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A Classroom Financial Market Experiment

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Abstract

This computerized web experiment immerses students in an environment where they are in the role of bank managers, complementing existing experiments in which they act as depositors. The experiment is programmed to run on a variety of devices, including student's phones and is suitable for use in intermediate macroeconomics or money and banking courses. Students learn the basic elements of bank balance sheets, the tradeoffs a bank makes when it hedges against liquidity risk, and the macroeconomic implications of the network aspects of the banking system. Key parameters are chosen by the instructor, and all results are saved as a spreadsheet data file. Early trials show that a team's performance is positively correlated with its success in managing interbank deposits.

1. Introduction

This is an exciting time to be teaching undergraduate macroeconomics. The Great Recession has generated intense political and economic controversy. Students are very motivated to study macroeconomics and they wonder about the financial crisis and its role in creating the recession. Undergraduate instructors are now faced with a dilemma. The financial, behavioral and balance-sheet elements of recessions have not been a traditional focus of business cycle models at the undergraduate level. Graduate level models incorporating these issues are difficult to translate into intermediate level macroeconomics or money and banking courses. As a result, undergraduate textbooks appear disturbingly schizophrenic. The formal models presented are of the traditional monetary and fiscal policy sort including AD/AS and IS/LM. These models are manipulated and examined at a high level of proficiency. By contrast the financial, behavioral and balance-sheet aspects of the financial crisis are presented in a descriptive manner. These elements are not combined in any comprehensive model or even as a series of models.[1]

Our goal is to bridge the gap between graduate level theory and undergraduate pedagogy by using an experiment incorporating key elements of the financial sector including behavioral and balance-sheet considerations. Our experiment is effectively a model of a financial sector with a network of banks but without graduate level math. The experiment combines three theoretical elements: the Diamond-Dybvig model; banking networks; and inter-bank deposits. There is implicitly a central bank acting as lender of last resort. Other classroom banking experiments include those of Hester (1991), Cameron (1997), Laury and Holt (2000), Hazlett (2003), Balkenborg, Kaplan, and Miller (2011), Kassis, Hazlett and Battisti (2012).[2]

The new experiment differs from existing banking and bank run experiments:

- Banks can hedge aggregate liquidity via interbank deposits.
- Vulnerability of the system to financial shocks is endogenous, in that banks can choose (or not) to mutually insure each other against external liquidity shocks.
- The networked experiment is extremely flexible with respect to hardware requirements and can be run on students' mobile phones.

Instructors can set key parameters in the experiment via a parameter setup screen. The experiment runs via a web browser interface on a server at the University of Alaska Experimental Economics Lab. Instructors can track team choices and equity value in real time. Experiment results are saved in a spreadsheet file which can be analyzed later.

For a class of 40 students the experiment can be run and students debriefed in about 60 minutes, assuming the class has been previously taught the basics of bank balance sheets. The only constraint on class size is the capacity of the nearest web access point. By comparison, Hester's computerized simulation of bank portfolio management ran over eight weeks and required teaching assistants to play the role of a central bank and assist students with the technical aspects of the simulation.

[1] Araujo, O'Sullivan and Simpson (2013) summarize and discuss the current approaches in intermediate macroeconomics texts.

[2] *Veconlab* at the University of Virginia maintains a menu of internet instructional experiments including bank run experiments: http://veconlab.econ.virginia.edu/admin.htm

The source code is available under a GPL 3.0 license, which essentially grants permission to use, modify, and distribute the code for any purpose as long as the modified source code is also available for other users.[3]

2. Experiment Design

The experiment's design is based on Allen and Gale's (2007) extension of Diamond and Dybvig's (1983) model of a bank run, which examines the importance of the network structure of interbank deposits in the context of liquidity shocks and potential contagion. The experiment is also consistent with Gorton's (2010) characterization of shadow banking liquidity problems as the cause of the recent financial crisis.

The experiment reinforces students' comprehension of banking behavior and terms such as: bank equity/capital; bank reserves; asset management; depositors; equilibrium; liquidity and risk. It raises the question of what constitutes money and whether malfunctioning interbank credit can be as economically damaging as shocks to traditional M1 and M2.

Students learn to manage a bank within a financial sector that has a particular industrial organization. The links between banks are to some degree endogenous since teams have discretion as to whether to establish credit relations with another bank.

Successful performance in the experiment is a function of a team's management of interbank deposits in a stochastic environment. The optimal management of these deposits depends on coordination with assigned partner banks to manage risk that arises from random behavior by bank depositors.

Banks in this experiment do not go bankrupt since a central bank will cover deposit shortfalls via loans.[4] So a bank run in the sense of a panic is not a feature of the experiment. Bank equity is the measure of performance. Teams can go into negative equity.

All interest rates are exogenous parameters set by the instructor. Students can only choose quantities when they allocate assets. The central bank is not managed by students, it supplies needed liquidity at a penalty discount rate. The banking framework in the experiment is generic enough to serve as a metaphor for the shadow banking system. Students learn to think about their local banking network as a system with the interbank relationships at the core of what can go right or wrong. The external world (as represented by bank depositors) is an exogenous factor.

[3] *Vcweb* (a Virtual Commons project) is the framework for developing the experiment. It is based on the *Django* Python web application framework. The jQuery Mobile library provides client-side UI features tailored to mobile devices.

[4] This is a pedagogical necessity. From one author's prior experience students react strongly against being shut out of the activity halfway through an experiment if their bank goes bust.

The environment of this experiment differs from the standard bank run experiment. Panicking bank customers pose a challenge for liquidity management, but the networked structure of interbank deposits provides opportunities for addressing this challenge. Whether there is adequate aggregate liquidity in the system is a parameter choice of the instructor. The message of the experiment is closer to the Gorton view that financial sector problems arise from within the sector due to the management of a form of private money, interbank deposits.

3. The Experiment Protocol

Student teams manage banks in a three-period decision setting. Students have to decide how to respond to the behavior of *depositors*, who may be impatient (patient) and demand funds in period two (three) by managing assets on their balance sheet. Depositors are computer programs, not real people, and their levels of patience are determined by random draws that can be flexibly parameterized by the instructor. The baseline parameters follow Allen and Gale (2007); it is equally likely that 25% or 75% of the depositors will be patient with the larger (smaller) number of impatient depositors reflecting recession (normal) economic conditions in the banks region.

Students are first placed in teams of two or three. Teams must be assigned in multiples of four since banks operate in groups/networks of four.[5] Each network operates independently of events in the other networks. In our pilot runs teams are not allowed to communicate although this would be an interesting potential treatment.

The network structure and protocol follows Allen and Gale (2007), omitting the possibility of bankruptcies or a run on banks by depositors. This protocol maintains the Allen and Gale scenario of potentially having aggregate demand for liquidity exceeding aggregate supply, with consequent heavy losses in the financial sector as banks are forced to make forced sales of corporate loans at a loss. The prospect of inadequate liquidity is endogenous with the baseline parameters, insofar as the banking system can protect itself against losses by always keeping a sufficient buffer of liquid assets (cash and/or bank deposits) in period two.

Teams are given a set of instructions that detail the nature of the task, their objectives and the reward system and specific parameters which include bank size, network structure, interest rates, and probability of liquidity shocks:[6]

- They will be managing a bank via its balance sheet.
- Their objective is to maximize their shareholders' *equity* at the end of the last round. Each round is independent, so maximizing equity (also called *bank capital*) is equivalent to maximizing profit for the bank over the course of the individual rounds.
- The session is conducted with full information; teams are told the values of all relevant parameters including, of course, interest rates and the probability of impatient depositors in period two.

[5] A map of a typical arrangement of networks is shown in Diagram One in the Appendix.

[6] A sample instruction sheet is included in the Appendix.

- Profits and losses carry over between rounds except for designated practice rounds at the start of the experiment.[7]
- A reward system is announced. For example, if a team ends the final round with the highest equity each member receives five dollars. Alternatively a team could be chosen at random to receive a reward proportional to its equity.
- The length of the experiment (number of independent rounds) and the length of rounds (in seconds) is disclosed.
- The structure of rounds, each of which is divided into three periods is explained.
- In period one of a round teams make their asset allocation decisions, determining first their interbank deposits, and then the mix of illiquid loans and liquid securities on their balance sheet.
- In periods two and three teams can only observe how their decisions and the decisions of other teams play out given the resolution of uncertainty about the behavior of depositors. At the end of period three they see the profit or loss they made that round and their new level of equity.
- Equity can be negative if a team mismanages the bank.

At the start of each round the bank starts with $100 in deposits. That means the liability side of the balance sheet starts with $100 of deposits and whatever level of equity was carried over from the previous round. The bank will have to return the $100 in deposits over the course of periods two and three. Patient depositors who keep their deposits in the bank through period three will be paid a rate interest that is low relative to returns on bank loans. In period one the bank chooses how to allocate the $100 in deposits on the asset side. Equity is not in play as a tool for the bank to generate profit since bank equity/shares cannot be sold or traded and effectively acts only as a score sheet. Equity is a residual and not a choice variable.

Some depositors turn out to be impatient in period two and demand their money immediately. The bank must repay these depositors even if that ends up decreasing equity to the point where it becomes negative. Negative equity can be interpreted as shareholders having to pay the banks' depositors out of their own pocket. A bank never actually closes down in this experiment, but shareholders can take losses with no downward limit.

The choice alternatives in period one are for banks to split the $100 between cash reserves, corporate loans and interbank deposits. Cash reserves earn no interest in period three but are available to pay depositors if needed in period two. Corporate loans represent business opportunities which will return a high rate of interest to the bank in period three. The disadvantage of these bonds is their illiquidity. If they need to be recalled in period two to meet the demands of impatient depositors they have to be sold at a punitive discount.

The first decision is the amount of the interbank deposit. These are made unilaterally to a partner bank located in the same country (network) and must be accepted by them. This deposit returns a moderate rate of interest in period three and has the advantage that it can be recalled in period

[7] At the instructor's option, practice rounds in which the networked structure is absent and banks operate in isolation are also feasible.

two if necessary to meet the demands of impatient depositors. If bank A anticipates receiving a deposit from bank B it can offset that by making its own unilateral deposit to bank C.

Teams know the relevant interest rates and the penalty rate for discounting corporate loans in the case of a forced sale. There is no credit risk, or possibility of default on corporate loans. However, in every round teams have to decide in period one how to allocate their $100 without knowing how many depositors will be impatient in period two and demand their money back.

Period one ends with the second decision, the allocation of deposits – including interbank deposits received - between loans and cash reserves. The accounts in periods two and three are settled as depositors show up to redeem they money. This happens automatically according to an algorithm that maximizes profits (or minimizes losses) for the individual bank. As impatient depositors show up in period two the system first allocates non-interest bearing cash to settle claims, then recalls loans to the other bank, then finally sells corporate bonds as a last resort. If after all this some unsatisfied depositors are still remaining, the bank's shareholders are forced to reach into their own pockets to pay them back and equity decreases. Reducing equity is the final option after cash reserves, interbank loans, and corporate bond sales are exhausted.

There is an important geographical element to the baseline design parameters with each group of four banks representing a single country with two regions. In the baseline parameters, one region in each country experiences recession and one experiences normal economic conditions. Banks are grouped in regions according to the pattern diagrammed below. Students can be shown, for clarity, a diagram illustrating how banks are connected to each other. **Diagram One** shows a world with four countries. Examples of the student screen are shown in **Diagram Two**. Examples of an instructor's screen as it appears on an Ipad are shown in **Diagram Three.**

In period two, the determination of each regions economic condition is discovered. A recession causes depositors to withdraw cash from banks at a high rate to maintain consumption. Our baseline parameters are such that within a single country the two regions have perfectly inversely correlated economic conditions. So if Region A is experiencing a recession then Region B will be experiencing normal conditions. This inverse correlation generates the potential for a mutually advantageous strategy to hedge liquidity risk. If a bank is located in the region hit by recession a large number of impatient depositors pull out their cash in order to maintain consumption. A bank in the region with normal conditions, on the other hand is perfectly willing to loan money to the bank in the other region since its own depositors will not be withdrawing their cash. This correlation is consistent with the baseline scenario in the Allen and Gale (2007), but may be flexibly altered by the instructor.

Banks know that the other region will have inversely correlated shocks, so interbank lending can make banks in both regions better off through an exchange of deposits that act as a form of insurance. Our pilot experiments also used the baseline probabilities from the Allen and Gale model. Given a 50/50 per cent chance of either a 25 per cent withdrawal in period or a 75 per cent withdrawal, the average will be a 50 per cent withdrawal. A symmetric equilibrium in which optimal mutual insurance occurs, is for each bank to deposit $50 in its partner bank. Half the banks will need only $25 in period two to meet depositor's demands. The other half will need $75.

If the banks cooperate perfectly, insurance will be complete and every bank will make $50 of corporate loans each round generating maximum surplus for the financial sector. The question is, which teams will figure out the optimal strategy? What happens if one team in a network does not, or cuts back on its deposits with its partner banks?

4. Sample Results and Discussion

The experiment was run with students in Principles of Economics, Intermediate Macroeconomics and Money and Banking. The former comprised a broad range of sophomore majors. The latter two included mostly majors in Economics, Accounting, Management and Finance.

The experiment worked well on all types of devices, whether laptops, tablets, Apple or Android smartphones. The only technical difficulty was internet connectivity. In a classroom sharing an access point with many users a student relying on wifi sometimes finds it difficult to connect. A good way to sort students into teams was to require at least one backup device per team. If a team lost their connection to the experiment they could log back in since their bank remained functional but without any proactive asset management. Rounds were set at four minutes although later rounds in an experiment can be shortened as experienced teams need less time to make decisions.

The decisions of a total of 72 banks (18 networks of four banks each) from five classroom sessions make up the dataset in the pilot study. Each bank was comprised of a group of from 2-4 students acting collaboratively as decision makers. Key insights about the data and the opportunities for student learning are gleaned from comparisons of behaviors by low and high earners over the course of the session. Subjects are categorized as low and high earners relative to median earnings within their own session.

When interbank lending is available, the first task is to determine how much to deposit in the partnered bank. In the classroom parameterization for these sessions the average liquidity shock is $50 per bank, or in aggregate, half the deposits in the banking system. The efficient amount for risk neutral institutions to place in long term loans, therefore, is 50 per cent - the amount of bank deposits that are not subject to demand by impatient depositors.

One efficient solution to the problem is a symmetric Nash equilibrium in which each bank deposits $50 in the other region and invests $50 in loans, keeping $50 on hand for depositors. Banks will either recall $25 if they receive the liquidity shock (recession) or will have an extra $25 on hand if they are in the low liquidity demand region (no recession). Thus the interbank deposit system makes the efficient implementation feasible.

High earners mirrored fairly closely the long term loan decisions of the symmetric equilibrium. On average they deposited just over $47 with their counterpart bank in the other region. Low earners deposit less only about $31. Earnings of course, will depend primarily on the

appropriateness of the lending decision, conditional on an adequate liquidity hedge. We see significantly less lending by low earners, however the differences are not as great as in the deposits, a surprising finding given the dramatic difference in earnings.

Figures 1a and 1b help explain the dramatic difference in earnings. The variability of lending is much greater in the group with low earnings, as evidenced by the large standard deviation of loan amounts in Figure 1b. The nonlinear relationship between earnings and lending is made clear in Figure 2 which displays both the individual data points and a quadratic fit of the relationship.

Figure 1a: Loans by round for low (0) and high (1) earning banks

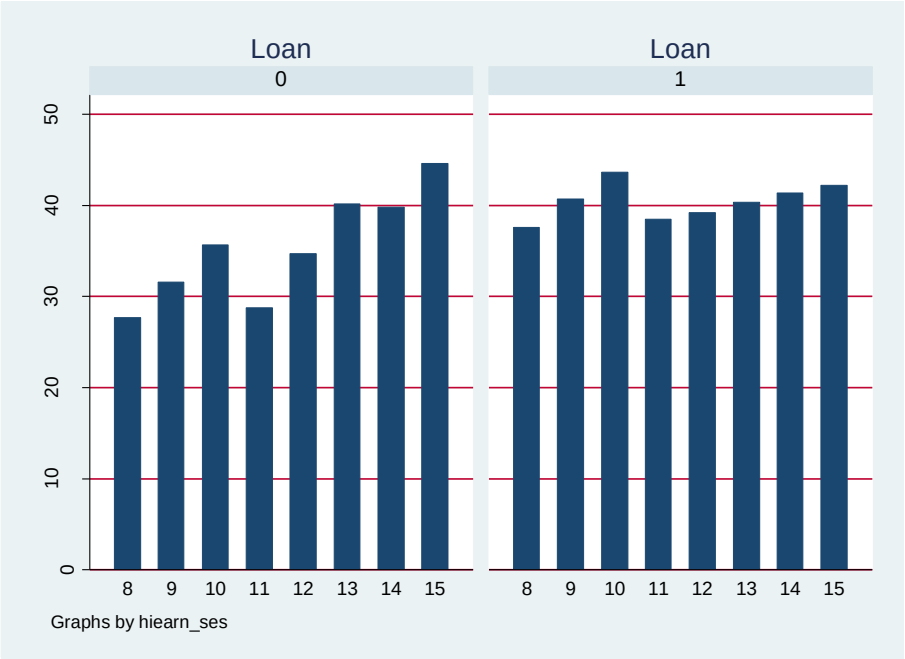

Figure 1b: Standard deviation of loans by round for low (0) and high (1) earning banks

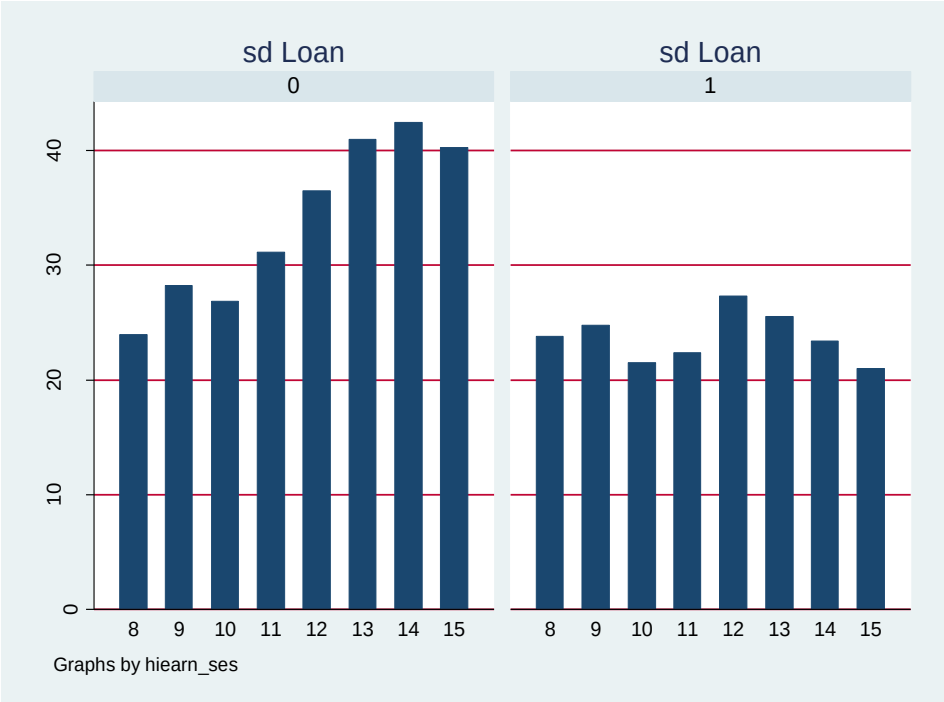

Figure 2: Quadratic fit of lending to earnings

Table 1: Earnings, Deposits, and Loans

	Mean Earnings	Mean Deposit	Mean Loan	N
Low Earners	-104.45	30.19	35.92	36
High Earners	9.41	47.42	44.86	36

Debriefing was conducted in class at the conclusion. The most profitable teams were invited to share their strategies, and the least profitable their mistakes. Students were required to write lab reports, with an option to write an extra-credit paper describing their strategy. The discussion and reports revealed some interesting aspects of the student experience.

The most common strategies were to:

- Make a $75 deposit with the (receiving) partner bank, keeping $25 in cash and using whatever cash the other (depositing) partner bank deposited to make long-term loans. This was a zero-risk strategy with respect to incurring a penalty from insufficient funds to pay impatient depositors.
- Make a $25 deposit with the (receiving) partner bank, keeping $75 in cash and whatever cash the other (depositing) partner bank deposited, then dividing that amount in some way between cash and long-term loans. These tended to be high-risk

strategies, with teams betting that their region would be lucky and avoid regional recessions.

- One team tried to guess the probability of a recession from what had happened the previous round even though they were told recessions and booms were random.
- One team, the most profitable in its session, allowing for interest rate differentials, set its interbank deposit at $94 and used the remaining $6 and whatever cash the depositing partner bank deposited to make loans. They calculated that the gain from holding zero cash going into round two more than offset the potential loss from $6 of long term loans being sold at a large discount (the $6 liability only applied if the depositing partner bank made a deposit of at least $25.) This was a fairly sophisticated strategy because to a large degree it insulated this team from being too greatly affected by the choices of the counterparty depositing bank.
- Some teams did not have a consistent strategy, either because they did not understand the rules, or overreacted to gains and losses in the previous round.

In their lab reports students had to answer a question about "what economic principles does this experiment demonstrate?" Some of the more thoughtful answers included:

- "The experiment illustrates the principle that people will base their actions according to how they think someone else will act. It also illustrates the need for trust in this type of banking system, technically people would be able to insure each other against the risk of impatient borrowers in this experiment but since they do not trust what the other banks are doing this does not happen."
- "This experiment demonstrates how interconnected banks are. When one bank experiences trouble due to a poor balance of illiquid assets and liquid liabilities, the surrounding banks will suffer."
- "The primary principle demonstrated by our experience is the role of uncertainty, expectations, and their relationship with information."
- "This experiment demonstrated the principle of imperfect information. We were not able to see the whole "economy" of banks and what was happening in each region."
- "The experiment, therefore, demonstrated and seemed to test for bank activity with the absence of reserve and capital requirements."
- "Expectations influence behavior."
- "Although this experiment greatly simplified banking institutions, it illustrated their co-dependent relationships."

In his report one student proposed a very interesting variation on the experiment: an increase in bank size based on previous earnings.

5. Conclusion

In this paper we describe a computerized web experiment that immerses students in a banking network. Students act as managers of a bank's portfolio of assets. Banks are linked as part of a network. The experiment has been designed to run on students' smart phones. It is suitable for use in a course in intermediate macroeconomics or a course in money and banking. The experiment bridges the gap between graduate level theory and undergraduate pedagogy by

incorporating network elements of the financial sector as well as behavioral and balance-sheet considerations. Early trials show that a team's performance is positively correlated with its success in managing interbank deposits, consistent with the financial contagion model of Allen and Gale (2000.)

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Appendix

Diagram One

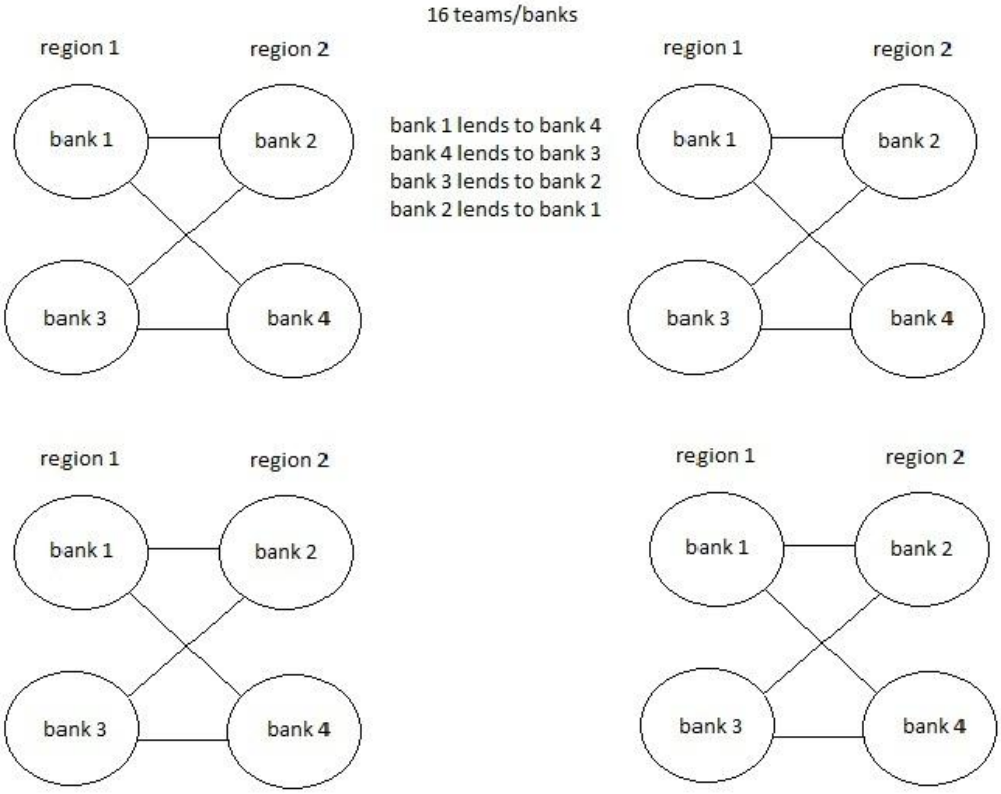
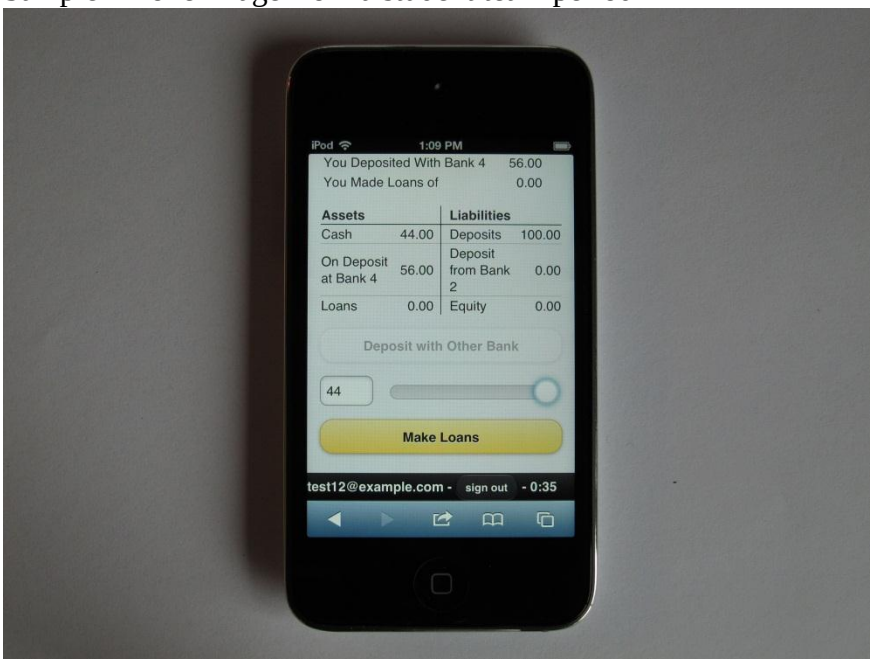


Diagram Two

Sample iPhone image from a student team period 1



Sample Iphone image from a student team period 3

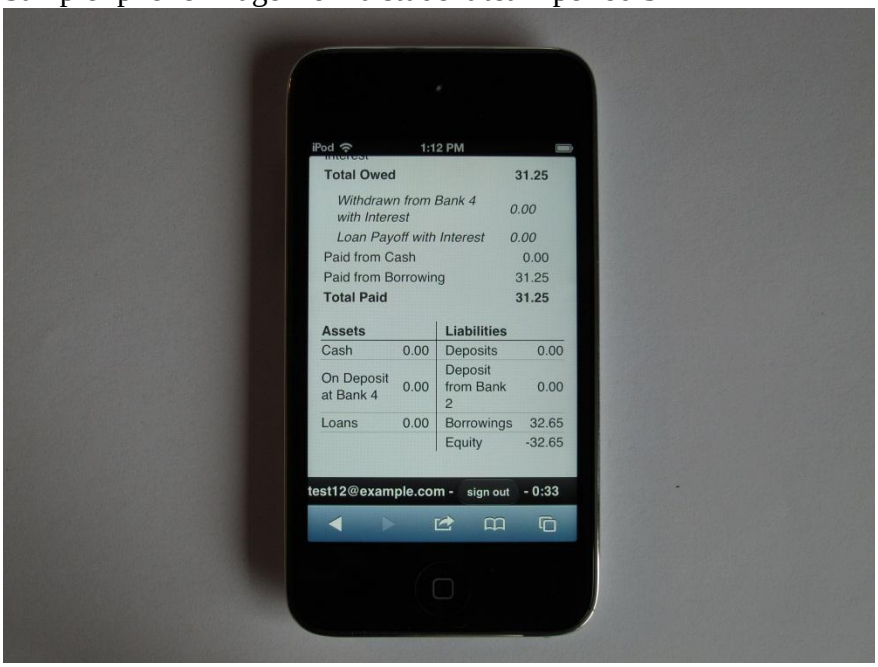
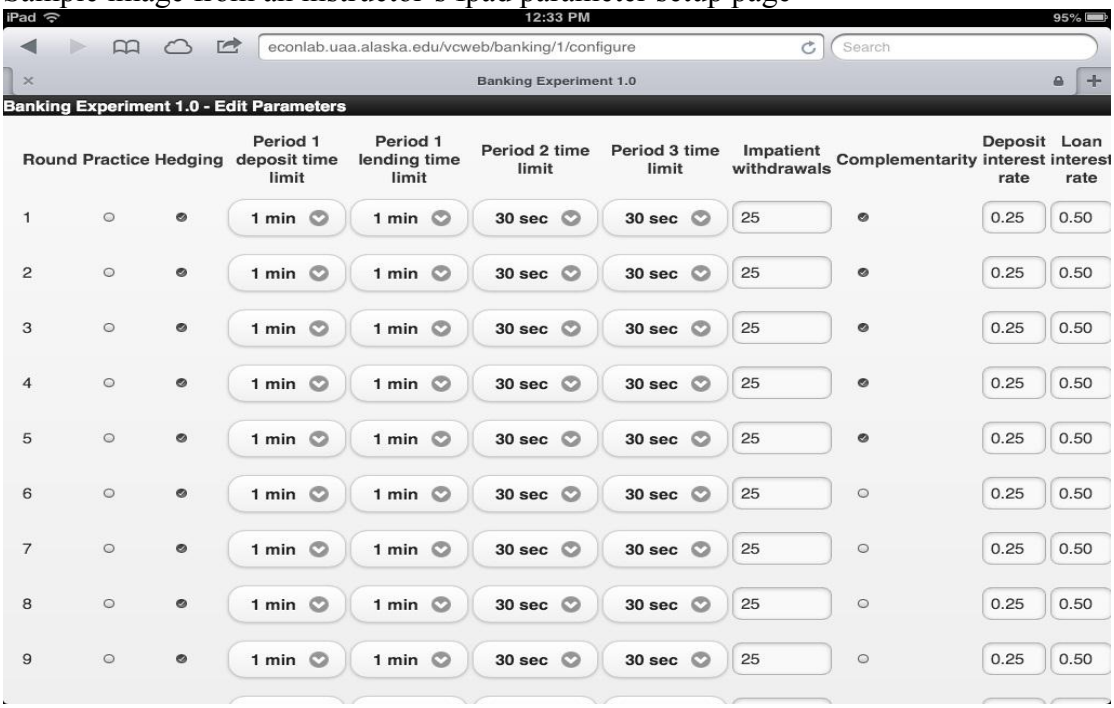
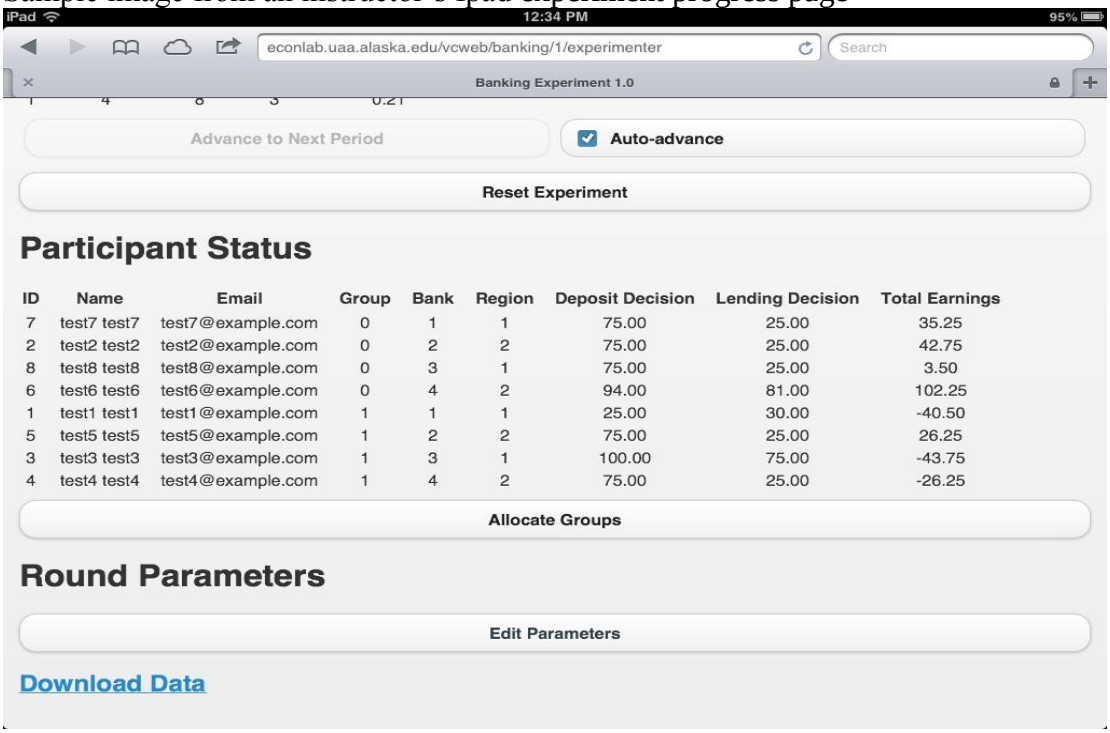


Diagram Three

Sample image from an instructor's Ipad parameter setup page



Sample image from an instructor's Ipad experiment progress page



Sample Team Instructions

You are a bank.

You will participate in trading over a certain number of rounds.

Each round is a repeat of the same situation except that profits and losses carry over and accumulate. If the conditions of the experiment are going to change you will be warned ahead of time.

Within each round there are three periods.

Period one is divided into two stages.

You will be told the time allowed for each period. Periods may be cut short by the instructor with warning first.

In period one stage one you decide how to allocate $100 in customer deposits between making a deposit with a partner bank in a different region of your country and keeping some cash. A deposit in a partner bank allows you to withdraw without penalty in period two if you need it. If you don't need it in period two the deposit will carry over to period three and you will earn interest.

In period one stage two you find out what deposit your other partner bank (also in a different region) made with you. You then choose how much cash you wish to allocate to making a corporate loan that will pay off with interest in period three.

Cash earns zero interest.

In period two you find out how many impatient customers have shown up to withdraw their money. If you do not have enough cash on hand the software automatically draws down your deposit with the partner banks as needed. Then if you still do not have enough cash it automatically liquidates your corporate loans at a discount so you are losing money on the corporate loans.

In period three all interest is paid. You may receive interest from deposits with your partner bank, and corporate loans. Your see your total cumulative profit or loss show up in your equity/capital account.

The software does all the work in periods two and three – you just watch what happens.

You will be told the relevant interest rates before the experiment starts.

You do not get to refuse any deposits from your (other) partner bank in stage one of period one, you must accept it.

Within the same region the same number of impatient depositors will show up in period two.

If there is a recession in a region many customers will withdraw in period two.

Interest rates

Paying patient depositors in period 3: 50%

Paying/receiving interest from another bank in period 3: 25%

Receiving interest from a corporate loan in period 3: 50%

Loss on a corporate loan sold early in period 3: 60%