on the exogenous condition of the bank. The total group payoff is maximized at $24 or $3. In the bank run equilibrium, the first six investors in the queue choose period 1consumption, regardless of type. These six agents earn $1 and all others earn nothing.

It is rational for Type I agents to consume immediately, independent of expectations, since this is the only choice that results in a positive payoff for them. Hence, it is more interesting to consider choices made by Type II agents. Optimal decisions for Type II agents are very sensitive to expectations about what other Type II agents will choose. Patient investors will not withdraw deposits as long as they feel confident that the bank will remain liquid. However, a patient investor who observes many others withdrawing deposits might rationally fear a bank run, and should withdraw his or her own deposits. Hence, the earlier a Type II agent comes in the decision making queue, the more uncertainty that person faces about what others will do.

It is straightforward to analyze expected payoffs for a Type II agent who is the last decision maker in the period, since the only uncertainty comes from the die throw. For example, consider the decision of a Type II agent who observes four people withdraw and five people who do not withdraw, and is the last decision maker in the queue. This person will earn $1 for choosing to withdraw; since fewer than six withdraw decisions have been made in the period. The expected payoff for choosing not to withdraw is $3*(1-p) + $0* (p), implying that it is optimal to not withdraw for any value of p less than or equal to 2/3. Decisions for Type II agents who come at other points in the queue can be analyzed in a similar manner, but the analysis becomes increasingly complicated as the actions of more people must be taken into account.

IV. Experimental Design

320 subjects were recruited in groups of 10 from undergraduate and graduate classes at the College of William & Mary in Williamsburg, Virginia. The sessions lasted approximately one hour and subjects earned an average of $20.23. Because the bank run model includes risk (in the form of the condition of the bank) and uncertainty (in the form of others' decisions), subjects' risk preferences may play a role in decision making. For this reason, our experimental design includes a decision making exercise to measure person-specific risk tolerance.

Risk Preferences

In our model, we measure risk preferences three ways: (1) through a lottery choice economics experiment with real money payoffs designed by Holt and Laury (2002), (2) through a series of survey questions framed around an agent's reaction to various hypothetical scenarios, and (3) through a series of survey questions aimed to measure an agent's frequency of participating in risk-oriented behavior such as wearing a seatbelt or gambling[1]. A copy of the survey questions may be found in Appendix A.

In the Holt and Laury (2002) design, agents make 10 decisions between Option A or Option B. Each option contains two possible payoff amounts with a specific probability associated with each payoff. Option A is a "safer" choice because there is less variance in the payoffs than in Option B. Moving down the list of 10 choices, the payoffs associated with the options are fixed but the probability of receiving the higher payoff in an option increases moving from Option 1 to 2 to 3 etc. For example, in Decision 1, the high payoff is paid if the throw of the ten-sided die is 1 and the low payoff is paid if the throw of the ten-sided die is 2-10. In Decision 2, the high payoff is paid if the throw of the ten-sided die is 1 or 2 and the low payoff is paid if the throw of the ten-sided die is 3-10. By Decision 10, the choice is between amounts of money that are fixed, either the high payoff or the low payoff. A full copy of the Holt and Laury (2002) experimental instructions may be found in Appendix B.

Subjects generally begin by choosing Option A (the safe option) in Decision 1, when the chance of winning the higher Option B payoff is relatively small. The point at which subjects switch from the safe option to the risky option can be used to classify their

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[1] Anderson and Mellor (2008) examine the stability of risk preferences among subjects by comparing measures obtained from the first two elicitation measures. They find that risk preferences are not stable across the majority of subjects and conclude that unobserved variables such as effort may also influence risk preferences. Anderson and Mellor (2008) do note, however, that correlation between survey based risk responses and economics experiment measures may differ depending on the frame of the question (i.e. job based scenarios versus inheritance questions).

risk aversion level. For example, subjects who choose Option A (the safe choice) in the first four decision rows are risk neutral. A risk averse subject will choose Option A more than four times and a risk-seeking subject will choose the safe option fewer than four times.

Subject's decisions in the experiment are used to define a range of values for the coefficient of relative risk aversion (CRRA). In the regression analysis, we use the mid-point of the range for the CRRA. Holt and Laury (2002) report ranges for a utility function of constant relative risk aversion in their paper. Values of $r<0$ indicate risk-seeking preferences, $r=0$ indicates risk neutrality, and values of $r>0$ indicate risk aversion.

All 320 subjects completed the Holt and Laury risk preferences experiment at the beginning of the session[2]. Once subjects completed all 10 decisions, one decision was randomly chosen for payment using a ten-sided die. Subjects kept track of earnings throughout the experiment and were paid after completion of the bank run experiment and the final survey questions.

We follow Anderson and Mellor (2008) in dealing with irrationalities or inconsistent decisions made by subjects. In the Holt and Laury (2002) experiment, Decision 10 is a choice between amounts of money that are fixed, $6.00 for Option A or $11.55 for Option B. 10 subjects (3%) selected Option A in Decision 10, a guaranteed smaller payout in our model, and were thus dropped from the model.[3] In other literature, additional adjustments are made to account for those that choose all "risky" choices, all

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[2] A copy of the instructions that were read aloud and provided to the subjects can be found in Appendix C.
[3] Possible explanations are that the subject did not understand the instructions.

"safe" choices, or who "switched back" to a safe choice after already selecting a risky one. Of the 10 subjects that were already dropped for selecting a guaranteed lower payout in Decision 10, 4 made all "safe" decisions and the remaining 6 "switched back" at least once during the experiment. One additional subject is dropped from our model for selecting all "risky" choices. This brings our observable lottery choice risk preference measures to 309 of our initial 320 subjects.

Bank Runs

After completion of the lottery choice game, subjects were given instructions for the bank run experiment. A copy of these instructions can be found in Appendix C. In 32 sessions, ten subjects served as decision makers in a given session. Each session consisted of 10 periods. In 16 sessions, the ten decision makers were told that there would be 3 Type I and 7 Type II people in each decision making period. In another 16 sessions, the decision makers were not told the number of Type I and Type II agents. A person's type is private and is assigned by shuffling and distributing index cards labeled "Type I" or "Type II" at the beginning of each period. The type-specific payoffs described above are presented to subjects in tabular form and explained at the beginning of the session. Subjects were chosen in a randomly determined sequence to choose either "Take" or "Leave", where "Take" corresponds to withdrawing one's investment and consuming during the period and "Leave" corresponds to deferring consumption to the end of the period. Subjects were not provided this interpretation. Subjects were provided with a record sheet, where they recorded their decision for each decision-making period. The experimenter announced the choices to the group as they were made to prevent volatility in interpretation of individual announcements. For example, it may be possible to gain additional information depending on how each agent verbally speaks his or her decision. At the end of each period without a bank run, the experimenter threw a ten-sided die to determine the condition of the bank. In five periods of each session, the bank's condition was good if the throw of a ten-sided die yielded a 1 through an 8, otherwise it was bad (p=.2). In the remaining five periods of each session, the bank's condition was good if the throw of the die was a fixed range that varied between sessions. Treatment parameters are depicted in Table 1.

Table 1: Treatment Parameters in Bank Run Experiment

Sessions	Distribution of "Types"	Bank Condition: Periods 1-5	# Runs: Periods 1-5	Bank Condition: Periods 6-10	# Runs: Periods 6-10
1-4	Known	0.2	4	0.5	3
5-8	Known	0.2	5	0.6	17
13-16	Unknown	0.2	7	0.5	13
9-12	Unknown	0.2	11	0.6	17
25-28	Known	0.2	5	0.3	5
17-20	Known	0.2	4	0.4	8
29-32	Unknown	0.2	8	0.3	7
21-24	Unknown	0.2	6	0.4	7

Survey

Finally, subjects were asked to complete a survey questionnaire with demographic information, as well as questions regarding reactions for risky scenarios and frequency of actual risky behavior. The survey questions used in this study can be found in Appendix A. The two scenario based risk questions are listed below:

> "Suppose that you are the only income earner in your family. Your doctor recommends that you move because of allergies and you have to choose between two possible jobs. The first would guarantee you an annual income for life that is equal to your parents' current total family income. The second is possibly better

> paying, but the income is less certain. There is a 50-50 chance the second job would double your total lifetime income and a 50-50 chance that it would cut it by a third. Which job would you take – the first job, or the second job?”
>
> “Suppose that a distant relative left you a share in a private business worth one million dollars. You are immediately faced with a choice -- whether to cash out now and take the one million dollars, or to wait until the company goes public in one month, which would give you a 50-50 chance of doubling your money to two million dollars and a 50-50 chance of losing one-third of it, leaving you 667 thousand dollars. Would you cash out immediately or wait until after the company goes public?”

After each question, all subjects were asked two additional questions. One presented more risky options, in which the downside risk associated with the second job or investment was increased to a 50% decline. The other question presented less risky options than the initial scenario, where the downside risk of the second job or investment was a 20% decline.

Principal component analysis[4] was used to create a single factor score for risk preferences in the two described scenarios. Independent variables were the binary choices (risky or safe) that each agent selected between the risky option and the safe option for each scenario. For example, in the first scenario, an agent would be coded as risk-taking if he or she accepted the second job immediately or throughout any of the downside fluctuations. Similar to the lottery choice risk measure, adjustments were made to this measure in consideration of irrationalities or inconsistencies made by agents. Observations were dropped if agents switched from a safe option to a risky option when

[4] We choose to employ principal component analysis in our model as a way to (1) reduce the number of highly correlated variables and (2) estimate the underlying variability among those specific independent variables. Principal component analysis is the methodology of extracting the underlying commonality between a given set of independent variables. Under such methods, each variable is plotted and each scatter plot is rotated to be variance maximizing. The goal of the rotation is to maximize the variance in the new “factor” variable (i.e. to explain as much variation as possible) and minimize the variance around the independent variables.

the amount of risk increased or if agents switched from a risky option to a safe option when the amount of risk decreased. Six variables were used in the creation of the aggregate factor score. Using principal component analysis, these multiple binary choices were combined linearly to create a single variable for risk preferences in qualitative scenarios.

One final risk measure was calculated using principal component analysis of risky behavior specific to each agent. Subjects were asked to rank how often (if ever) they wear a seatbelt in a car, drive over the speed limit, gamble or purchase lottery tickets, and smoke. Again, a factor score of risk aversion for behaviors was calculated. We assume that students accurately and honestly reported their behavior and, therefore, no adjustments were necessary for this measure.

V. Results

DD (1983) analyzed 2 specific equilibria, one in which all investors choose to withdraw assets (a "panic run") and another in which all investors choose to leave assets invested (a "socially optimal equilibrium"). In addition to the equilibria DD (1983) consider, we analyze two other outcomes. We define our third outcome as a "delayed panic run." It occurs when there is a run on the bank even though the first six investors did not all take. We define our fourth outcome as "selectively optimal." This occurs when there is not a run on the bank, though some players act incongruently with their assigned type. More simply, a selectively optimal outcome occurs when there is not a run on the bank and more than 3 subjects choose take. Table 2, below, depicts examples of each type of outcome. A subject's assigned type is listed beneath their participant number and decision. A shaded box indicates that a subject behaved incongruently with their assigned type, while bold merely denotes a subject that was assigned Type I, the role of an impatient investor.

Table 2: Sample Periods of Bank Run Experiment

Session	Period	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	Outcome
2	2 (Type)	S16:T II	S15:T II	S20:T II	S17:T II	S14:T II	S19:T II	. .	. .	. .	. .	Panic Run
2	8	S13:L II	S12:L II	S20:L II	**S11:T I**	**S16:T I**	S17:L II	**S15:T I**	S14:L II	S18:L II	S19:L II	Socially Optimal
8	6	S35:L II	**S39:T I**	S32:T II	S36:T II	**S33:T I**	S31:T II	S40:L II	S37:T II	. .	. .	Delayed Panic
7	1	**S22:T I**	S24:T II	S26:L II	S29:L II	S25:T II	S30:L II	S21:L II	S28:L II	**S27:T I**	**S23:T I**	Selectively Optimal

In our sample, panic runs occurred 20% of the time. As expected, panic runs occurred more when subjects did not know the underlying distribution of types. When the distribution was known, panic runs occurred 14% of the time, while their occurrence increased to 26% when the distribution of types was unknown. It was observed that panic runs typically occurred in earlier rounds or when the probability of the bank failing increased at period 6. The initial uncertainty of how other investors would react prompted subjects to take. In rounds with relatively lower observable risk (i.e. lower probability of bank failure); trust among investors was typically regained, leading to an increase in delayed panic runs or selectively optimal outcomes. In rounds with relatively higher observable risk (i.e. higher probability of bank failure), subjects were unable to regain trust and the panic runs continued.

The socially optimal equilibria occurred most often, 37% of the time. We find that as the probability of bank failure increased, the number of socially optimal equilibria declined. When the distribution of types was known, the sum of the socially optimal equilibria ranged from 23 when the probability of the bank failing was 20-30% to 5 when the probability of the bank failing was 20-60%. Similarly, when the distribution of types was unknown, the sum of the socially optimal equilibria ranged from 18 when the probability of the bank failing was 20-30% to 2 when the probability of the bank failing was 20-60%. We also find a significant difference in the occurrence of socially optimal equilibria when we provide information about the distribution of types. In the unknown treatment, socially optimal equilibria occurred in 28% of the periods, while in the known treatment it occurred in 45% of the periods.

Delayed panic runs and selectively optimal outcomes occurred 20% and 24%, respectively, with little difference between known and unknown treatments. They occur most frequently when subjects are attempting to regain trust, as they transition from a panic run to socially optimum equilibria.

Overall, Type I subjects behaved consistently with theory by choosing take. Thus, differences across periods were driven primarily by the behavior of Type II subjects. Next, we examine the determinants of individual behavior for Type II subjects.

Using simple t-tests for difference of means, we find that Type II subjects who choose to take, on average, have a higher midpoint of the coefficient of relative risk aversion (mid-CRRA), as determined by the Holt and Laury (2002) experiment. More simply, Type II agents that take are significantly more risk averse using Holt and Laury's (2002) risk metric (Type II agents "Leave" = .28, Type II agents "Take" = .35, p-value = 0.00). Similarly, Type II agents that take are significantly more risk averse using our factor analysis metric for risk aversion for hypothetical scenarios (Type II agents "Leave" = -0.24, Type II agents "Take" = 0.87, p-value 0.00). No significant relationship can be determined between Type II agents that take and our factor analysis metric for risk aversion of self-reported behaviors. As previous literature suggests, we also find that women are significantly more risk averse than men in both the Holt and Laury (2002) mid-CRRA metric (male = .25, female = .36, p-value = 0.00).

Table 3 reports the marginal effects from a panel regression analysis using robust standard errors and controlling for random effects.[5] The dependent variable equals one if the participant chose take and zero if not. The marginal effects are calculated holding the continuous variables (order, probability of failure, previous take decisions in a round, total number of previous runs, and various risk measures) at their means and the indicator variables (if there was a run in the immediately preceding round, if the type distribution was known and publicly announced, and female) at zero. The marginal effects for the indicator variables are for discrete changes of the indicator variable from 0 to 1. Coefficients may be interpreted as changes in the probability that a Type II player will choose take. Model 1 controls for the mid-CRRA, as defined by Holt and Laury (2002). Model 2 and Model 3 control for factor score of self-reported risky behavior and factor score of risky qualitative scenario questions, respectively.

As expected, we find subjects who make decisions later in the queue are less likely to take, implying that subjects factor publicly observable information into their decision making processes. As the order increases (i.e. subjects make decisions second,

[5] Running a Breusch Pagan Lagrange Multiplier Test (LM Test) (prob> chi = .05) suggests that random effects is appropriate over standard OLS regression.

third, fourth…), the probability that a Type II player chooses take decreases by 5.5%. Surprisingly, we find the effect of knowing the distribution of types to have little impact on an agent's decision to take. The same is true for sex. Though females, on average, are more risk averse than men, we cannot conclude that they are more likely to take in our bank run experiment after controlling for risk aversion.

Table 3: "Take" Decision by a Type II player as a function of Risk Preferences

	Model 1	**Model 2**	**Model 3**
Order	-0.061	-0.062	-0.062
	(0.000)**	(0.000)**	(0.000)**
Probability of Bank Failure	0.211	0.186	0.184
	(0.001)**	(0.002)**	(0.002)**
# of Previous Take Decisions	0.118	0.121	0.121
	(0.000)**	(0.000)**	(0.000)**
Last Round Run	0.064	0.064	0.063
	(0.003)**	(0.002)**	(0.003)**
# of Previous Runs	0.011	0.014	0.014
	(0.082)	(0.030)*	(0.031)*
Known Distribution of Types	-0.025	-0.016	-0.014
	(0.190)	(0.368)	(0.445)
Female	0.025	0.030	0.030
	(0.156)	(0.095)	(0.085)
Mid-CRRA	0.049		
	(0.034)*		
Risk_Behavior		0.020	
		(0.136)	
Risk_Scenario			0.033
			(0.012)*
Constant	0.181	0.196	0.196
	(0.000)**	(0.000)**	(0.000)**
Observations	2694	2794	2794
Number of Agents	309	320	320

NOTE: Robust p values in parentheses
* significant at 5% level; ** significant at 1% level

A distinguishing feature of our experimental design and model is its ability to separate the effects of an increase in the probability of bank failure from an increase in the probability of a bank run on an investors' decision to withdraw assets. Which matters more: investors' opinions about the bank or investors' opinions about the behavior of other investors? We find that the impact of the probability of failure is far greater in magnitude than the impact of the behavior of other investors. For example, as the probability of failure on the bank increases (from 20-30% or from 30-40%, etc.) a Type II player, on average, is 21% more likely to take. This coefficient decreases slightly when we control for the factor scores of self-reported risky behavior and of risky qualitative scenario questions. As the number of take decisions in a round increases (i.e. from 1 to 2 ‘takes’ or from 3 to 4 ‘takes’), a Type II player, on average, is only 12% more likely to take. This suggests that there may be a stronger relationship between bank runs and the strength of the banking institutions than between bank runs based on others’ decisions[6].

An interesting question to consider is how sensitive investors are to previous bank runs. Which has a larger effect on a Type II player’s decision to take: the total number of previous bank runs or if there was a bank run in the round immediately preceding? We find that the indicator variable for if there was a bank run in the last round has a larger impact than the total number of bank runs in a session. For example, if there was a bank run in the previous round, a Type II player is 6% more likely to choose take in the current round. Alternatively, as the number of previous runs increases from 1 to 2, from 2 to 3, etc., the probability that a Type II player chooses take only increases by 1%. These values remain fairly stable as we control for other risk measures.

Since panic-based bank runs are self-fulfilling, it can be rational for individuals to react to past investor behavior. On the other hand, in our experiment, the probability of a bank failure in any given round is independent of past bank failures. Thus, it is irrational for subjects to take based on the previous bank failures; ultimately a function of prior die

[6] Running an F-test (p-value = 0.00) indicates that the two variables of interest are statistically and significantly different from one another.

throws. Similar to our analysis on how bank runs affect investors, we control for the impact of a dummy variable for the existence of a failure in the round immediately preceding and the impact of the total number of failures leading up to that round. These results can be found in Table 4 and are labeled Model 1 and Model 2, respectively. Similar to Table 3, Table 4 reports the marginal effects from a panel regression analysis using robust standard errors and controlling for random effects. The dependent variable still equals one if the participant chose "take" and zero if not.

We find that both variables of interest have a negative impact on a Type II player's decision to take, though the indicator variable for if a failure existed in the previous round is not significant. As noted above, this is irrational, but consistent with the "Lightening Doesn't Strike Twice" effect, observed in other experiments. As the number of previous failures increase from 1 to 2, 2 to 3, etc., on average, a Type II player is less likely to take by 3%.

Table 4: "Take" Decision by a Type II Player as a function of Bank Failures

	Model 1	Model 2
Order	-0.061	-0.060
	(0.000)**	(0.000)**
Probability of Bank Failure	0.217	0.265
	(0.000)**	(0.000)**
# of Previous Take Decisions	0.118	0.118
	(0.000)**	(0.000)**
Last Round Run	0.059	0.062
	(0.006)**	(0.004)**
# of Previous Runs	0.012	0.011
	(0.071)	(0.095)
Known Distribution of Types	-0.023	-0.016
	(0.228)	(0.409)
Female	0.014	0.017
	(0.430)	(0.347)
Risk_Scenario	0.019	0.017
	(0.153)	(0.202)
Mid-CRRA	0.043	0.043
	(0.065)	(0.064)
Risk_Behavior	0.021	0.023
	(0.109)	(0.091)
Last Period Failure	-0.022	
	(0.240)	
# of Previous Failures		-0.032
		(0.003)**
Constant	0.188	0.180
	(0.000)**	(0.000)**
Observations	2694	2694
Number of Agents	309	309

NOTE: Robust p values in parentheses
* significant at 5% level; ** significant at 1% level

VI. Discussion and Conclusion

DD (1983) consider two potential equilibria, one in which all investors withdraw their assets and another in which all investors do not withdraw. The majority of our periods are characterized by one of these equilibria. Panic runs occurred 20% of the time and socially optimal equilibria occurred 37% of the time. We observed "delayed runs" 20% of periods, defined as a bank run when the first six subjects did not choose take. We also observed "selectively optimal" outcomes 24% of periods, defined when a bank run does not occur, but some subjects act incongruently with their assigned type.

To better understand individual behavior, we collect information on risk preferences and we find risk aversion to be positively associated with choosing take, even after controlling for other investors' behavior and the condition of the bank. Our experimental results also suggest that an investor is much more sensitive to a bank's fundamental stability condition than to other depositors' behavior.

It is unlikely in practice that an investor will receive a simplified one-shot piece of information around the probability that a bank or security will fail. Thus, an interesting topic for future research in this field is a study that addresses how investors process more information about the bank's condition.

Our model also considers how long investors retain information. Do subjects accumulate information over time while observing the number of bank runs and bank failures? Or do results from a previous round outweigh this aggregate information? In reference to bank runs, we find that subjects are more likely to withdraw if there is a run in the round immediately preceding than if there was an increase in the total number of bank runs.

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Appendix A: Survey Questions

Instructions

ID Number:

At this time, we would like all participants to complete this survey. All information provided in this survey will be treated as confidential and cannot be used to identify individual participants. We will not ask for your name, address, or other personal information that can identify you. Please try to complete the entire survey, but you can choose not to answer certain questions if you don't want to, and you can end the survey at any time. All information you provide will be kept confidential.

Please answer the questions by writing your response in the box provided or by marking an **X** over the circle that corresponds to your answer.

In what year were you born?

What is your zip code?

What is your gender?

- Male
- Female

What category best describes your racial and ethnic background?

- White or Caucasian
- Black or African American
- Hispanic
- Asian Asian-American
- Multiracial or other

How often do you wear a seatbelt when driving or riding in a car?

- Always, or almost always
- Most of the time
- Some of the time
- Never, or almost never

If you drive a car, how often do you drive over the speed limit?

- Always, or almost always
- Most of the time
- Some of the time
- Never, or almost never
- Not Applicable; I don't drive a car

How often have you gambled or purchased lottery tickets in the last year?

- Never
- Once or twice
- Between three and twelve times
- More than 12 times

What best describes your religious affiliation?

- None
- Catholic
- Protestant
- Jewish
- Muslim
- Other religion

Do you now smoke cigarettes every day, some days, or not at all?

- Every day
- Some days
- Not at all
- I prefer not to answer this question.

A drink of alcohol is 1 can or bottle of beer, 1 glass of wine, 1 can or bottle of wine cooler, 1 cocktail, or 1 shot of liquor. During the past week, how many days did you have at least one drink of any alcoholic beverage?

○ I prefer not to answer this question.

On the days when you drank, about how many drinks did you drink on average? Type no answer if you prefer not to answer this question.

○ I prefer not to answer this question.

Suppose that you are the only income earner in the family. Your doctor recommends that you move because of allergies, and you have to choose between two possible jobs. The first would guarantee you an annual income for life that is equal to your current total family income. The second is possibly better paying, but the income is also less certain. There is a 50-50 chance the second job would double your total lifetime income and a 50-50 chance that it would cut it by a third. Which job would you take -- the first job or the second job?

- First job
- Second job
- Do not know

Suppose the chances were 50-50 that the second job would double your lifetime income, and 50-50 that it would cut it in half. Would you take the first job or the second job?

- First job
- Second job
- Do not know

Suppose the chances were 50-50 that the second job would double your lifetime income and 50-50 that it would cut it by twenty percent. Would you take the first job or the second job?

- First job
- Second job
- Do not know

Suppose that a distant relative left you a share in a private business worth one million dollars. You are immediately faced with a choice -- whether to cash out now and take the one million dollars, or to wait until the company goes public in one month, which would give you a 50-50 chance of doubling your money to two million dollars and a 50-50 chance of losing one-third of it, leaving you 667 thousand dollars. Would you cash out immediately or wait until after the company goes public?

- Cash out
- Wait
- Do not know

Suppose that waiting a month, until after the company goes public, would result in a 50-50 chance that the money would be doubled to two million dollars and a 50-50 chance that it would be reduced by half, to 500 thousand dollars. Would you cash out immediately and take the one million dollars, or wait until the company goes public?

- Cash out
- Wait
- Do not know

Suppose that waiting a month, until after the company goes public, would result in a 50-50 chance that the money would be doubled to two million dollars and a 50-50 chance that it would be reduced by twenty percent, to 800 thousand dollars. Would you cash out immediately and take the one million dollars, or wait until after the company goes public?

- Cash out
- Wait
- Do not know

Appendix B: Lottery Choice Experiment Instructions

You will be making choices between two lotteries, such as those represented as "Option A" and "Option B" below. The money prizes are determined by throwing a ten-sided die. Each outcome, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, is equally likely. Thus if you choose Option A, you will have a 1 in 10 chance of earning $6.00 and a 9 in 10 chance of earning $4.80. Similarly, Option B offers a 1 in 10 chance of earning $11.55 and a 9 in 10 chance of earning $0.30.

Decision	Option A	Option B	Your Choice Circle One
1st	$6.00 if the die is 1 $4.80 if the die is 2 - 10	$11.55 if the die is 1 $0.30 if the die is 2 - 10	**A** or **B**

Each row of the decision table contains a pair of choices between **Option A** and **Option B**.

You make your choice by circling either "A" or "B" in the far right hand column of the table. Only one option in each row (i.e. for each Decision) can be circled.

Decision	Option A	Option B	Your Choice Circle One
1st	$6.00 if the die is 1 $4.80 if the die is 2 - 10	$11.55 if the die is 1 $0.30 if the die is 2 - 10	**A** or **B**
2nd . .	$6.00 if the die is 1 - 2 $4.80 if the die is 3 - 10	$11.55 if the die is 1 - 2 $0.30 if the die is 3 - 10	**A** or **B**

Even though you will make ten decisions, **only one** of these will end up being used. The selection of the one to be used depends on the throw of a ten-sided die. No decision is any more likely to be used than any other, and you will not know in advance which one will be selected, so please think about each one carefully. The first throw of the ten-sided die fixes the row (i.e. the Decision) that will be used to determine your earnings. For example, suppose that you make all ten decisions and the throw of the die is 9, then your choice, A or B, for decision 9 below would be used and the other decisions would not be used.

Decision	Option A	Option B	Your Choice Circle One
. . 9th	$6.00 if the die is 1 - 9 $4.80 if the die is 10	$11.55 if the die is 1 - 9 $0.30 if the die is 10	**A** or **B**

After the random die throw fixes the Decision row that will be used, we need to make a second die throw to determine the earnings for the Option you chose for that row. In Decision 9 below, for example, a throw of 1, 2, 3, 4, 5, 6, 7, 8, or 9 will result in the higher payoff for the option you chose, and a throw of 10 will result in the lower payoff.

Decision	Option A	Option B	Your Choice
9th	$6.00 if the die is 1 - 9 $4.80 if the die is 10	$11.55 if the die is 1 - 9 $0.30 if the die is 10	**A** or **B**
10th	$6.00 if the die is 1 - 10	$11.55 if the die is 1 - 10	**A** or **B**

For decision 10, the random die throw will not be needed, since the choice is between amounts of money that are fixed: $6.00 for Option A and $11.55 for Option B.

Making Ten Decisions: At the end of these instructions you will see a table with 10 decisions in 10 separate rows, and you choose by circling one choice (A or B) in the far right hand column for each of the 10 rows. You may make these choices in any order.

The Relevant Decision: One of the rows (i.e. Decisions) is then selected at random, and the Option (A or B) that you chose in that row will be used to determine your earnings. Note: Please think about each decision carefully, since each row is equally likely to end up being the one that is used to determine payoffs.

Determining the Payoff: After one of the decisions has been randomly selected, we will throw the ten-sided die a second time. The number is equally likely to be 1, 2, 3, ... 10.

This number determines your earnings for the Option (A or B) that you previously selected for the decision being used.

Instructions Summary

To summarize, you will indicate an option, A or B, for each of the rows by circling one choice in the far right hand column.

Then the throw of a ten-sided die fixes which row of the table (i.e. which Decision) is relevant for your earnings.

In that row, your decision fixed the choice for that row, Option A or Option B, and a final throw of the ten-sided die will determine the money payoff for the decision you made.

DECISION SHEET

Decision	Option A	Option B	Your Decision Circle One
1	$6.00 if the die is 1 $4.80 if the die is 2-10	$11.55 if the die is 1 $0.30 if the die is 2-10	**A** or **B**
2	$6.00 if the die is 1 -2 $4.80 if the die is 3-10	$11.55 if the die is 1-2 $0.30 if the die is 3-10	**A** or **B**
3	$6.00 if the die is 1-3 $4.80 if the die is 4-10	$11.55 if the die is 1-3 $0.30 if the die is 4-10	**A** or **B**
4	$6.00 if the die is 1-4 $4.80 if the die is 5-10	$11.55 if the die is 1-4 $0.30 if the die is 5-10	**A** or **B**
5	$6.00 if the die is 1-5 $4.80 if the die is 6-10	$11.55 if the die is 1-5 $0.30 if the die is 6-10	**A** or **B**
6	$6.00 if the die is 1-6 $4.80 if the die is 7-10	$11.55 if the die is 1-6 $0.30 if the die is 7-10	**A** or **B**
7	$6.00 if the die is 1-7 $4.80 if the die is 8-10	$11.55 if the die is 1-7 $0.30 if the die is 8-10	**A** or **B**
8	$6.00 if the die is 1-8 $4.80 if the die is 9-10	$11.55 if the die is 1-8 $0.30 if the die is 9-10	**A** or **B**
9	$6.00 if the die is 1-9 $4.80 if the die is 10	$11.55 if the die is 1-9 $0.30 if the die is 10	**A** or **B**
10	$6.00 if the die is 1-10	$11.55 if the die is 1-10	**A** or **B**

Result of first die throw (to determine Decision): ___________

Result of second die throw (to determine payoff): ___________

Payoff: ___________

Appendix C: Bank Run Experiment Instructions

Instructions

This is an experiment in the economics of decision making. In this experiment, you will be asked to make one decision, either Take or Leave, in each of 10 decision making periods. Your payoff will be determined by your decision, by the decisions of others, and by chance. Look at the decision sheet that follows. At this time please record your identification number (from the index card you were given at the beginning of the session) in the space labeled "Your ID Number" at the top of your record sheet. Each row on the sheet corresponds to a different period. We will sequentially ask you to choose Take or Leave. The order of decisions will be determined randomly.

You have each been assigned a letter, A through J, and we will draw letters from a cup (without replacement) to determine the order in which you make decisions in a period. Your letter is written on a card taped to the storage compartment above your desk. At this time please record your letter in the space labeled "Your Letter" at the top of your record sheet. When we draw your identification letter, please record your decision, "T" for take or "L" for leave in the appropriate space on your record sheet. For example, if your letter is drawn 1st, you should record your decision in the column labeled "1st". When you record your decision, please circle it to distinguish it from the decisions of others. When your letter is drawn, we will come to your desk and announce your decision to the group. Please remain quiet while decisions are being announced. You should also record the decisions of the other players as they are announced in the set of columns labeled 1st through 10th, moving from left to right across your record sheet.

Payoffs

At the beginning of each period, you will be given an index card labeled either "TYPE 1" or "TYPE 2". When you are given the index card at the beginning of the period, please record your type (1 or 2) in the space labeled "Your Type" on your record sheet. The type cards will be collected, shuffled and randomly redistributed each period. *There will be 3 TYPE 1 players and 7 TYPE 2 players each period.* Your type determines your possible earnings for the period. Table 1 shows earnings for TYPE 1 players. TYPE 1 players earn $1 for choosing Take and $0 for choosing Leave.

Table 2 shows possible earnings for TYPE 2 players. Notice that the relevant row in the table depends on the total number of Take decisions made in a period and the roll of a ten-sided die. If you choose Take, your receive $1. If you choose Leave your payoff depends on how many people choose Take in the period and on the throw of a 10-sided die. If fewer than 6 people choose Take in any given period, the payoff for choosing Leave is determined <u>at the end of the period</u> in the following manner: First, a ten-sided die is rolled. If the outcome is 1 through 8, you receive $3. If the outcome of the die roll is 9 or 10, you receive $0. Note that the roll of the 10-sided die is only relevant for TYPE 2 players who choose Leave.

If 6 people choose Take, the period ends for TYPE 1 players and TYPE 2 players with the 6th person's Take decision. At that point, everyone who chose Take (including the 6th person) receives $1 for the period. Any person who chose Leave or who did not get to make a decision in the period receives $0 for the period.

All players should record the result of the die throw, earnings for the period and cumulative earnings at the end of each period.

TABLE 1: TYPE 1 EARNINGS

Your Decision	Your Payoff
Take	**$1**
Leave	**$0**

TABLE 2: TYPE 2 EARNINGS

<table>
<tr><th>Your Decision</th><th colspan="2" rowspan="2"></th><th>Your Payoff</th></tr>
<tr><td>Take</td><td>$1</td></tr>
<tr><td rowspan="4">Leave</td><td>Number of Take Decision</td><td>Result of Die Throw</td><td></td></tr>
<tr><td rowspan="2">Less Than 6</td><td>1-8</td><td>$3</td></tr>
<tr><td>9 or 10</td><td>$0</td></tr>
<tr><td>6</td><td></td><td>$0</td></tr>
</table>

Your ID Number_______

Your Letter _______

Decision Sheet

Period	Your Type (1 or 2)	Decisions (T for Take or L for Leave) 1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Result of Die Throw (1- 10)	Your Earnings	Cumulative Earnings
														$0.00
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

TABLE 1: TYPE 1 EARNINGS

Your Decision	Your Payoff
Take	**$1**
Leave	**$0**

TABLE 2: TYPE 2 EARNINGS

<table>
<tr><th>Your Decision</th><th colspan="2" rowspan="2"></th><th>Your Payoff</th></tr>
<tr><td>Take</td><td>$1</td></tr>
<tr><td rowspan="4">Leave</td><td>Number of Take Decision</td><td>Result of Die Throw</td><td></td></tr>
<tr><td rowspan="2">Less Than 6</td><td>1-3</td><td>$3</td></tr>
<tr><td>7 -10</td><td>$0</td></tr>
<tr><td>6</td><td></td><td>$0</td></tr>
</table>

TABLE 1: TYPE 1 EARNINGS

Your Decision	Your Payoff
Take	**$1**
Leave	**$0**

TABLE 2: TYPE 2 EARNINGS

<table>
<tr><th>Your Decision</th><th></th><th></th><th>Your Payoff</th></tr>
<tr><td>Take</td><td></td><td></td><td>$1</td></tr>
<tr><td rowspan="4">Leave</td><td>Number of Take Decision</td><td>Result of Die Throw</td><td></td></tr>
<tr><td rowspan="2">Less Than 6</td><td>1-4</td><td>$3</td></tr>
<tr><td>5 -10</td><td>$0</td></tr>
<tr><td>6</td><td></td><td>$0</td></tr>
</table>

TABLE 1: TYPE 1 EARNINGS

Your Decision	Your Payoff
Take	**$1**
Leave	**$0**

TABLE 2: TYPE 2 EARNINGS

<table>
<tr><th>Your Decision</th><th colspan="2" rowspan="2"></th><th>Your Payoff</th></tr>
<tr><td>Take</td><td>$1</td></tr>
<tr><td rowspan="4">Leave</td><td>Number of Take Decision</td><td>Result of Die Throw</td><td></td></tr>
<tr><td rowspan="2">Less Than 6</td><td>1-5</td><td>$3</td></tr>
<tr><td>6 -10</td><td>$0</td></tr>
<tr><td>6</td><td></td><td>$0</td></tr>
</table>

TABLE 1: TYPE 1 EARNINGS

Your Decision	Your Payoff
Take	**$1**
Leave	**$0**

TABLE 2: TYPE 2 EARNINGS

Your Decision			Your Payoff
Take			**$1**
Leave	**Number of Take Decision**	**Result of Die Throw**	
	Less Than 6	1-6	**$3**
		7 -10	**$0**
	6		**$0**