

Experimental Instructions

Introduction

Welcome to this experiment in economic decision-making. Please read these instructions carefully as you, and the other participants, will have to successfully answer some questions that check your understanding of the material in these instructions before you can proceed on to the study.

The study consists of a number of rounds. Each round consists of three periods: 1, 2 and 3. Each round is independent of all other rounds; your choices begin anew each new round.

For completing this study you are guaranteed a participation payment of ... and you can earn more depending on the decisions that you and other participants make. Specifically, at the end of the experiment your payoffs from k rounds, randomly selected, will be added to your participation payment. Since you do not know which rounds will be chosen, you will want to do your best in every round.

Overview

There are N participants in this study. $N/2$ participants play the role of *bankers* that accept deposits from customers in period 1 of each round, and $N/2$ participants play the role of *accountants* that assess the bank's liquidity and solvency in period 2. Each banker represents one bank and each accountant assesses one bank. The customers are automated robot players as discussed below.

The $N/2$ banks are divided up into two "regions". One half of the banks service customers in Region I while the other half service customers in Region II. Each bank remains in their assigned region for the duration of this study.

While you will only play one role, that of a banker or an accountant, it is important that you understand both roles. Your role as a banker or accountant will be revealed after the completion of the comprehension quiz that follows these instructions. You will remain in the same role as a banker or accountant in all rounds of this study. Each banker will represent the same bank in every round while each accountant will be randomly assigned to one bank at the start of each round.

At the start of each round you are given an endowment of xx points and you can earn additional payoff points. If you are an accountant, your payoff points in each round depend on the accuracy of your assessment of your bank's liquidity and solvency in period 2. If you are a banker, your payoff points in each round depend on the allocations you make of your customer's deposits between Cash and Assets in period 1, the market price for Assets that will be determined by your choices and the choices of other bankers in period 2, as well as your accountant's assessment of whether your bank is **Solvent** or **Not Solvent**.

Bankers and the Market for Assets

Bankers make decisions in periods 1 and 2 of each round. At the beginning of period 1, 100 customers, who are all automated robot players, deposit 1 unit of cash in their bank. Therefore, at the beginning of each round, every banker receives 100 units of deposits from customers. Then, in period 1, each banker has to decide how many of its 100 deposit units to put into assets, the

amount A , with the remaining amount $100-A$ in cash, C . The banker makes this allocation decision by moving a slider bar on the computer screen for the amount A of deposits he/she wants to put into Assets with 100 minus that choice being the amount C of deposits that remain in Cash (with $C = 100 - A$). The banker confirms his/her decision by clicking on a submit button.

Deposits held as Cash earn no interest but are available to meet customer withdrawals of deposits in period 2. Assets, on the other hand, take time to mature. For each unit of deposits that a banker allocates to Assets in period 1, there is a payoff of 2 units (a 100% return) in period 3. Assets **MUST** be held until period 3 in order to earn this return. Moreover, as discussed below, there will be a market among bankers for the buying and selling of Assets in period 2 that all $N/2$ bankers can choose to participate in. The objective of the banker is to ensure that his/her Bank remains Liquid and Solvent as explained below.

Each banker offers their patient customers the right to withdraw their deposit of 1 unit of cash with no interest or return in period 2. They further offer that if their patient customers keep their deposit in their bank until period 3 (the last period of the round), then those customer will get an equal share in the profits earned on the Assets and any cash that the bank holds into period 3, provided that the bank is not illiquid or declared insolvent, as detailed below.

In making their allocation decision, bankers face two kinds of uncertainty. The first concerns the number of customers who are impatient or patient as described in the table below.

State	Region I	Region II
s_1	67 impatient, 33 patient	33 impatient, 67 patient
s_2	33 impatient, 67 patient	67 impatient, 33 patient

There are two “states”, labeled s_1 and s_2 , for the numbers of impatient and patient customers each banker will be dealing with depending on their region. At the start of each new 3-period round, both states are equally likely. Bankers do not learn the state until period 2, but they have to make their allocation of deposits decision in period 1. If they are in Region I (II) and it is state s_1 , then they will have more (less) impatient customers than in region II (I). Symmetrically, if they are in Region I (II) and it is state s_2 , then they will have less (more) impatient customers than in region II (I). Specifically, 67 impatient customers means that they will definitely face a withdrawal of $w = 67$ units of deposits in period 2, while 33 impatient customers means that they will definitely face a withdrawal of $w = 33$ units of deposits in period 2.

Bankers also face a second kind of uncertainty about what their *patient* customers will choose to do. While an impatient customer always withdraws his/her deposit in period 2, a patient customer *may wait to withdraw later in period 3 or choose to withdraw early in period 2 along with impatient customers*. Whether patient customers withdraw later in period 3 or early in period 2 depends on the accountant’s solvency assessment (as explained in the section Accountant below).

At the start of period 2, Bankers know *precisely* the number of their customers who are impatient and who will withdraw their deposits in period 2 (either $w=33$ or $w=67$), but, they don’t know what their patient customers will choose to do. Before any period 2 withdrawals are made, bankers can participate in a centralized market to buy or sell Assets. Each Asset that they sell yields them an immediate payoff in Cash according to the market price for Assets, P . Each Asset a banker purchases yields them a payoff of 2 if held until period 3. For instance, if given the realized state s_1 or s_2 , the banker finds that they have allocated too many deposits to Assets to meet period 2 Cash withdrawal demands, then they can *sell* some of their Assets in exchange for Cash deposits.

On the other hand, if, given the state, they find that they have allocated too little to Assets (and too much to Cash) to incentivize their patient customers to wait to withdraw in period 3, then Bankers can use some of their Cash deposits to *buy* Assets from other bankers.

If a banker chooses to be a buyer of Assets then they decide on the amount of Cash they want to bid, b . That is, they can bid any amount from zero up to the amount of Cash they have available. If they choose to be a seller of assets, then they choose the quantity q of Assets that they want to sell, which can be any quantity from zero up to the number of Assets they own. After all bankers have submitted either quantities of Assets to sell or bids of Cash for Assets, the market price of Assets, P , is determined as follows:

$$P = \frac{\text{Total Amount of Cash Bid by all Bankers}}{\text{Total Units of Assets Offered by all Bankers}}$$

If there is no quantity of Assets offered and/or bids of Cash for Assets in the asset market of period 2, then there is no market price and no exchanges take place.

When all $N/2$ bankers have confirmed their choices in the asset market, the market price for the round is determined by the formula given above for P .

Assuming there is a market price P , then all exchanges take place at that market price, P . If a banker bids b units of Cash, then, after the market, that banker will get b/P Assets that are in addition to the Assets they already had, but will have b less Cash. If they sell q Assets, then after the market, they will have $P \times q$ more units of Cash in addition to the Cash that they already had, but q fewer assets.

The banker's decision screen for the period 2 market for Assets is shown in Figure 1.

In this round, w of your customers are Impatient
Based on your initial allocation, you have A in Assets and 100-A in Cash

You are a buyer:

Amount of cash you want to bid (b)

0
C

OR

You are a seller:

Quantity of assets you want to sell (q)

0
A

Price forecast (P^f)

0.01
5

Based on this information the bank is:

Liquid
Solvent

And your expected payoff is:

Your final choices

b =

OR

q =

P^f =

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Figure 1: Market Decision Screen

At the top of the screen bankers are informed of the number of impatient customers in their region for the current round and how many of deposits the bank holds in Assets A, or in Cash (100-A). Below that is a “sandbox” where, by moving a slider, bankers can experiment with buying or

selling assets that mature in period 3. Bankers must choose one role, to be a buyer or a seller of assets and then submit a bid of cash, b , to buy assets, or a quantity of Assets, q , to sell for cash.

In addition, bankers are asked to move the market price slider to what they forecast the market price, P^f , will be for the round. Given this forecast for the market price P^f , the banker's bid b , or sell quantity q , the computer program will alert bankers as to whether their bank may face a liquidity or solvency problem.

A bank is considered *liquid* if the banker has enough Cash on hand to meet the withdrawal demands ($w=33$ or $w=67$) of its (robot) impatient customers in period 2. That is if $(100 - A) - b \geq w$ for banks, whose bankers buy assets and if $(100 - A) + P \times q \geq w$ for banks, whose bankers sell assets. A bank is considered *solvent* if the banker has enough invested in assets to make the bank's patient customers willing to wait to withdraw their funds in period 3, that is if the banker is likely to be able to offer a payoff higher or equal than 1 to its patient customers. That is if $(100 - A) - b + 2 \times (\frac{b}{P} + A) \geq 100$ provided the banker has chosen to be a buyer, and if $(100 - A) + 2 \times (A - q) + P \times q \geq 100$ provided the banker has chosen to be a seller.

Based on the above conditions, the box "Liquid" will turn to "NOT Liquid" if, given the banker's forecast for the market price, P^f and the buy or sell decision, the banker may be unable to meet withdrawal needs of the bank's w impatient customers in period 2. The box "Solvent" will turn to "NOT Solvent" if, given the banker's forecast for the market price the buy or sell decision, the bank's patient customers are not likely to earn a return greater than 1, and as a result, they withdraw early in period 2 along with the impatient customers. Bankers can adjust their buy or sell decision and/or their market price forecast, P^f to become "Liquid" or "Solvent" or both, at least *in expectation*.

The notifications on the banker's decision screen as to whether or not they are liquid and/or solvent rely on the banker's forecast of the market price, P^f , and not on the actual realization of the market price, P . If the forecast of P^f is incorrect, then the bank could be either not liquid or not solvent or both, regardless of what the decision screen reports. Therefore, it is very important bankers try to accurately forecast the market price P^f . To better incentivize accurate price forecasts, bankers can earn payoff points for forecast accuracy depending on how close their price forecast, P^f , is to the actual market price, P as determined by all participants. Specifically, the banker's points for forecast accuracy are determined by the formula:

$$\text{Forecast points} = \frac{zz}{1 + |P^f - P|}.$$

Notice that the maximum points earned for forecast accuracy is zz and that these points decrease the greater is the absolute value of the difference $|P^f - P|$ between your forecast, P^f and the actual market price, P ; a banker gets the maximum of zz points only if $P^f = P$. The table below shows the forecast points for a sample of possible forecast errors $|P^f - P|$ you could make.

Forecast error $ P^f - P $	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4	0.2	0.0
Forecast points	$\frac{zz}{2.8}$	$\frac{zz}{2.6}$	$\frac{zz}{2.4}$	$\frac{zz}{2.2}$	$\frac{zz}{2.0}$	$\frac{zz}{1.8}$	$\frac{zz}{1.6}$	$\frac{zz}{1.4}$	$\frac{zz}{1.2}$	zz

Remember that, independently of the solvency condition, whether the patient customers will withdraw early will depend on the accountant's assessment of whether your bank is Solvent or NOT Solvent. Whether or not a bank is declared solvent by the accountant will depend on the

banker's choices, the number of impatient customers, the market price and the judgment of the accountant, as explained in the next section. However, the accountant is incentivized to judge the bank *solvent* if he/she believes the bank has enough invested in assets to be able to offer patient customers a payoff greater than 1, that is if the bank satisfies the solvency condition given above.

Each banker will earn payoff points, provided that their bank is liquid and the accountant assigned to that bank declares that the bank is solvent.

If the accountant declares the bank solvent for the round, then the (robot) patient customers are programmed to wait until period 3 to withdraw from the bank. In that case, the banker's own payoff points, equals the payoff earned by each of the patient customers in their bank, which is the bank's period 3 earnings divided by the number of patient customers ($100 - w$). This payoff points depend on whether the banker is a buyer or a seller of assets:

$$\text{Banker's payoff if liquid and accountant declares solvent} = \begin{cases} \frac{(100-A)-b+2\times(\frac{b}{P}+A)-w}{100-w} & \text{if buyer} \\ \frac{(100-A)+2\times(A-q)+P\times q-w}{100-w} & \text{if seller} \end{cases}$$

If the bank is illiquid or if the accountant declares the bank insolvent for the round, then the bank is declared *bankrupt* and the banker earns zero payoff points.

At the end of the study, the computer program randomly chooses k rounds for payment. In c of those rounds, the banker gets the payoff points earned depending on whether their bank is Liquid or Not Liquid and whether the accountant has declared it Solvent or Not Solvent (as described above). In $k - c$ of those k rounds, the banker gets the payoff points earned from forecasting the market price, (up to zz points). These points and the xx endowment for each chosen round are summed up and converted into money at the fixed rate of 1 point = money. These earnings are added to the participation payment and paid in private.

Accountants

Accountants do not make decisions until period 2 of each round. At that time the accountant is informed about their matched bank's initial allocation between assets A and cash ($100 - A$) in period 1, the number of impatient customers the bank faces, w and the market price of assets, P . However, the accountant does not know the amount of assets that the banker may have bought (b) or sold (q) in the market and hence whether or not the banker is actually liquid and/or solvent. The accountant must assess whether the bank is liquid and solvent.

The accountant's decision screen is shown in Figure 2. 2.

The top of the screen shows the banker's initial allocation between assets, A , and cash, $C = 100 - A$, the number of impatient customers the bank faces (w) and the Asset Price, P , for the round. Below that is a "sandbox" with two sliders one corresponding to the banker's buying assets and another to the banker's selling assets. Initially both sliders are set at zero, which represents the case where the banker neither buys nor sells assets. By moving the first slider, the accountant can experiment with the different amounts of cash the banker may have bid b^* , to buy assets, and by moving the second slider the accountant can experiment with the quantity of assets, q^* , the banker may have sold for cash. Note that the banker cannot bid more cash than it had, nor sold more assets than it possessed, and the banker cannot be a buyer and a seller at the same time. Therefore, if the accountant thinks the banker is a buyer then they will want to guess the amount of cash the banker

**In this round, the bank's initial allocation is A in Assets and $(100-A)$ in Cash
w of the banks customers are Impatient and the Asset price is P**

Bank is a Buyer:

Amount of cash bid by the bank (b^*)

0
C

OR

Bank is a Seller:

Quantity of assets offered by the bank (q^*)

0
A

Based on this information
the bank is:

Liquid

Solvent

Your final choices:

$b^* =$

OR

$q^* =$

You declare the bank:

☐ Liquid

☐ Not liquid

☐ Solvent

☐ Not Solvent

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Figure 2: Accountant Decision Screen

bid b^* to acquire assets at price P (an amount between 0 and the banker's deposits of Cash) and so q^* will be set to zero by default. If the accountant thinks the banker is a seller, then they will guess the quantity of assets the banker sold at price P , q^* , an amount between 0 and the banker's allocation of deposits to Assets, and b^* will be set to zero by default.

Based on the accountant's guesses of q^* or b^* , and given the market price P and the realized value for $w=33$ or $w=67$, the computer program will indicate whether the bank faces a liquidity or solvency problem. The box "Liquid" will turn to "NOT Liquid" if, given b^* and q^* , the banker will be unable to meet the withdrawal needs of impatient customers in period 2. The box "Solvent" will turn to "NOT Solvent" if given b^* and q^* , patient customers will earn a payoff lower than 1.

As noted earlier, underlying these calculations by the computer program, a bank is *liquid* only if the banker has enough invested in Cash to satisfy their impatient customers withdrawal demands in period 2, that is if $(100 - A) - b \geq w$ for bankers that buy assets and if $(100 - A) + P \times q \geq w$ for bankers that sell assets. In indicating that the bank is liquid, the computer program simply uses the accountant's guesses for b^* and q^* in the liquidity formulas above.

A bank is *solvent* if the banker has enough invested in assets to make its patient customers willing to wait to withdraw in period 3 or if $(100 - A) - b + 2 \times \left(\frac{b}{P} + A\right) \geq 100$ provided the banker has chosen to be a buyer, and if $(100 - A) + 2 \times (A - q) + P \times q \geq 100$ provided the banker has chosen to be a seller. Again, the computer program simply uses the accountant's guesses for b^* and q^* in computing solvency using these formulas.

As was true for bankers, the computer calculations of whether the bank is liquid/not liquid and solvent/not solvent rely on the accountant's guess about b^* or q^* and *not* on the actual amount of cash the banker bids b or the quantity of assets q the banker sells in the asset market. Therefore, accountants will want to accurately guess these values. To incentivize accurate guesses, accountants will earn payoff points each round depending on the accuracy of their guess about the actual

amount bid b or quantity of assets offered for sale, q , by the banker of the bank they are monitoring. Specifically, the accountant's payoff for forecast accuracy is determined by the formula:

$$\text{Accountant's forecast points} = \frac{yy}{1 + |b^* - b| + |q^* - q|}$$

Notice that the maximum an accountant can earn for forecast accuracy is yy and these forecast points decrease the greater is the absolute value of the difference between the forecast b^* or q^* and the actual choice of the banker b or q ; Accountants get the maximum of yy points only if they correctly forecast the banker's choice for b or q , that is $b^* = b$ or $q^* = q$. Remember, if the accountant enters a forecast for b^* then q^* is automatically set to 0, while if she/he enters a forecast for q^* then b^* is automatically set to 0.

In addition to guessing the bank's asset market position and its amount of purchases or sale of assets and considering what these guesses imply for Liquidity and Solvency, at the bottom of the screen the accountants must declare whether they think their bank is Liquid or Not Liquid and Solvent or Not Solvent by clicking next to one of these two choices for each. For each correct declaration the accountant earns yy payoff points for the round. An incorrect declaration earns 0 points.

Once the accountant has made these choices, the results for the round will be determined. If the accountant declares the bank solvent, the (robot) patient customers wait to withdraw funds from their bank in period 3. Bankers learn whether their banks are liquid, whether they were declared solvent by the accountant and if both of those conditions are satisfied, they learn the patient customer's period 3 payoff. They also learn the accuracy of their forecast for the market price and the number of points earned for each.

Accountants learn the actual asset trading activity of the banker, the forecast accuracy of their guesses of that activity, and the accuracy of their liquidity and solvency declarations, as well as the number of points earned for each.

At the end of the study, the computer program randomly chooses k rounds for payment. In c of those rounds, the accountant gets the points earned from their liquidity assessment. In c of those rounds, the accountant gets the points earned from their solvency assessment. In $k - 2c$ rounds, the accountant gets the points earned from guessing their banker's choice of b or q (up to yy points). All points including the xx endowment for each chosen round are summed up and converted into money at the fixed rate of 1 point = money. These earnings are added to the participation payment and paid in private.

Summary

Summarizing, the timing of moves in each period is as follows:

- Period 1: (a) Each participant receives an endowment of xx points.
- (b) Bankers receive 100 units of deposits and decide on the amount A of deposits to invest in Assets with a payoff of 2 if held until period 3. The amount $C = 100 - A$ goes to Cash on hand earning no return.
- (c) Accountants learn their matched bank's initial allocation between Assets and Cash.

- Period 2: (a) Bankers and accountants learn the number of impatient customers, w for their Region and bank.
- (b) With knowledge of w and the initial allocation A , bankers decide whether they want to buy or sell assets and enter a forecast for the market price P^f .
- (c) When all N bankers have confirmed their choices in the asset market, the market price P for the round is determined.

$$P = \frac{\text{Total Amount of Cash Bid by all Bankers}}{\text{Total Units of Assets Offered by all Bankers}}$$

- (d) Bankers and accountants are informed of the market price, P
- (e) With knowledge of the bankers initial allocation (A and $C = 100 - A$), the number of impatient customers w , and the market price P , accountants assess whether the Bank is Liquid or Not Liquid, as well as Solvent or Not Solvent. To help the accountant in his/her assessment he/she will be also asked to guess how much cash the banker has bid for assets (b^*) or the quantity of Assets the banker has sold (q^*) in the asset market.
- Period 3: (a) Accountants learn the actual asset trading activity of the banker, the forecast accuracy of their guesses of that activity, and the accuracy of their liquidity and solvency declarations, as well as the amount of payoff points earned for each.
- (b) The accountant gets yy point if he/she declares that the bank is Liquid (Not Liquid) and the bank has (not) enough cash to meet withdrawal needs of its impatient depositors.
- (c) The accountant earns yy point if he/she declares that the bank is Solvent (Not Solvent) and the bank has (not) enough assets and cash to offer a payoff of at least one unit to its patient depositors in period 3.
- (d) The accountant earns up to zz point based on the accuracy of their guess of the bank's trading activity in the asset market.
- (e) Bankers are informed about whether their bank is Liquid or not Liquid and whether the accountant has declared their bank Solvent or Not Solvent. If the bank is Liquid and the account declares it Solvent, then

$$\text{Banker's payoff if liquid and accountant declares solvent} = \begin{cases} \frac{(100-A)-b+2 \times (\frac{b}{P}+A)-w}{100-w} & \text{if buyer} \\ \frac{(100-A)+2 \times (A-q)+P \times q-w}{100-w} & \text{if seller} \end{cases}$$

If the bank is either Not Liquid or the accountant declares it Not Solvent, then the banker's payoff is zero points.

- (f) Bankers earn up to zz points based on the accuracy of their price forecast.

Comprehension Quiz

1. True/False. Which of the following statements is true and which is false?

- When choosing how many deposit units to put into assets (in period 1 of each round) bankers know that is equally likely that their bank will face 67 or 33 impatient customers in period 2 of that round.

[TRUE]

- Impatient customer can decide to withdraw in period 3 together with patient customers.

[FALSE: only patient customers can decide to withdraw their deposit in period 3]

- Impatient customers withdrawal demands in period 2 can be paid with assets that mature in period 3.

[FALSE: They can only be paid with Cash in hand]

- After learning the number of impatient customers, bankers can participate in a centralized asset market where they can buy or sell assets for cash.

[TRUE]

2. Single choice. If your bank is in Region II and you learn that the amount of impatient customers your bank will have this round is 67. How many impatient customers any other bank in Region I will have?

- a 67
- b 33
- c 67 or 33
- d none of the above

[Answer: b]

3. If after learning the amount of impatient customers a banker realizes that they have ___ of their deposits allocated to Assets to meet period 2 Cash withdrawal demands, then they can ___ Assets in exchange for Cash deposits from other bankers.

- a too little; buy
- b too little; sell
- c too much; buy
- d too much; sell

[Answer: d]

4. Fill in the blank. If in a given round the total amount of Cash bids is 57 and the total quantity of Assets offered is 75, the market price of Assets, P , will be: ___

[Answer: 0.76]

5. Fill in the blank. If in a given round a banker bids 24 units of Cash, and after the market exchange takes place P is 1.2 their bank will have ___ Assets in addition to Assets they already had.

[Answer: twenty or 20]

6. Fill in the blank. If in a given round a banker sells 40 Assets, and after the market exchange takes place P is 1.2 then they will have ___ units of Cash in addition to the Cash they already had.

[Answer: forty-eight or 48]

7. Single choice. An accountant should declare the bank insolvent if he/she believes that after the period 2 asset market, the bank will be unable to:
- a meet the withdrawal needs of impatient customers in period 2.
 - b meet the withdrawal needs of patient customers in period 2.
 - c pay patient customers at least 1 unit in period 3.
 - d pay patient customers at least 2 units in period 3.

[Answer: c]

8. Single choice. If the accountant declares the bank solvent:
- a All its patient customers will decide to withdraw early (in period 2).
 - b The banker earns zero payoff points.
 - c The accountant earns an equal share of the of the banks profit in period 3.
 - d The accountant earns yy payoff points if the bank is actually solvent.

[Answer: d]

9. Fill in the blank. At the end of the study, the computer program randomly chooses [input box 1] rounds for payment. In [input box 2] of those rounds, the accountant gets the points earned from their liquidity assessment. In [input box 3] of those rounds, the accountant gets the points earned from their solvency assessment. In [input box 4] rounds, the accountant gets the points earned from guessing their bankers choice of b or q.

[Answer Box1: k; Box2: c; Box3: c; Box4: k-2c]

10. Fill in the blank. At the end of the study, the computer program randomly chooses [input box 1] rounds for payment. In [input box 2] of those rounds, the banker gets the points earned if their bank is liquid and declared solvent by the accountant. In [input box 3] of those rounds, the banker gets the points earned from forecasting the market price.

[Answer Box1: k; Box2: c; Box3: k-c]