Economic Instruction

In this section, the *Journal of Economic Education* publishes articles, notes, and communications describing innovations in pedagogy, hardware, materials, and methods for treating traditional subject matter. Issues involving the way economics is taught are emphasized.

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Instructional Simulation of a Commercial Banking System

Donald D. Hester

In this article, I describe simulations of commercial banking systems that have been used successfully in a large class in money and banking at the University of Wisconsin–Madison. My goal in developing the enabling software was to provide a lively learning environment where students could interactively explore economics in a relatively unstructured environment.[1]

Each student in the class is responsible for managing a bank in imperfectly competitive markets where random shocks, unknown competitor strategies, and discretionary monetary policies exist. As a manager, a student must make six decisions each week that allocate the bank's resources among cash assets, two types of securities, and three types of loans. These decisions influence a bank's growth and its profitability. A teaching assistant plays the role of a central bank in a banking system that includes about eighty banks. A teaching assistant has considerable latitude to use monetary policy instruments of his or her choosing. The goals of the simulation exercises are to teach portfolio theory and to permit students to appreciate the robustness of markets and the subtleties of institutional constraints and decisionmaking under uncertainty in a general equilibrium setting.

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DESCRIPTION OF THE BANK SIMULATION EXPERIMENT

The experiment begins with the distribution of a set of rules and procedures for submitting moves on a microcomputer network; these rules and procedures are reproduced in the Appendix. Students receive no instructions about what moves they should make, although there are broad safeguards in the software to prevent destructive typing errors. The bank simulation is played for eight rounds (weeks). During each round, only one submission is allowed per player. Students are encouraged to discuss their plans with other players and to consult other available references. Teaching assistants respond to questions about technical aspects of the simulations but do not provide advice about specific moves.

The grade on this exercise is determined by a short written report that describes the strategy a student would use in the experiments if they were repeated. Students are expected to draw on their experimental results when preparing their reports, but grades do not depend on whether a student's bank was profitable. The instructions state that the students' goal is to maximize the welfare of the stockholders they serve. The reports suggest that students do attempt to maximize profits, but there is no assurance that this is the case.

In the bank game, there are two market levels. Securities in each of the banking systems are traded on a systemwide market. Thus, interest rates on one-period bills or consols are the same in all clearing areas in a system. The software incorporates demand functions for bills and consols. Bills must be ordered each round and pay an unknown interest rate that is market clearing. Consols are marked to market and can only be traded at an unknown price that is determined in the coming round. Consols can be sold short up to a margin ceiling. Thus, banks can engage in a limited amount of liability management because the proceeds from short sales are available to fund other assets. Substantial capital gains and losses occur when interest rates change, and these can be realized through adroit trading.

Three types of loans are available in the simulation experiments—mortgage loans, installment loans, and commercial and industrial loans. Loans are made and federal funds are traded in a local (clearing-area) market. New mortgage and installment loans are ordered by a bank at the beginning of each round and mature after several rounds, as described in the Appendix. A demand function for the stocks of mortgage and installment loans by the public, with interest rates as arguments, is incorporated in the software. The interest rate on each variety of loan is determined by combining new orders with the existing stock of unamortized loans and equating this with the public's demand. Interest rates on these loans are fixed for the duration of each loan.[2]

The volume of commercial and industrial (C & I) loans cannot be directly controlled by a bank. Instead, a bank extends lines of credit that are used at a rate that is endogenously and stochastically determined. Like the demand for other loans, the demand for C & I loans is a function of interest rates.

The utilization rate of lines of credit is defined as the ratio of C & I loans to lines of credit at a bank. It is a function of the set of interest rates that cleared markets at the end of the preceding round, the ratio of lines of credit to demand deposits at a bank, and random shocks. The utilization rate increases when the C & I loan interest rate falls relative to other asset interest rates. The interest rate on C & I loans changes each period; in effect, all C & I loan rates are pegged to "prime." C & I loans have a rich institutional specification that includes compensating balances, commitment fees, and penalties for canceling lines of credit. Details about this specification are reported in the Appendix.

In addition to the random utilization rate, demand deposits are subject to random shocks. Demand deposits have a 20 percent reserve requirement. Banks absorb the cost of servicing deposits. This cost is an increasing function of calendar time and the amount of deposits banks acquire in a clearing area. As banks seek more deposits, they are interpreted to be encountering rising costs and to be inflating prices in the area.[3]

In each clearing area, an auction market for federal funds exists. In each round, students provide an interest rate at which they would be willing to offer any excess reserves in the local funds market. The software clears the funds market and, if necessary, provides additional funds from the central bank discount window at a penalty rate. If a bank borrows more funds at the discount window than its net worth, the excess over its net worth is borrowed at twice the penalty discount rate.

A central bank is a specialized bank that is not permitted to make loans to the public. It holds bills and consols and trades federal funds in each of the clearing areas of the system. It is allowed to make discretionary moves only at the system level. The software automatically (passively) rearranges the bank's portfolio to ensure that bill or consol interest rates are identical in all clearing areas. The central bank may change the discount rate and engage in repurchase operations in securities markets, if it wishes to pursue an activist policy at the system level. It may also actively trade bills and consols. It can peg the federal funds rate within limits by setting a rate and mechanistically doing repurchases until that rate is approximately achieved. Central banks operate autonomously in each system and their actions can be only incompletely observed by commercial banks.

The information that is available to each player at the beginning of a round is displayed in Table 1. Each student gets a hard copy of the information pertaining to his or her bank each Monday the game is in progress. The difference between federal funds purchased and sold in a clearing area implies that a central bank was intervening, passively or actively. Students may share information with others in their clearing area. To facilitate analysis, I make available a second summary table of interest rates and quantities in all clearing areas for inspection on the microcomputer network. Tables 2 and 3 are an example of this summary. It can be used to determine whether a central bank was actively trading in the federal funds market, because students can infer net free reserves in each system from the information

TABLE 1
Player Information:
Statement of Condition of Your Commercial Bank at the End of Year 1

Assets		Liabilities and net worth	
Cash and equivalent	23.47	Demand deposits	117.35
Federal funds sold	1.76	Federal funds purchased	.00
Treasury bills	13.60	Discount window borrowings	.00
Treasury bonds	14.18	Capital, surplus, and undistributed profits	8.04
Commercial and industrial loans	17.17		
Installment loans	22.71		
Mortgage loans	32.50		
Total	125.39	Total	125.39

(All quantities are in millions of dollars)

Bank net operating income during this year was 1.06 million dollars.
Your bank paid a dividend to stockholders of .27 dollars per share.
Treasury bonds and bank capital in your accounts include a capital gain of .44 million dollars.
At the close of business outstanding lines of credit amounted to 108.12 million dollars, and their average utilization was 15.88 percent.

For the 19 operating banks in this clearing area the corresponding aggregate balance sheet is

Assets		Liabilities and net worth	
Cash and equivalent	2,177.62	Demand deposits	10,888.10
Federal funds sold	35.65	Federal funds purchased	36.65
Treasury bills	1,241.30	Discount window borrowings	171.29
Treasury bonds	1,272.21	Capital, surplus, and undistributed profits	752.55
Commercial and industrial loans	1,662.70		
Installment loans	2,211.00		
Mortgage loans	3,248.10		
Total	11,848.59	Total	11,848.59

Recent market interest rates in percentages are

Commercial and industrial loans	6.71	Treasury bills	6.13
Treasury bonds	6.06	Mortgage loans	7.26
Installment loans	7.41	Penalty discount rate	10.00
Average deposit cost	4.97	Average federal funds rate	5.00

Owing to predictable amortization of existing assets, if no new actions are taken, the bank will end the next year with 23.53 million dollars of mortgage loans, 11.52 million dollars of installment loans, no treasury bills, and the amount of treasury bonds shown above.
To obtain the assets shown in the balance sheet above, last time the bank acquired 13.60 million dollars of treasury bills, .00 million dollars of treasury bonds, 6.80 million dollars of mortgage loans, and 13.60 million dollars of installment loans. Lines of credit were increased by − 12.92 million dollars.
You offered to sell funds at a rate of 5.000.

Use the following form to plan and then key in moves for your bank in round 2

Treasury bills desired	= _____	Installments desired	= _____
Consols desired	= _____	Additional credit lines	= _____
Mortgage loans desired	= _____	Rate funds offered at	= _____

TABLE 2
Example of Publicly Available Banking System Information from Most Recent Run—Interest Rates in Clearing Areas

Area	C & I	T bills	Bonds	Mortgages	Installments	Discount	Deposits	Period
101	6.71	6.13	6.06	7.26	7.41	10.00	4.97	1
102	7.13	6.13	6.06	7.29	7.40	10.00	4.95	1
103	7.07	6.13	6.06	7.35	7.37	10.00	4.96	1
104	6.97	6.13	6.05	7.33	7.26	10.00	4.96	1
105	7.13	6.13	6.06	7.29	7.34	10.00	4.96	1
201	6.73	6.12	6.06	7.38	7.38	10.00	4.97	1
202	6.76	6.12	6.06	7.36	7.44	10.00	4.97	1
203	7.02	6.12	6.06	7.28	7.40	10.00	4.96	1
204	7.06	6.12	6.06	7.36	7.44	10.00	4.96	1
205	7.02	6.12	6.06	7.29	7.34	10.00	4.95	1
301	6.63	6.11	6.11	7.33	7.40	10.00	4.97	1
302	6.87	6.11	6.11	7.32	7.45	10.00	4.96	1
303	6.69	6.11	6.11	7.31	7.49	10.00	4.96	1
304	6.76	6.11	6.11	7.30	7.43	10.00	4.97	1

Note: The first digit of a clearing-area number identifies a system.

TABLE 3
Example of Publicly Available Banking System Information for Most Recent Run—Balance-Sheet Information (in Millions of Dollars)

Area	Cash	T bills	Bonds	C & I	Installments	Mortgages	Deposits	Discount window	Capital	Assets
101	2,178	1,241	1,272	1,663	2,211	3,248	10,888	171	753	11,849
102	2,137	1,204	1,301	1,432	2,233	3,201	10,686	71	757	11,628
103	2,153	1,227	1,260	1,459	2,276	3,115	10,766	5	744	11,615
104	2,175	1,231	1,301	1,512	2,388	3,115	10,874	64	766	11,860
105	2,160	1,231	1,299	1,429	2,297	3,188	10,800	35	752	11,730
201	2,181	1,238	1,285	1,655	2,261	3,083	10,906	61	736	11,851
202	2,181	1,238	1,304	1,637	2,197	3,125	10,907	23	733	11,822
203	2,173	1,234	1,248	1,486	2,228	3,218	10,867	10	747	11,732
204	2,258	1,235	1,302	1,467	2,201	3,123	10,837	0	734	11,721
205	2,151	1,231	1,299	1,487	2,297	3,188	10,755	132	759	11,732
301	2,192	1,252	1,241	1,714	2,235	3,150	10,962	76	731	11,885
302	2,165	1,232	1,238	1,567	2,182	3,173	10,827	15	723	11,708
303	2,176	1,247	1,248	1,679	2,148	3,195	10,882	74	722	11,780
304	2,177	1,237	1,221	1,635	2,204	3,192	10,884	65	731	11,824

Note: The first digit of a clearing-area number identifies a system.

reported in Table 3. (The first digit of the clearing-area number in both Tables 2 and 3 identifies a system, and students can recognize data for their clearing area.)

Central banks do not know the public's demand functions for assets and are not informed in advance about shocks to these functions that are imbedded in the software. The shocks result from exogenous changes in the economy being modeled. Once a week, a news bulletin is issued to the class. Demand curves shift vertically in a plausible manner in reponse to the news announcements. Central banks devise their own responses to news bulletins and to conditions that develop because of actions by students.

Banks are never closed because of unfavorable results, although a bailout occurs when a bank's net worth falls below minus 10 percent of its deposits. The bailout restores a bank's net worth to zero. The number of banks that submit moves varies from week to week; this variation is an additional source of uncertainty. If moves are not submitted, a bank's portfolio is frozen. At the start of a simulation, banks differ in size by up to a factor of twenty.

MULTIPLICITY OF APPROACHES

The bank simulations can be viewed from many perspectives. For example, one can approach the project focusing on liability management. Banks may acquire liabilities by extending lines of credit to gain compensating balances, by going short in the market for consols, and by borrowing in the market for federal funds. First-order conditions for profit maximization require that the expected marginal cost of each of these sources be equated with the expected marginal revenue that can be earned in asset markets. In the case of deposits, it is necessary to allow for reserve requirements when comparing costs.

Another approach is to focus narrowly on the market in federal funds and attempt to "sting" rivals by lending at very high interest rates when rival banks are overly ambitious purchasers of funds and by borrowing when there is a glut of cheap funds. Because the central bank is a trader, this approach requires careful "Fed watching" and attention to the amount of discount-window borrowing. It requires that a bank carefully study moves by rival banks.

A third approach is to speculate in the consol market. In the spirit of Keynes's liquidity preference theory, profits can be realized by closing out short positions as consol rates peak and closing out long positions as consol rates reach lows. There are transaction costs and margin requirements in the consol market to take into account.

A fourth approach is to evaluate news bulletins and either use them as a guide about how interest rates are likely to move or to assume that others are automatons and be a contrarian. A more formal approach to forecasting interest rates is also possible. On occasion, students have attempted, with some success, to estimate demand functions from data that have been

generated in earlier rounds of the game. There are thirteen observations on clearing-area loan markets in each round of the bank game.

An interesting dynamic dimension of the game exists in the market for commercial and industrial loans. Extending lines of credit commits a bank to making C & I loans in the future. Although lines of credit bring compensating deposit balances, these balances often are insufficient to fund the C & I loans that are generated. The utilization rate is partly determined by the configuration of interest rates in the *preceding* round. When several large banks in a clearing area aggressively extend lines of credit, a cumulative destructive collapse may ensue because of rising loan volumes and plummeting loan interest rates. However, when only a few banks undertake a roughly geometric expansion of lines of credit, a very profitable expansionary trajectory can be achieved. There is a substantial penalty (lost good will) when banks reduce lines of credit. Understandably, banks prefer to have other banks absorb this penalty when a clearing area is flooded with too many low-yielding C & I loans.

Another approach is to employ portfolio diversification and gap management. As long as assets are yielding more than liabilities, a surprisingly large variety of tactics and rules of thumb are available to hedge and avoid risk. Gaps can be controlled by paying attention to fixed and variable rate assets and liabilities. Banks with negative net worth are especially interesting to manage because, if they go to the discount window, they pay twice the discount rate.

Finally, there is ample evidence that players in a clearing area engage in strategic misrepresentations to others in the area and retain the services of consultants who previously played the game. On occasion, students have reported seeking advice from actual bankers. Sometimes, coordinated moves by a group of banks are submitted. Regulations, such as limiting banks to a single submission and requiring identification numbers for access to the game, are essential to deter fraud.

EXPERIMENTAL RESULTS AND A MODEL OF BANK PORTFOLIO BEHAVIOR

The classes reported on in this article had an enrollment of about 225, primarily juniors and seniors who had completed several economics courses. A class was divided into three autonomous banking systems, with a teaching assistant acting as a central bank. Each banking system was further divided into four or five urban markets or "clearing areas," which roughly corresponded to a discussion section.

Given the large number of possible approaches to the bank simulation and the inexperience of the participants, one would expect to observe an evolutionary rather than a stationary process. Indeed, the written students' reports indicated that further changes would have occurred if the simulations had been repeated. In this section, I report summary statistics from the simulations and results from tests of several simple hypotheses and then propose a model of portfolio behavior by students.

TABLE 4
Mean Market Interest Rates for Aggregate of Three Banking Systems

Round	C & I	T bill	Consols	Mortgages	Installments	Deposits	Effective cost	Federal funds
				Semester 1				
1	6.87	6.12	6.07	7.31	7.40	4.96	6.20	5.00
2	7.28	6.48	5.90	7.94	8.05	5.05	6.31	4.97
3	7.13	6.18	5.97	7.98	8.09	5.16	6.45	5.43
4	7.06	6.22	5.70	7.97	7.87	5.15	6.44	5.58
5	7.18	6.29	5.86	7.65	7.64	5.15	6.44	5.82
6	7.02	6.18	6.22	7.57	7.45	5.30	6.63	6.14
7	6.78	6.62	6.26	7.51	7.72	5.23	6.54	6.27
8	6.50	6.63	6.34	8.09	7.95	5.22	6.53	6.43
9	6.08	6.84	6.15	7.88	8.12	5.37	6.71	6.71
				Semester 2				
1	6.93	6.13	6.08	7.34	7.42	4.96	6.20	5.00
2	7.22	6.29	6.00	7.68	8.28	5.04	6.30	4.34
3	6.59	5.88	5.97	7.32	7.33	5.20	6.50	5.24
4	6.80	6.14	5.95	7.28	7.33	5.20	6.50	5.95
5	7.03	6.29	6.08	7.00	7.60	5.16	6.45	6.17
6	6.92	6.49	6.43	7.43	7.23	5.28	6.60	5.88
7	6.51	6.37	6.67	7.25	7.79	5.25	6.56	6.34
8	5.85	6.65	6.87	7.26	7.76	5.28	6.60	6.72
9	5.33	6.63	6.89	7.19	7.60	5.29	6.61	6.63

Summary Statistics and Analyses of Variance

Interest rates for assets and liabilities in each of nine rounds in the two semesters are reported in Table 4. They are means of the market rates that emerged in all clearing areas, irrespective of banking system affiliation. Round one rates were initial conditions for the simulations and did not reflect any decisions by students.

In Table 4, the effective cost of funds is the immediately preceding cost of deposits multiplied by 1.25 to correct for the presence of the 20 percent reserve requirement.[4] It is the marginal cost of deposit-based funds that are available to finance assets. The last column in Table 4 is the interest rate on funds sold in the federal funds market. In each semester, the gap between these two interest rates disappeared by the ninth round, a first-order condition for profit maximization. The interest rate on one-period treasury bills was tolerably close to these rates as well in the last two rounds of each semester. The gaps between these three money-market rates narrowed as the simulation proceeded.

Interest rates on consols are more difficult to interpret. Because capital gains can be realized only by trading consols, speculators might view consols as an interest-bearing bond with an attractive option to realize gains on occasion. By analogy to a convertible bond, the yield on consols might be expected to be somewhat lower than returns on other assets. Alternatively, risk-averse investors might require a premium for the inconvenience of being exposed to possible capital losses. A third interpretation is that individuals looking for a cheap source of funds might want to sell consols short, if the interest rate on consols is lower than can be earned on other assets. From this perspective, one might expect the consol rate to tend toward the rate on short-term assets. Finally, because central banks are allowed to trade consols, monetary policy initiatives must be taken into account. For whatever reasons, the consol rate approximately equaled the rates on short-term assets by the end of the simulation at the end of the second semester but was substantially below them in the first semester.

In both semesters, banks were savaged by a destructive explosion in the utilization rate of lines of credit. This systemic instability resulted from attempts by the banks to grow by extending lines of credit. As more lines were extended, the interest rate on commercial and industrial loans began to fall relative to other asset interest rates. The growing gap between this loan rate and other interest rates, together with other lags in the system, caused the utilization rate to rise. In both semesters, the plunge occurred in the second half of the simulation, after players had several rounds of experience. As explained earlier, banks needed to cut lines of credit to escape from this situation. Because they would incur a large penalty for cutting lines, banks appeared to delay in the hope that rivals would cut lines first.

Interest rates on mortgage and installment loans were high throughout both games. These loans had no secondary market and, thus, were illiquid. Also, if a bank changed the level of installment loans, it was required to pay

TABLE 5
Mean Portfolio Shares as Percentages of Total Assets—All Systems

Round	Cash	T bills	Consols	C & I	Installments	Mortgages	Deposits	Discount window	Capital
					Semester 1				
1	18.4	10.5	10.8	13.3	19.0	26.9	91.8	.8	6.3
2	21.2	8.0	12.1	13.1	17.4	24.4	89.0	.9	6.6
3	18.7	10.3	11.6	13.2	18.3	24.3	87.8	2.0	6.6
4	18.4	10.2	13.6	14.5	16.4	23.1	87.8	1.6	7.3
5	17.4	10.1	12.4	14.9	16.3	25.0	86.0	2.7	7.0
6	17.7	9.2	10.4	15.7	15.9	25.5	88.1	.7	6.9
7	18.5	7.0	10.8	17.0	16.5	25.4	87.5	.6	7.2
8	18.2	7.0	10.6	18.8	16.1	25.9	87.9	1.5	7.4
9	17.5	5.8	11.0	21.3	15.8	25.9	87.1	1.4	7.9
					Semester 2				
1	18.6	10.5	10.8	13.2	19.0	26.9	92.2	.4	6.3
2	21.1	9.6	11.7	13.3	15.9	24.5	89.9	.3	6.5
3	17.7	12.2	11.6	13.5	16.2	24.8	87.1	2.4	6.6
4	17.6	9.1	11.0	14.7	17.7	26.1	87.0	2.6	6.7
5	17.7	8.2	10.0	15.3	18.2	27.4	86.8	2.9	6.7
6	20.1	5.7	6.9	16.2	18.9	28.2	89.4	.1	6.4
7	19.0	6.8	6.3	17.0	18.3	29.4	89.3	.6	6.4
8	17.8	5.2	6.8	18.5	20.0	28.3	88.2	2.0	6.5
9	17.8	5.3	6.9	20.4	19.2	27.5	87.8	2.1	6.8

Notes: Asset and liability shares do not sum to 100 percent because federal funds sold and federal funds purchased, respectively, are not shown. Also in the calculation of total assets, consols sold short are displayed as a "negative" asset rather than as a liability. (This convention does not affect the balance-sheet identity, but slightly increases percentages for all elements except consols.)

a penalty in proportion to the change. The differences between these loan rates and the rates on short-term assets can be interpreted as liquidity premiums. However, in many of their bank reports, students claimed that they had erred by investing so little in them; if they were to replay the game, they would have bought more mortgage and installment loans. The truth is unknown.

The means of clearing-area percentage allocations of assets in the two semesters for each of the nine rounds are reported in Table 5. The divisor was the sum of deposits, federal funds purchased, discount-window borrowings, and capital. The data were generated only for active commercial banks in each round; portfolios of central banks were not included.

There are several interesting points in this table. In the first period of play, round two, substantial excess reserves existed—cash was more than 21 percent of *assets.* Players either misunderstood the need to replace amortizing assets or underinvested in the mistaken belief that this was prudent. Excess reserves occasionally occurred in clearing areas in subsequent rounds, but never to this extent.

The rising utilization rate clearly affected commercial and industrial loans. The crisis was far from over at the end of the game in both semesters. In both semesters, a conspicuous shift away from treasury bills occurred in the middle of the game, as players responded to differences in interest rates. In the second semester, but not in the first, there was also a sizable shift away from consols and slight increases in installment and mortgage loans. Play was more aggressive in the second semester, as is evident from the larger amount of discount-window borrowing. Capital grew more slowly in the second semester because larger capital losses were sustained on consols as interest rates rose and, perhaps, because competition eroded profits.

The patterns in Tables 4 and 5 were the result of a number of different forces. The dominant element undoubtedly was the growth in understanding of the game by inexperienced players. The teaching assistants, acting as central banks, also were experimenting with a number of policy instruments and with explaining the game to students. Monetary policies appeared to differ appreciably across the banking systems. The number of active banks in a clearing area varied from week to week.[5] The news bulletins had different impacts on the structure of demand in different weeks in each semester. Second-semester students had a chance to consult with first-semester students and, therefore, were probably a little more informed. To gain a feel for which of these forces were important, I posed three simple hypotheses:

1. In each semester, after allowing for a common learning path, there are differences in clearing-area interest rates and portfolio shares across banking systems.
2. In each semester, after allowing for a common learning path and banking system effects (hypothesis 1), there is a relation between the number of participating banks in a clearing area and interest rates and portfolio shares.

TABLE 6
Tests of Hypotheses About Clearing-Area Interest Rates

Semester	C & I	T bills	Consols	Mortgages	Installments	Deposits
			1. Banking system effects (df = *2, 106*)			
1	No	Yes	Yes	Yes	Yes	No
2	Yes	Yes	No	No	No	No
			2. Number of competitor effects (df = *1, 105*)			
1	Yes	No	No	Yes	Yes	Yes
2	Yes	No	No	Yes	Yes	Yes
			3. Clearing-area heterogeneity (df = *10, 95*)			
1	Yes	No	No	Yes	Yes	No
2	Yes	No	No	Yes	Yes	No

Note: Yes means null hypothesis was rejected at the .01 level in an F test.

3. In each semester, after allowing for a common learning path, banking system effects, and the number of participating banks, additive differences exist in clearing-area interest rates and portfolio shares.

The first of these nested hypotheses tests for the joint presence of central bank policy and expositional effects, the second for market-size effects, and the third for clearing-area heterogeneity.

The three hypotheses were tested each semester with 117 observations on clearing areas. Table 6 reports whether or not the null hypothesis of no effect was rejected for six interest rates. Table 7 gives this information for eight balance-sheet ratios. Because the markets were imperfectly competitive, it is not obvious whether the hypotheses are viewed better from a price or a quantity perspective. The quantity dimension is a bit subtle in Table 7 because the dependent variable is in ratio form. Intuition serves better when analyzing interest rates.

It is apparent that banking system effects were quite different in the two semesters (see Table 6). Central bank policies did differ considerably across teaching assistants, especially in the first semester. (The relation between specific policy moves and interest rates is analyzed in the next section.)

A surprisingly strong and plausible relation existed between interest rates and the number of competitors. Loan interest rates were negatively related and deposit costs positively related to the number of players in each semester. The number of players always exceeded eight in a clearing area. Conventional wisdom is that five or ten players are sufficient to get close to a competitive equilibrium. As indicated in Table 6, significant gains in market efficiency were obtained as the number of players rose beyond eight in these markets.[6] There was no significant relation between the number of players in a clearing area and security interest rates, a plausible outcome given that security markets were systemwide. There were about four times as many

TABLE 7
Tests of Hypotheses About Clearing-Area Portfolio Shares

Semester	Cash	T bills	Consols	C & I	Installments	Mortgages	Deposits	Discount window	Capital
				1. Banking system effects (df = *2, 106*)					
1	Yes	No	Yes	Yes	No	No	No	No	Yes
2	No	No	No	Yes	No	No	No	No	Yes
				2. Number of competitor effects (df = *1, 105*)					
1	No	No	No	Yes	Yes	Yes	Yes	Yes	No
2	No	No	No	Yes	No	No	No	Yes	No
				3. Clearing-house, heterogeneity (df = *10, 95*)					
1	No	No	No	Yes	Yes	Yes	No	No	Yes
2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

Note: Yes means null hypothesis was rejected at the .01 level in an *F* test.

traders in systems as in clearing areas. An increase in players in one clearing area was often randomly offset by a decrease in another area within a banking system.

Results for the third hypothesis (Table 6) indicate that the number of players was only one source of the differences in clearing-area interest rates. There were no significant differences in either deposit or security interest rates within a banking system. The personalities of players and their interactions resulted in distinctive local competitive situations in loan markets. These might have converged to a common pattern with more rounds of play, but the students' reports suggest that convergence was not imminent.

Substantial differences in banking system effects were evident when portfolio shares were compared in the two semesters (see Table 7). As noted in Table 6, banking system effects were more evident in the first semester.

The effects of variations in the number of competitors were evident in ratios of C & I loans and discount-window borrowings to assets, but not for other ratios in the second semester. The pattern in the first semester suggests that variations in the number of competitors influenced portfolio shares more extensively; as noted in Table 6, the effects were in markets for loans and deposits. I have no explanation for why the two semesters' results differed. The first-semester result is plausible, because loan demand functions have different interest rate elasticities. Profit maximization implies that one should observe different portfolio shares when the number of competitors varies.

Additive clearing-house fixed effects in portfolio shares were pronounced, especially in the second semester. In both semesters, the null hypothesis could be rejected for the three loan markets and for the ratio of capital to assets. Loan markets varied because competitors differed in their loan specialization and in their aggressiveness. Differences in the ratio of capital to assets reflected variations in clearing-area profitability, because at least half of net operating income was undistributed to shareholders. Areas with large holdings of C & I loans were relatively unprofitable.

The presence of large additive clearing-area effects in all but discount-window borrowing in the second semester suggests that variations in competition in banking systems were more extreme then. When banks in one clearing area were aggressively bidding for loans, they had to fold fewer securities to avoid borrowing at the penalty discount rate. The securities markets thus conveyed the effects of excess bidding for loans in some areas to other areas because, with fewer securities demanded, security interest rates were forced up. In effect, funds were raised for loans by aggressive banks by lodging securities in the portfolios of banks where competition was sluggish. Aggressive banks also acquired more deposits by extending more lines of credit, which required them to hold more cash as required reserves.

A Model of Bank Portfolio Moves

In this section, new orders by banks for bills, bonds, mortgage loans, installment loans, and lines of credit are studied, together with the offering

rate for federal funds. The data were analyzed at the clearing-area level because the hypotheses involved interest rates, which were observed only at that level. Because the number and sizes of banks and asset amortization varied across clearing areas, all data involving quantities of assets were deflated by summed *net* direct acquisitions of loans and securities in an area.[7] This correction for heteroscedasticity is difficult to defend theoretically; therefore, results were also calculated without deflation for all active banks in an area (those results are examined in the section on monetary policies).

To model the moves submitted by students, I started with the observable information they possessed. Before submitting moves, a player could review the immediately preceding and earlier balance sheets and interest rates (reported in Tables 1, 2, and 3). Apparently, experience was a potentially important determinant of moves, for the data in Tables 4 and 5 exhibit pronounced trends. Also, it is very likely that students' understanding of the simulations was changing over time.

I hypothesized that students attempted to maximize an increasing and possibly concave function of bank net income.[8] I assumed that they made predictions about interest rates in the coming period using recently observed interest rates and, possibly, changes in recently observed interest rates. Despite the fact that markets were imperfect, I assumed that students viewed themselves as interest-rate takers. If one further assumes that students had constant, absolute risk-aversion (negative exponential) utility functions and that the distribution of interest rates was normal, then, following Parkin (1970), asset demands are linear functions of interest rates. As Parkin argued, an implication of this formulation is that assets should have positive own interest rate elasticities and negative cross interest rate elasticities.

In what follows, I reinterpreted Parkin's linear model to apply to asset acquisitions (moves) rather than asset levels. The estimated model has (deflated) moves expressed as a linear function of time and the most recently observed interest rates. This reinterpretation is straightforward for acquisitions of bills, bonds, installment loans, and mortgage loans. With due allowance for variations in the utilization rate, the model is also appropriate for describing changes in lines of credit. The model implies nothing about the interest rate at which banks offer excess reserves. Nevertheless, for symmetry, this offering rate is related to the same set of explanatory variables.

The data used in the model were for clearing areas; in each semester, 104 observations were available (thirteen clearing areas times eight periods). Specifically, the dependent variables were clearing-area asset acquisitions (including lines of credit) expressed as a fraction of clearing-area direct asset acquisitions and the mean interest rate at which excess reserves were offered. Using ordinary least squares, I regressed the dependent variables on time and five asset interest rates. The bank demand functions were identified, because they incorporate the last observed interest rates; the public demands for funds were a function of market-clearing interest rates.

The results for each semester are presented in Table 8. Coefficients on own interest rates always had positive signs and usually were several standard er-

rors greater than zero. Cross-elasticities in asset demand functions were negative when averaged. In this and subsequent tables, an asterisk on a regression coefficient implies that the null hypothesis was rejected at the .05 level in a two-tailed test. Two asterisks on an F statistic imply that the null hypothesis for the regression was rejected at the .01 level. With the exception of one equation, consols in semester 1, the null hypothesis of no relation between moves and time and recently observed interest rates was rejected (Table 8). The model seemed to describe student moves with plausible signs and some success.[9]

The model was more successful in describing the second-semester game. Using the model was justifiable if the elasticity of students' expectations about future interest rates was about unity. If the model was actually used, interest rate expectations were neither rational nor adaptive.[10] Significant trends in interest rates were apparent (see Table 4), and no learning was implied by the specification in Table 8. The model's apparent success also suggests that students were risk averse.

EVIDENCE OF MONETARY POLICY EFFECTIVENESS AND EXOGENOUS SHOCKS

I analyzed clearing-area interest rates and moves for evidence of policies by central banks and traces of exogenous shocks. The teaching assistants who controlled central banks were free to manipulate monetary policy instruments in ways of their own choosing. They might have hinted at or announced their intentions. In some cases, their moves were negated by software intervention that was required to insure that bill and bond interest rates were uniform across clearing areas. Monetary policies could have been potent in the bank simulation, but generally they were not aggressively used.

Five central bank policy tools were assessed. Four could have had an immediate impact and were examined by regressing contemporaneous clearing-area interest rates on their settings. They are changes in central bank holdings of bills or bonds (exclusive of capital gains), a central bank's net purchase of federal funds, and the interest rate at which a central bank offered federal funds. Because central banks operate at the system level, each of these tools was expressed as an average per-clearing-area move. The test was whether central bank moves were detectable above other "noise" that affects clearing-area rates.

The fifth variable was the extent to which banks in a clearing area had been borrowing at the discount window in the immediately preceding period. If the ratio of borrowing to deposits had been high in an area, banks were expected to cut back on their asset acquisitions and to offer funds to rivals at a high interest rate. Central banks could force banks arbitrarily far into the discount window by aggressively doing repurchase transactions. Banks could also put themselves into the market by overacquiring assets in the preceding rounds. The test of this fifth variable could not distinguish between policy initiatives and moves by overly acquisitive banks.

TABLE 8
Regression Analyses of Moves—Trends and Last Observable Rates

Coefficient	Funds rate	T bills	Consols	Mortgages	Installments	Lines
			Semester 1			
Intercept	1.470	.931*	−.386	.088	.367*	.983
	(1.602)	(.218)	(.307)	(.171)	(.186)	(.506)
Time	.069*	−.008*	−.011*	.013*	.007*	−.009
	(.026)	(.004)	(.005)	(.003)	(.003)	(.008)
C & I rate	−.156*	−.004	−.003	.006	.001	.048*
	(.056)	(.008)	(.011)	(.006)	(.006)	(.018)
T bill rate	.514	.018	−.052	.012	.022	−.144
	(.270)	(.037)	(.052)	(.029)	(.031)	(.085)
Consol rate	.214	−.113*	.153*	−.026	−.014	.115
	(.217)	(.030)	(.042)	(.023)	(.025)	(.069)
Mortgage rate	−.320	.034	.019	.032	−.085*	.055
	(.203)	(.028)	(.039)	(.022)	(.024)	(.064)
Installment rate	.423	−.026	−.034	−.010	.070*	−.166*
	(.222)	(.030)	(.043)	(.024)	(.026)	(.070)
SEE	.508	.069	.097	.054	.059	.160
R^2	.344	.273	.152	.278	.161	.249
F ratio	8.478**	6.061**	2.891	6.234**	3.101**	5.369**

	Semester 2					
Intercept	10.097*	.585	−1.244*	.314	1.344*	.807
	(2.120)	(.356)	(.554)	(.329)	(.349)	(.549)
Time	.203*	−.032*	−.030*	.022*	.040*	−.017
	(.036)	(.006)	(.009)	(.006)	(.006)	(.009)
C & I rate	−.108	−.015	−.027	.022	.019	.118*
	(.100)	(.017)	(.026)	(.015)	(.016)	(.026)
T bill rate	.203	.102*	.056	−.042	−.116*	−.076
	(.276)	(.046)	(.072)	(.043)	(.045)	(.071)
Consol rate	−.243	−.058	.172*	−.052	−.062*	−.018
	(.184)	(.031)	(.048)	(.028)	(.030)	(.048)
Mortgage rate	−.667*	−.023	.071	.060*	−.108*	−.162*
	(.182)	(.031)	(.048)	(.028)	(.030)	(.047)
Installment rate	.145	−.017	−.053	−.016	.086*	.053
	(.147)	(.025)	(.038)	(.023)	(.024)	(.038)
SEE	.520	.087	.136	.081	.086	.135
R^2	.559	.436	.174	.179	.442	.418
F ratio	20.51**	12.50**	3.404**	3.528**	12.79**	11.62**

Note: Standard errors of coefficients are in parentheses. *Indicates it has an associated *t* absolute value of 1.96 or more. **Implies significance at the .01 level.

Before a game commenced, a series of additive shocks and associated "scenario" announcements were created. The shocks were embedded in the software, and the announcements were delivered weekly, just before the shocks occurred. The shocks and announcements are reported in Table 9. The announcements were intended to reveal the signs but not the magnitudes of shocks. In this section, interest rates and moves are examined to see if numerical shocks substantially remained in clearing-area interest rates and if moves were affected by announcements. Students' reports frequently indicated that they considered the news bulletins before making a move; however, their analyses of the contents were quite varied.

Interest rates in clearing areas were regressed on the number of active banks, four variables measuring central bank policies, and three shock variables (see Table 10). Interest rates were negatively related to the number of competing banks. The third and fourth coefficient rows in each semester in the table multiply the mean clearing-area increases in central bank portfolios of bills and consols, each scaled by dividing by 100. The means differed in each time period across the three banking systems. Increases in the amounts of bills and consols held by central banks are, plausibly, negatively related to corresponding security interest rates; the coefficient estimate was significantly different from zero in three of the four cases. In both semesters, an increase in the number of central bank securities held was associated with significantly *higher* interest rates for some other assets. This last result seems paradoxical; I expected unannounced contemporaneous purchases of securities to drive down security interest rates and to have no effect on other rates. The interpretation is unclear, but one possibility is that central bank transactions were partly conditioned by the news bulletins.[11]

The fifth row of coefficients in Table 10 in each semester multiplies mean clearing-area federal funds purchased by a central bank, divided by 100. I expected that purchases of funds would drive interest rates higher, especially if a central bank pursued the policy aggressively. With one exception, the coefficients did not differ significantly from zero. The games were not dominated by central bank policies! The sixth row of coefficients multiplies the interest rate at which central banks were offering federal funds. Coefficients were frequently significantly different from zero, but were not easily interpreted without additional information about how central banks were setting this rate. The trend was up in all banking systems, and the patterns of signs suggest that the coefficients were broadly capturing trends.

The effects of shocks on clearing-area interest rates were complex. First, in five of six cases, a positive exogenous shock caused corresponding clearing-area interest rates to be higher by a statistically significant amount. Second, in three of the six cases, one could not reject the hypothesis that the coefficient on a shock was unity; that finding suggests that banks did not see the relation between the news bulletins and loan interest rates. In two cases, the actual shocks were partially offset by system responses—the coefficients were significantly less than unity. In the case of second-semester C & I loans, shocks seemed to have been amplified by system responses.

TABLE 9
News Announcements and Loan Demand Displacements

Round	Announcement	C & I	Installments	Mortgages
	Semester 1			
1	(None)	.0	.0	.0
2	A boom in private-sector borrowing	.2	.3	.2
3	Rising imports in anticipation of a collapsing dollar.	.0	.5	.3
4	A wave of consumer bankruptcies is occurring.	.1	−.1	.0
5	Recession is developing as consumer confidence wanes.	.2	−.4	−.2
6	Dollar falls dramatically as economy weakens.	.3	−.5	−.1
7	Exports begin to rise, and domestic economy strengthens.	.2	−.2	−.2
8	Government announces a new program to subsidize construction.	.0	−.2	.2
9	Recovery accelerates with stimulus from exports and construction.	.1	.1	.2
	Semester 2			
1	(None)	.0	.0	.0
2	Recession looms because of continuing glut of imports.	.1	.2	−.2
3	Severe recession, with wave of household bankruptcies.	−.3	−.5	−.3
4	Government cuts taxes and sharply increases defense spending.	.2	−.2	−.1
5	Government eliminates subsidies to housing industry—military buildup continues.	.4	.0	−.4
6	A wave of corporate leveraged buyouts is occurring.	.5	−.2	.2
7	Government cuts poverty and welfare programs.	.2	.3	.1
8	Imports again surge as government continues defense buildup and dollar appreciates.	−.2	.5	.1
9	Rising rate of manufacturing bankruptcies as profits are eroding with surging imports.	−.5	.2	−.1

TABLE 10
Regressions of Interest Rates on Policy Variables and Shocks

Regressor	C & I rate	T bill rate	Consol rate	Mortgage rate	Installment rate
			Semester 1		
Intercept	11.382	6.606	5.798	10.513	10.341
Number	−.149*	−.037*	−.032*	−.132*	−.135*
	(.040)	(.009)	(.012)	(.017)	(.015)
Increase in T bills ÷ 100	.269*	−.207*	−.006	.063	.017
	(.112)	(.025)	(.034)	(.047)	(.042)
Increase in consols ÷ 100	−.081	.030*	−.061*	.020	.004
	(.064)	(.014)	(.019)	(.027)	(.024)
NPF ÷ 100	.096	−.014	.009	−.016	−.032
	(.126)	(.028)	(.038)	(.053)	(.047)
Offering rate	−.329*	.033	.135*	−.115*	−.066
	(.128)	(.029)	(.039)	(.053)	(.048)
C & I shock	.054	.716*	−.643*	−.021	.123
	(1.069)	(.240)	(.324)	(.447)	(.404)
Installment shock	1.145*	−.397*	−.212	.055	.582*
	(.549)	(.123)	(.166)	(.230)	(.207)
Mortgage shock	−2.120*	1.217*	.167	.895*	.414
	(1.033)	(.231)	(.313)	(.431)	(.390)

	Semester 2				
Intercept	9.998	6.549	5.792	9.895	9.908
Number	−.158*	−.007	.005	−.112*	−.116*
	(.022)	(.009)	(.012)	(.015)	(.016)
Increase in bills ÷ 100	.053	−.016	−.061*	.120*	.086*
	(.052)	(.020)	(.029)	(.034)	(.036)
Increase in consols ÷ 100	−.099	.056*	−.137*	−.017	.014
	(.053)	(.021)	(.030)	(.035)	(.037)
NFP ÷ 100	.024	−.007	−.047*	.001	.004
	(.035)	(.014)	(.019)	(.023)	(.024)
Offering rate	−.143*	−.014	.079*	−.111*	−.075*
	(.045)	(.018)	(.025)	(.029)	(.031)
C & I shock	1.421*	−.037	−.368*	.028	.099
	(.155)	(.061)	(.087)	(.102)	(.109)
Installment shock	−.342	.553*	.232*	.148	1.063*
	(.208)	(.082)	(.116)	(.137)	(.146)
Mortgage shock	−.679*	.442*	.867*	.407*	−.576*
	(.272)	(.107)	(.152)	(.178)	(.190)

Notes: Summary statistics are available from the author. Standard errors of coefficients are in parentheses. *Indicates it has an associated t absolute value of 1.96 or more.

Third, securities rates were usually significantly affected by shocks, even though there were no direct shocks in the equations that determined security interest rates. The explanation for securities rates effects can be found in adding-up constraints and/or central bank policies. The overall conclusion is that news was an important determinant of market outcomes, even if shocks were not accurately gauged.

Tables 11 and 12 report the effects of policy initiatives and shocks on clearing-area moves. The dependent variables were the total orders by banks in a clearing area, divided by the number of banks. The model specification corresponds to that considered in Table 8, but with no deflation. Monetary policy is primarily concerned with magnitudes of credit flows, not the proportions in which banks allocate total cash flows. The sign and significance patterns in the first seven rows of coefficients in Tables 11 and 12 resemble those in Table 8; interpretations will not be repeated here.

Coefficients in row eight in Tables 11 and 12 refer to clearing-area discount-window borrowings, as a percentage of deposits in the immediately preceding period. Because the discount rate is known to exceed the interest rates that banks can earn on other assets, banks have a strong incentive to reduce asset acquisitions when overextended. One expects direct asset acquisitions in a clearing area to be negatively related to the percentage of recent overextension. Also, banks might attempt to gouge rivals by offering federal funds at a high interest rate when an area had been overextended. The relation between decisions to extend lines of credit and discount-window borrowing is ambiguous, because new lines of credit might afford temporary relief by bringing in compensating balances. Over the long run, extending lines of credit will worsen a bank's need for funds by driving up the utilization of lines of credit. In both semesters, those predictions were borne out, although statistical significance was largely confined to the second semester. Monetary policy can thus curb extensions of credit by forcing banks into the discount window.

Coefficients in rows nine through eleven of Tables 11 and 12 describe the relation between loan-market shocks and moves. A positive loan-market shock was associated with a news announcement just before a move was submitted that was designed to promote one or more of the loans as good investment opportunities. If the signal was correctly decoded, there should have been a positive relation between a shock and acquisitions of those loans and a negative relation between the shock and acquisitions of securities and other loans. In both tables, the results present a mixed picture. In ten of twelve cases, acquisitions of securities were negatively related to loan shocks, and, in six cases, by statistically significant amounts. However, in only one of eighteen cases in the two tables was a loan shock significantly related to a loan acquisition variable. In four of six cases, a positive relation existed between acquisitions and the sign of a loan shock. There was a tendency to raise the rate at which funds were offered whenever a positive shock was sustained, especially in the case of C & I loans. I concluded that either the news announcements were noisy and inaccurately interpreted or

TABLE 11
Portfolio Moves in Response to Lagged Rates, Trend, Window Borrowing, and News Bulletins—Semester 1

Coefficient	T bills	Consols	Mortgages	Installments	Lines	Offer rate
Intercept	51.801	−24.055	−66.263	−47.070	175.96	−1.017
Trend	−4.715*	−2.091	1.883*	1.140	.091*	.091
	(1.021)	(1.099)	(.818)	(.845)	(2.127)	(.035)
C & I rate	2.788	−1.314	5.015*	4.683*	9.800*	−.140*
	(1.615)	(1.738)	(1.295)	(1.337)	(3.365)	(.055)
T bill rate	7.896	−11.987	8.956	16.437*	−33.857	.828*
	(9.221)	(9.927)	(7.393)	(7.638)	(19.217)	(.313)
Consol rate	−9.344	26.578*	−3.580	−4.310	13.199	.196
	(6.798)	(7.319)	(5.451)	(5.631)	(14.168)	(.231)
Mortgage rate	12.101	1.324	7.219	−14.182*	2.579	−.461*
	(6.404)	(6.894)	(5.135)	(5.305)	(13.346)	(.217)
Installment rate	−8.986	−5.231	−2.700	13.138*	−13.621	.588*
	(6.886)	(7.414)	(5.522)	(5.704)	(14.352)	(.234)
100DW ÷ DEP	−.660	−.441	−.251	−.891*	−1.150	.025
	(.510)	(.549)	(.409)	(.422)	(1.063)	(.017)
C & I shock	−47.294*	−49.876*	14.928	23.363	65.999	1.667*
	(23.263)	(25.046)	(18.653)	(19.270)	(48.483)	(.790)
Installment shock	−23.924*	1.867	10.226	23.216*	9.303	.541
	(10.183)	(10.963)	(8.165)	(8.435)	(21.222)	(.346)
Mortgage shock	−4.372	−21.013	−4.679	−27.112	52.568	−.542
	(17.463)	(18.802)	(14.003)	(14.466)	(36.396)	(.593)
SEE	14.479	15.588	11.610	11.994	30.176	.491
R^2	.366	.216	.261	.257	.260	.411
F ratio	5.367**	2.558**	3.283**	3.216**	3.269**	6.494**

Note: Standard errors of coefficients are in parentheses. *Indicates it has an associated *t* absolute value of 1.96 or more. **Implies significance at the .01 level.

TABLE 12
Portfolio Moves in Response to Lagged Rates, Trend, Window Borrowing, and News Bulletins—Semester 2

Coefficient	T bills	Consols	Mortgages	Installments	Lines	Offer rate
Intercept	134.17	−90.597	128.59	223.27	39.866	6.508
Trend	−3.832*	−2.759*	3.730*	6.554*	−4.280*	.159*
	(1.530)	(1.388)	(1.201)	(1.179)	(1.519)	(.041)
C & I rate	3.334	−.435	5.476	5.526	14.215*	−.168
	(3.938)	(3.572)	(3.093)	(3.034)	(3.910)	(.107)
T bill rate	5.790	3.042	−20.152*	−31.316*	−11.827	.427
	(10.332)	(9.373)	(8.114)	(7.961)	(10.258)	(.280)
Consol rate	−7.265	18.755*	−7.565	−5.058	7.588	−.058
	(8.146)	(7.390)	(6.397)	(6.277)	(8.088)	(.221)
Mortgage rate	7.314	−2.663	18.602*	−7.039	−11.629	−.621*
	(7.014)	(6.363)	(5.508)	(5.404)	(6.964)	(.190)
Installment rate	−16.499*	−1.282	−11.804*	7.648	3.045	.301
	(6.598)	(5.985)	(5.181)	(5.084)	(6.550)	(.179)
100DW ÷ DEP	−.723	−2.176*	−1.347*	−1.209*	.187	.049*
	(.798)	(.724)	(.627)	(.615)	(.793)	(.022)
C & I shock	−24.793*	−3.875*	−11.968	−3.347	3.080	.393
	(9.619)	(8.725)	(7.554)	(7.411)	(9.550)	(.260)
Installment shock	−22.585*	6.690	−8.255	−3.860	−13.215	.146
	(8.780)	(7.965)	(6.895)	(6.765)	(8.717)	(.238)
Mortgage shock	−12.515	−18.032	8.869	−3.695	14.440	.034
	(12.939)	(11.738)	(10.161)	(9.970)	(12.846)	(.350)
SEE	18.693	16.957	14.680	14.403	18.559	.506
R^2	.470	.289	.271	.366	.493	.599
F ratio	8.231**	3.779**	3.456**	5.363**	9.044**	13.920**

Note: Standard errors of coefficients are in parentheses. *Indicates it has an associated *t* absolute value of 1.96 or more. **Implies significance at the .01 level.

that there were a large number of contrarian players. The news did cause players to shift away from securities.

SUMMARY

In this article, I have analyzed imperfectly competitive markets in which large numbers of very inexperienced players managed banks with varying degrees of success. A majority of the students who wrote course evaluations stated that they enjoyed playing and learned much from the simulation. I have no independent way to evaluate its instructional value.

One can see that, after eight rounds of play, the banking system somewhat resembled its real-world counterpart. Liquid assets such as bills, federal funds, and possibly consols had interest rates that approximately equaled the cost of deposit-based funds. Higher interest rates were associated with mortgage and installment loans. In the game, the public's supply of such paper was relatively inelastic (as in the real world). From an industry perspective, but not that of an individual bank, rationing loans to these markets was profit enhancing. I know of no mechanism that could account for rationing by banks. Autonomous individual banks were not maximizing profits in those markets. Banks were losing heavily in the C & I loan market. Moves to withdraw lines of credit in late rounds were insufficient, and the overall system was far from being in equilibrium. One immediately thinks of real-world parallels in loans to developing countries and leveraged buyout deals.

Despite this disequilibrium condition, monetary policies and news shocks did affect market outcomes and the moves players submitted in the bank simulation. The magnitudes of central bank policy initiatives and shocks were small relative to interest rate differentials among assets and across clearing areas.

The students operating the banks seemed to act on the basis of observable information and to extrapolate this information as if the elasticity of expectations was about unity. However, they also learned over time, as indicated in the narrowing of interest rate differentials in money market assets.

Learning is not adaptive. Instead, it seems to occur irregularly and discontinuously, through discovery that is only partially conditioned by the noisy intervening data from games.

APPENDIX
Description of Economics 330 Bank Simulation Exercise, February 1989

The computer output before you describes the condition of your bank at the start of this class exercise, and also the condition of all banks in the metropolitan clearing house area in which it resides. The number of banks in the area is approximately the number of students in your discussion session. The banks in your area vary in size and have different portfolios. With the exception of the federal funds market, all banks in your area face the same interest rates. Your TA plays the role of the Federal Reserve in this exercise. She or he may vary the discount rate, undertake open market operations, and intervene in security markets to maintain orderly conditions.

Market interest rates and costs are also shown on your output; they will change over time in response to local and systemwide forces of supply and demand. For purposes of this exercise, you may assume that market interest rates and net after-tax rates of return are identical.

The reserve requirement is 20 percent of deposits and must be held as cash and equivalent. If your bank does not have sufficient cash assets to meet its reserve requirement, the deficit must be borrowed in the federal funds market and, if necessary, from the Federal Reserve discount window at a penalty rate. So long as your discount-window borrowings are *less* than your bank's capital in a period, the penalty rate at the discount window is 10 percent. If you goof and your borrowings are larger than your bank's capital in a period, the penalty rate at the discount window is 20 percent. The computer will automatically take care of bookkeeping concerning your federal funds market activity and discount-window borrowing according to this rule and others that are stated below. The computer will always help you to minimize costs when making up a reserve requirement deficit. In the future, the Federal Reserve may announce a different discount rate; if so, the penalty rate for borrowing more than your bank's capital is twice the announced rate.

The banks in your clearing area compete directly in two ways. First, an increase in another bank's deposits will cause deposits at your bank to fall slightly. A bank's deposits may increase voluntarily as a result of some random shock or intentionally as it acquires compensating balances.

Second, all banks in your area make interest rate offers at which they would be willing to sell federal funds, in the event that they have excess cash, to banks with reserve deficits. The computer sums the deficits of all banks with reserve deficits in your clearing area and clears the federal funds market within your area by selling all available excess funds for banks at their indicated offering rates until either (1) the summed deficit is extinguished or (2) all excess cash has been distributed. The computer sells available excess cash according to bank interest rate offers, so that excess funds at the bank with the lowest interest rate offer are sold first, etc. In the event that two banks with excess cash make *identical* offers, the computer sells funds of the largest bank first. If available excess cash exceeds the summed deficit of deficit banks, banks with excess cash that submit high interest rate offers will end up holding idle excess reserves that earn *no* interest. If, on the other hand, available excess cash at all banks in the area is less than the summed deficit, all offers to sell will be accepted and the computer will draw down the difference from the discount window as explained above. All deficit banks borrow federal funds at a common rate of interest that is a weighted average of interest rate offers by banks with excess funds. If the discount window is activated for your area, all deficit banks borrow funds from the federal funds market and the discount window in the same proportion.

The Federal Reserve participates in each clearing area's federal funds market. Its position can be inferred from the difference between a clearing area's federal funds purchased and federal funds sold. For example, if your clearing area has federal funds purchased exceeding federal funds sold, the Federal Reserve was selling the difference in your area. It may have been doing this passively in an attempt to maintain orderly security markets or actively in an attempt to influence banking system behavior. You must examine the Fed's position in *all* of its clearing areas to determine whether it is actively attempting to influence the banking system.

Each bank has a *fixed* number of shares of common stock outstanding. The number of shares is roughly proportional to year one bank size. If a bank is profitable *and* if its net worth exceeds 5 percent of its deposits, the bank is presumed to pay a dividend to stockholders. When these two conditions are satisfied, the computer automatically pays out 50 percent of your net operating income to stockholders and a message will appear on your output that reports the dollar amount of dividends paid per share. You may find it instructive to compare dividends paid per share by different banks in your clearing area. If a dividend is paid, the remaining 50 percent of a

bank's net operating income is retained and added to its net worth. If no dividend is paid, a message to that effect appears and *all* net operating income is retained and added to a bank's net worth.

Your goal in this exercise is to maximize the well-being of your stockholders in each of a number of periods by manipulating six variables, or "controls," that are at your disposal. Specifically:

1. You may buy treasury bills that have a maturity of one period.
2. You may buy or sell treasury consols. A 1 percent brokerage fee is assessed for either sort of transaction. If the interest rate on consols that you *own* falls, the computer *automatically* credits the unrealized capital gain to both your securities account and your capital account. If the consol interest rate rises, the unrealized capital loss will be similarly deducted from these two accounts. In either event, a statement concerning the amount of such gain or loss will appear on your computer output—directly under the statement concerning operating income.
3. You may acquire mortgage loans that have a four-year maturity. You earn interest every year from these, but they are not amortized or paid off until the end of four years. Once you have bought a mortgage loan, its interest rate doesn't change. You may not sell mortgage loans.
4. You may acquire consumer installment loans that have a three-year maturity and that are partially amortized or paid off at the end of each period. Thus a $1.00 installment loan shrinks to a $0.67 installment loan after one period and further shrinks to a $0.33 installment loan after two periods. Again, once you have bought an installment loan, its interest rate doesn't change. You may not sell installment loans.
5. You may acquire or dispose of lines of credit. You automatically obtain compensating balances in the amount of 20 percent of your outstanding lines. If you choose to *dispose* of lines of credit, however, you will be assessed a penalty in the amount of 0.50 percent of the dollar value of the decrease because you will effectively have suffered a loss of customer good will. Lines of credit must be positive if you are to make any commercial and industrial loans. If your bank has lines of credit, each period it receives income from commitment fees that is equal to 0.15 percent of *outstanding* lines of credit. Your bank's *utilization rate* is given by the ratio of your bank's commercial and industrial loans to its lines of credit. Thus, if you had lines of credit of 1,000 and commercial and industrial loans of 250, your utilization rate is 25 percent. The utilization rate is a random variable. The *expected* utilization rate of your lines of credit is an increasing function of the ratio of your lines of credit to your demand deposits, and a decreasing function of the ratio of the interest rate on commercial and industrial loans to a simple average of the interest rates on other loans and securities that your bank could hold. If you have lines of credit outstanding that are equal to your demand deposits, with the initial set of interest rates you could expect the utilization rate to be about 20 percent.
6. You *must* provide an interest rate at which you would be willing to sell federal funds if you have excess cash. This interest rate must be less than the Federal Reserve's penalty discount rate, but can be arbitrarily close to the announced rate. If you attempt to put in an offer at or above the Fed's discount rate or fail to provide a rate, the computer will provide you with an assigned rate of 0 percent, which implies that you desire to *give away* all of your excess cash for one period.

Your task is complicated because you do not know

1. the fraction of your lines of credit that will be in use,
2. what your deposits will be in the current or future periods,
3. what the Federal Reserve or your competitors are doing, and
4. what current or future interest rates will be.

To submit moves and to observe information about recent activity in the dozen or so clearing areas that exist in this exercise, you must make use of the microcomputer laboratory in room 3218 Social Science. Information about the preceding week's activity may be obtained and moves for the current week submitted after 9:00 A.M. on Monday and before 5:00 P.M. on Friday of each week during hours when the microcomputer lab is open. A teaching assistant will be available in the laboratory between 3:00 and 5:00 P.M. on Wednesday, Thursday, and Friday of each week. Students participating in the bank simulation experiment will have priority on a set of eight PCs during these six hours. If you have a problem submitting moves or getting results, report the problem and all essential information to the TA on duty during these hours. If you submit moves at other times within the permitted five-day interval, you are on your own. Moves can be submitted from any PC in the microcomputer lab. You must submit moves every week to benefit fully from this exercise.

The software that permits you to participate is designed to be user friendly; it contains many messages or "prompts." It has been carefully tested but is *not* fail safe. Therefore, it is very important that you keep a written record of the moves you submit in a safe location. The output before you has spaces on the right to record the moves you plan to submit. Use them! The blanks on the left are for a related futures market exercise that commences in about three weeks. Ignore them until that experiment begins.

To avoid misunderstanding, each bank may submit *only one* set of moves each week. If you try to submit a second set of moves or to revise a set you have submitted in a week, you will be rebuffed by the software. Therefore, it is important to plan your moves carefully and to key them in accurately. You may abandon or abort a submission at any time before a statement that "your moves have been recorded" appears on a screen. Simply type an "A" and then hit the enter key (hereafter <enter>) to terminate a submission. If you abort a submission, you may resubmit later that same week without penalty. You may inspect recent results as often as you like.

The software is designed to help you avoid disastrous typing errors, but allows you plenty of chances to succeed and/or fail. For example, it will not allow you to buy bills or bonds in amounts that exceed 50 percent of your previous level of deposits. It will permit only moves defined to be legal in this handout.

During the week before the exercise begins, i.e., *before* 5 P.M. on Friday, February 24, you may practice submitting moves. Your practice moves will be discarded. TAs will be available to answer your questions that week in the microcomputer lab from 3:00 P.M. to 5:00 P.M. on Wednesday, Thursday, and Friday.

The process for submitting moves is quite simple. Enter Room 3218, follow instructions for 330 students posted inside, and find a free PC. If it is off, turn it on, and let it warm up. Eventually by following a series of prompts, you will reach a menu of instructional applications. Type MONITOR and then <enter>. If it is on, hit <enter>, and then type MONITOR, and hit <enter>. This activates software for this course. To transmit information, you must type in the information and then <enter>. For example, when you are asked "in which course do you game?" type 330 and <enter>. Then type in your ten-digit UW ID number, and supply other information in response to prompts. At the beginning of the next week, your TA will return printed output to all individuals who submitted moves, which begins a new round. It is a good idea to submit moves before Friday, to avoid last-minute congestion. A news bulletin about the banking system will be given each week in class on Monday; you should hear it before submitting moves.

This exercise is a model of a banking system, and, as such, it is a gross simplification of the real animal. Nevertheless, it has important real-world counterparts and should be taken seriously. For example, utilization rates and monetary policy moves by the Federal Reserve involve lagged and current effects in this system and in the real world. Deposits fluctuate in part because of the presence or absence of banks in your system. They also fluctuate because of random shocks, moves by your competi-

tors, and moves by the Fed. It is in the interest of everybody to submit moves every period to reduce deposit instability. Of course, your own bank makes no profits when it's not active!

Interest rates reflect forces of supply and demand both in your local clearing area and in the system of banks for which your TA is responsible. Each area may have distinctive local features, but in all cases, large increases in system (including the Federal Reserve) demand for some variety of asset will drive the associated interest rate down. You may be able to predict how demands for the different assets are changing by carefully analyzing data and statements by other bankers, the Fed, and others. You are encouraged to discuss and compare your policies with others in your discussion section. Remember, a good part of the business of banking is to collect and process information, including that generated by your rivals. Information on interest rates and aggregate balance sheets for all clearing areas in the most recent week can be viewed and copied onto paper if you have a printer turned on. (Ask a TA for help during the specified hours if you need assistance connecting a printer.) You are, of course, solely responsible for guiding your bank. You will need to critically evaluate your moves in the paper describing this project. You will be successful if you carefully plan your moves and keep notes indicating the reasons for your behavior.

In this game, you don't have to be profitable to get a good grade. You just have to be able to show—in good English—that you understand bank management well enough to deserve reappointment by a board of directors.

TECHNICAL APPENDIX

Utilization rate. As explained above, the utilization rate is a random variable with a substantial standard deviation. Even if you hold lines of credit equal to demand deposits, you may reasonably observe lines of credit utilization rates varying between .15 and .25. The equilibrium relationship mentioned in the text implies *very roughly* that shown in Figure A1. The solid line obtains when the interest rate on commercial and industrial loans equals a simple average of rates on other loans and securities. The dashed line indicates the relation when the interest rate on commercial and industrial loans is lower than this simple average.

Net income. This is the summation of assets times their corresponding interest rates minus the summation of liabilities times their corresponding interest rates less brokerage charges and penalties, plus commitment fees.

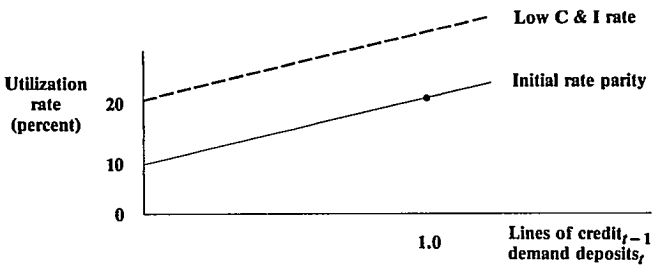
Available cash. At the start of each round, you will have the following resources available to invest: Bills + 0.8 expected change in deposits + amortization of installment and mortgage loans + excess reserves + federal funds sold + federal funds purchased + discount window borrowings − expected change in commercial and industrial loans + net income − dividends + proceeds from any bond sales that you make in that round.

Capital account. The following equation defines the relation between income and capital on your sheets: Net worth$_t$ = net worth$_{t-1}$ + net income$_{t-1}$ + capital gains$_t$ − dividends$_{t-1}$.

Short sales. It is possible that an announcement will be made that banks are allowed to hold a negative (short) position in consols, because of deregulation. If so permitted, your bank, in effect, would have the opportunity to borrow a limited amount of funds at the consol interest rate. A bank would never be allowed to sell so many consols short in any period that its resulting short *position* exceeded twice the bank's net worth. However, if a bank's net worth falls because of losses, outstanding short positions may exceed twice a bank's net worth. Capital gains and losses can be sustained from a short position in consols. For obvious reasons, a bank cannot have *both* a long and a short position.

Adjustment costs on consumer loans. Because of staffing requirements, a penalty

FIGURE A1
Lines of Credit



is assessed if the number of installment loans made in a period differs from the unamortized amount that your bank carries over into the following period. The penalty is 1.5 percent times the absolute value of the difference.

NOTES

1. The software underlying these experiments is described in Hester (1987). In 1988, microcomputer hardware and software became available at the University of Wisconsin that allowed the system to be operated on a network and facilitated analysis of data from simulation experiments. Thanks are due to Al Schubert at Wisconsin for extensive guidance in software design.
2. The bank simulation experiments have an associated futures market for mortgage loan contracts. It is an integral part of the overall instructional simulations, but, at the request of the editor, I have excluded all discussion of it in this article. It is described in Hester (1989).
3. Costs were assumed to rise slowly over time for two technical reasons. First, some students dropped the class over the course of a semester. When they left the game, the number of competitors dropped, and it got easier to make a profit. Second, banks retained at least 50 percent of their profits. These retained earnings were a zero-cost source of funds and led to rapid growth in bank profitability. The trend in deposit costs was designed to keep the game challenging.
4. Students were not told about the need to adjust deposit costs for reserve requirements when calculating the cost of funds, and very few reports mentioned this adjustment.
5. If a player failed to submit moves, the bank's portfolio was frozen. When moves were again submitted, the bank was restored with its stated variables unchanged. After the game was under way, it was rare for the number of banks in a clearing area to vary by more than three from week to week. There was very slight attrition of banks over the eight rounds that the game was played.
6. The sample of 117 observations included the initial round, which had no player input. The same pattern of significance was obtained in each semester when the initial round observations were excluded. The median number of banks in a clearing area was 16 at the end of a semester.
7. Specifically, the deflator was the sum of new orders for bills, consols, installment loans, and mortgage loans in a clearing area.
8. Before starting the simulation, students were exposed to the notion of mean/variance effi-

cient portfolios in a textbook (Simpson 1987, chap. 7). During lectures, they also were exposed to a variation of Edgeworth's 1888 model of a bank.

9. The model is not perfect, however, because, as Parkin explains, the *i*th rate coefficient in the *j*th equation should equal the *j*th rate coefficient in the *i*th equation. This symmetry condition appears to be violated, although given the reinterpretation of the model such a violation might reasonably occur. I have not bothered to test the hypothesis of symmetry formally.
10. In Hester (1989), variations of this model were considered and rejected using these data. In one variation, students were assumed to have rational expectations. In this variation, market-clearing interest rates rather than the most recently observed rates were used as arguments in the demand functions. Own rate elasticities were typically nonpositive, and the model was rejected. The reason for the model's failure was that equations were not identified, a common weakness of rational expectations models in which identifying restrictions are absent. In a second variation, the model was estimated using both recently observed interest rates and observable recent changes in these rates. This was an attempt to isolate adaptive expectations about interest rates. The estimated model did not lead to significant improvements in the description of clearing-area moves and was rejected.
11. It is notoriously difficult to disentangle policy initiatives and shocks in financial markets, as has been argued by Goldfeld and Blinder (1972). The difficulty carries over to simulated markets!

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