Technology and Financial Intermediation in a Multiproduct Banking Firm: An Econometric Study of U.S. Banks

by Colin Lawrence
and Robert P. Shay

Columbia Institute for Tele-Information
Graduate School of Business
Columbia University
809 Uris Hall
New York, NY 10027
(212)854-4222

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1985

This paper was published in the First Boston Working Paper Series. This paper will be published in a forthcoming book entitled Technological Innovation, Regulation, and the Monetary Economy, C. Lawrence and B. Shay, Eds., MA: Ballinger Publishing Company.

The authors are indebted to Allen Berger, David Humphrey, Frank Lichtenberg, John Murray, Mark Flannery, and Michael Smirlock for critical comments on earlier drafts. We are also grateful to Julian Silk for research assistance.

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ABSTRACT

The paper examines the impact of technology and financial intermediation on economies of scale and scope in a multiproduct firm (four banking outputs) while measuring elasticities of substitution among factor inputs, and the derived demand elasticity for inputs (labor, computers and financial capital).

Using the translog multiproduct production function, the study estimates the "seemingly unrelated system" with Shephard's cross-equation restrictions on banks subscribing to the Federal Reserve System's Functional Cost Analysis between 1979 and 1982.

The four outputs included in the equation are deposits, loans, investments and nonbanking expenses; the latter output representing expenditures on fee-based, nonbalance sheet services supplied to customers. The three input prices included are cost of financial capital, computer rental values and wages.

The study estimates ray economies of scale and tests for the existence of economies of scope among banks arrayed by asset size in four quartiles and for the group as a whole. Contrary to other studies, ray economies of scale are found among banks in the largest size quartile in 1980 and 1981 as well as among banks in the two lower quartiles in every year. This is the first time that significant ray scale economies have been encountered among larger banks.

C.E.S. and Cobb-Douglas technologies are, with few exceptions, rejected by the data. Additionally, tests of structural stability of the parameters across bank size, assumed in all previous studies, are

significantly rejected. Finally, we demonstrate that parameter estimates of the production function are highly sensitive to the inclusion (exclusion) of financial capital as an input.

I. Introduction

This investigation attempts measurement of the impact of computer technology upon economies of scale and scope (cost complementarities) and the elasticities of substitution between labor, financial capital and computers. It falls firmly within the emerging literature that since 1982, has corrected earlier attempts to measure scale economies by using Cobb-Douglas production technologies. These latter functions are flawed by the assumption that each product "output" of a financial intermediary is independent of other outputs in relation to cost and that such a specification precludes U-shaped cost curves. Beginning in 1982 the use of the translog functional form allowed researchers to relax the assumption of independent outputs and to test for the existence of economies of scope. The use of this production function has also permitted estimation of U-shaped cost curves, varying elasticities of substitution in inputs across banks, as well as specific measures of scale economies for each output. R. Alton Gilbert (1984) has traced the development of the research on bank costs through six stages, with the latter stage marking the beginning of tests for cost complementarity and the consequent measurement of economies of scope.

Despite the improvement in methodology and techniques of measuring economies of scale, the basic finding that scale economies are found only among small banks (below $50 million in deposits) has been supported consistently by studies preceding this one. A newer related finding is that diseconomies of scale are found in banks where deposits total more than $50 million in deposits. One finds this difficult to believe when there is such a rush towards interstate banking and one observes the massive reliance upon computer technology and electronic banking. Can it be the omission of data from the largest banks that are at the forefront of the application of technology which is responsible for biasing the estimates of scale economies? This is doubtful, since computer applications have been adopted widely throughout the banking system. The conclusion must then be that computer technology improves efficiency by expansion in plant size due to the presence of scope economies alone. The three most recent studies have identified the existence of cost complementarities (jointness), suggesting economies of scope, although one of the studies questions the use of the translog function to test for the existence of cost complementarities [Murray and White (1983), Gilligan, Smirlock and Marshall (1984), Benston, Berger, Hanweck and Humphrey (1983)].

The twin questions of the existence of scale and scope economies -- subadditivity -- are crucial in order to anticipate the possible effects of interstate banking and the lines of business that banks are permitted to enter. In particular, the abrogation of several clauses of the Glass Stangall Act contained in the current deregulatory policies would imply that the newly emerging financial structure would depend critically on the existence of scale and scope economies. If the latter economies do not exist beyond relatively small bank asset sizes, there is little reason to believe that permitting large banks to expand outside of state boundaries will result in only a few giant banks with thousands of branches to service our nation.[1] If scale and/or scope economies are present on the other hand, the possible benefits to the banking public through lower prices and a wider range of products at banks could well be appreciable. The question of market power and monopoly pricing would have to be considered if the elimination of competitors were sufficiently large to pose problems of size or restrictive bank practices among remaining banks.

Clearly the computer and telecommunications technology is changing the face of wholesale and retail banking. On the corporate side fund flows have been greatly speeded up by electronic cash management systems and electronic fund transfers are replacing paper check clearing, particularly on large sized transfers. On the retail side, automatic teller machines (ATMs) have made it possible for retail cash dispensing, deposit and revolving credit facilities [to operate] 24 hours daily, while home banking from on-line personal computers will make it possible for a family to conduct banking business as well as financial investment without leaving home. Point-of-sale funds transfers from banking accounts in retail stores will become commonplace as debit cards begin to gain acceptability as did credit cards. It is for these reasons that we believe that technology must be having a dramatic impact on costs in banking and other financial intermediaries and will continue to do so.

So we begin our study with two fundamental objectives:

(a) to improve upon the methodology used by other researchers in estimating scale and scope economies and to explicitly introduce computer capital into the analysis. To estimate elasticities of substitution between labor, computers and financial capital used to produce four banking outputs: Total Deposits, Loans, Investments and non-banking expenses (the provision of fee-based services such as data processing, trusts, safety boxes, etc.). These will be estimated across bank size over a four year period (1979-82) using the Federal Reserve's Functional Cost Data with about 650 banks each year.

(b) to develop and use measures that will indicate the impact of technological developments affecting banking upon economies of scale and scope. These include automatic teller machines, point-of-sale merchandising transactions and electronic check clearing volume.

We are presenting some initial results from our research that reveal some novel implications and problems connected with studies in bank costs. Because of the relation of the topic to current regulatory and legislative developments, we stress that our results are preliminary at this stage and should be interpreted with caution.

In contrast to other studies we find significant economies of scale <u>even</u> for large size banks (up to $2.5 billion in deposits). The reason that earlier studies fail to find this is that either they have ignored the multiproduct nature of the banking firm or statistically aggregated banks of all sizes in their samples. We find that the technological parameters differ across bank size. While in some cases we do find an absence of economies of scale, there is certainly no existence of diseconomies of scale.

We also find significant economies of scope between deposits and loans, as well as between deposits and investment.[2] There are also statistically significant economies of scope between fee-based banking services and deposits/investments. There appears to be significant diseconomies of scope between investment and loans.

Finally we found relatively high significant elasticities of substitution between computers and labor, often above 2 in some of the subsamples.

Our preliminary findings thus point to the likelihood that the computer/labor ratio will continue to rise dramatically as computer costs fall (relative to labor) and financial intermediaries will move towards concentrated supermarkets offering an array of financial services, thus exploiting both scope and scale economies.

II. The Production Function of Banks

1. Financial Intermediation

Theoretical models of the behavior of financial intermediaries (FI) has traditionally focused on financial portfolio choices (i.e. ex post this is summarized by the balance sheet). In sharp contrast, empirical studies concerned with estimating scale economies in banking, place emphasis on the transformation of physical inputs (labor, materials and physical capital) into higher valued financial output (demand deposits, value of earning assets, etc.). The latter empirical studies were initiated by Benston (1965) and Bell-Murphy (1967) using a Cobb-Douglas production function. This led to a proliferation of studies on scale economies in FI along the same methodological lines.[3]

The bulk of the empirical literature has ignored the portfolio choice aspect of FI. For example, interest costs account for around 70% of total costs and yet has received very little attention.[4]

It is our contention that empirical work must synthesize financial portfolio choice and production (cost) functions for an adequate treatment of economies of scale and scope. Ignoring the interest rate, where different shareholders have varying degrees of risk aversion could lead to serious specification error and inconsistent empirical estimation.

Neglect of the balance sheet has developed in our view because researchers have pragmatically tended to ignore the complex multiple input-output structure of banking.

Banks do not behave like nonfinancial corporations. They have a unique or atypical production function which lies at the heart of intermediation. As Sealey and Lindley (1977) have argued, financial capital (which includes deposits) is an input in a fixed proportion production function. This means that in the absence of fee-based services including trusts, brokerage and data services, a bank cannot expand output (earning assets) without increasing financial capital (i.e. deposits, other liabilities, equity). To avoid inconsistent estimation, this balance sheet restriction must be imposed on the cost structure.

2. The Dual Role of Transaction Deposits

Empirical work to date has included deposits as an output provided by banks to their customers. Deposits play this role by providing liquidity or transaction services. However, there is a second role. Deposits act as an input in the production of earning assets. While it is true that bank customers pay a fee in the form of commissions, checking fees, etc., in return for the transaction services, they are also paid interest on their deposits for supplying financial capital to the bank.

Since deposits have a dual role, the net price paid by the FI to the customer could be either negative or positive to settle the reciprocal trade. The terms of trade will depend upon the net marginal benefits customers derive from utilizing this transaction technology relative to their rate of time preference. In the following section we derive a net supply curve of financial capital.

3. A Simple Exposition of the Production Function

The flow of funds for an FI are postulated as follows: D is the net inflow of homogenous deposits and L is the flow of homogenous loans. The constraint applicable to financial intermediaries, that loans be funded by deposits, is also applicable to flows of funds in the analysis to follow.

For simplicity we ignore capital financing and reserve requirements. The first role is the output role -- FI sells a transaction service to its customers at a rate of $P per dollar of deposits per unit of time. Customers' demand function for this service is the usual downward sloping demand curve depicted in panel 1 of Diagram I as DD. On the other hand, although customers obtain a transaction service they are providing the bank with a flow of financial capital. Thus agents are refraining from consumption and must be compensated. They are providing a supply of financial capital at $i per dollar/deposit per unit time (the interest rate). The supply schedule is depicted in panel 1 of Diagram 1 as the SS schedule.

The net supply schedule of financial capital provided by borrowers is derived by subtracting the price per dollar/deposit per unit of time from the interest rate per dollar/deposit at each level of deposit on the horizontal axis of the upper panel of Diagram 2. This net supply curve is depicted as the NS curve in panel 2. The net price i - P could be either negative or positive. For example at point F on NS, customers provide intermediaries with $\$D_0$ of deposits at a negative price $i_0 - P_0$, i.e., they are willing to pay $\$P_0$ per \$ deposit for transaction services (point A on the DD curve in panel 1) and demand $\$i_0$ per \$ deposit (point B on the SS curve in panel 2). On the other hand, points above D, such

Diagram 1

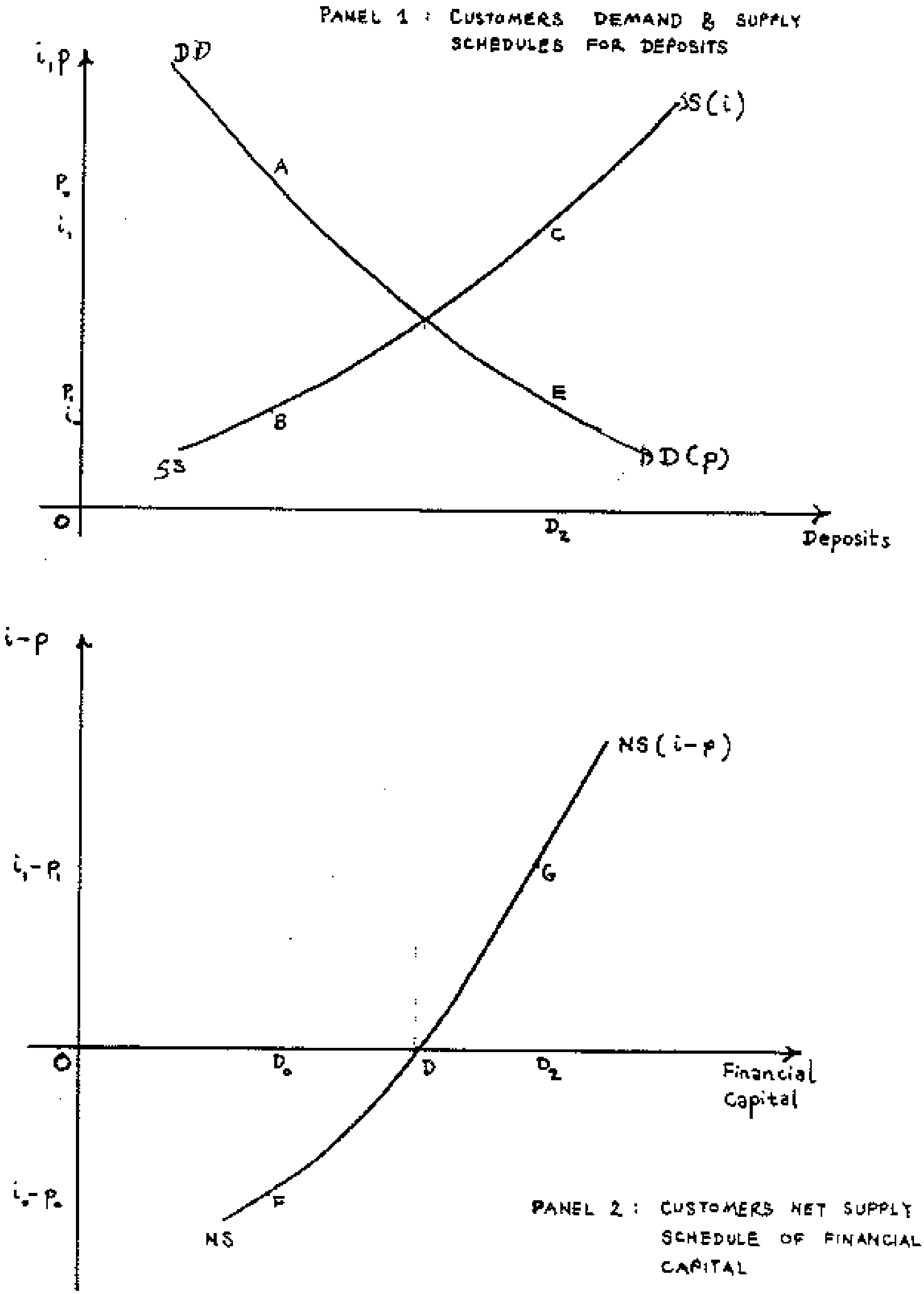
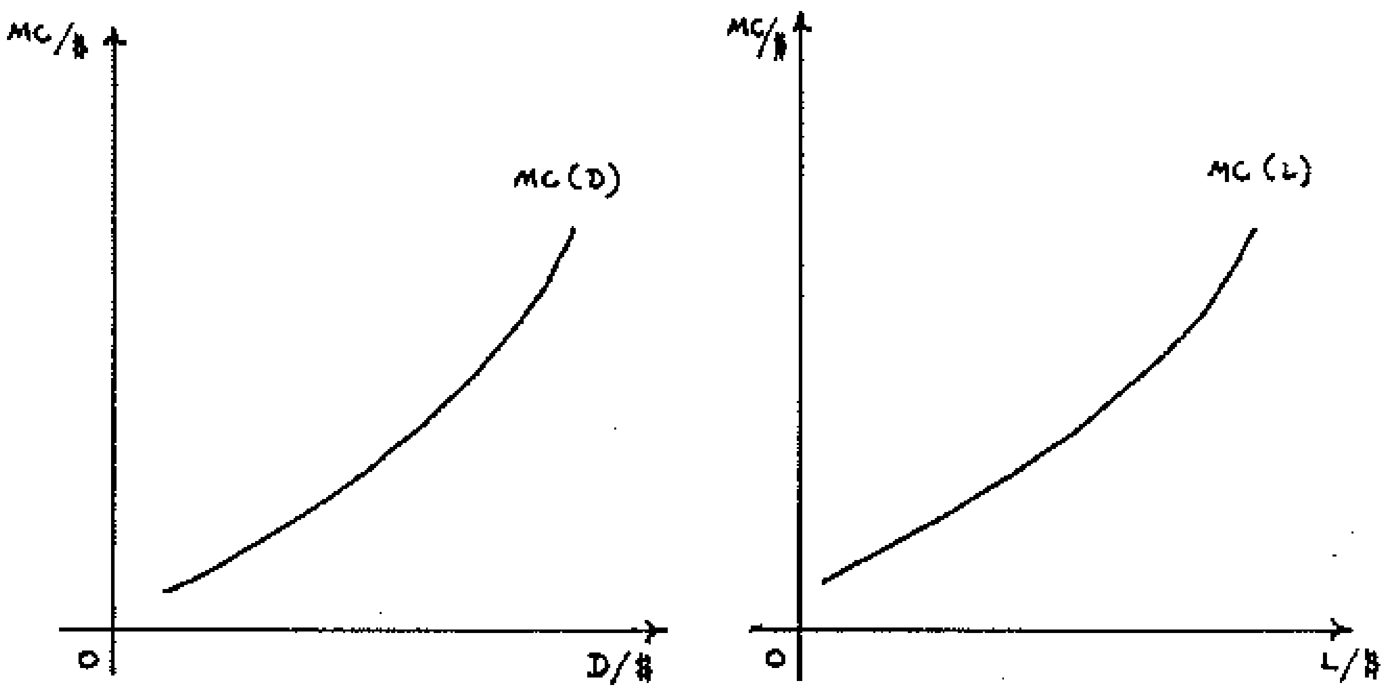

PANEL 1 : CUSTOMERS DEMAND & SUPPLY SCHEDULES FOR DEPOSITS
i, p
DD
A
SS(i)
C
E
B
SS
DD(p)
O
Deposits
i-p
NS(i-p)
G
O
D
F
NS
Financial Capital
PANEL 2 : CUSTOMERS NET SUPPLY SCHEDULE OF FINANCIAL CAPITAL

Diagram 2



(a)
THE SUPPLY OF TRANSACTION DEPOSITS

(b)
THE SUPPLY OF LOANS

as G, on the NS schedule imply a positive cost of capital, $i - P > 0$. At G, they will pay P_1 per \$ transaction services (point E on the DD curve) and demand i_1 per \$ deposit as suppliers of financial capital (point C).

An equilibrium will occur at whatever point the demand for the loan services offered by banks (not shown) intersects the net supply schedule for financial capital in the lower panel. The intersection of DD and SS represents the breakeven point where the marginal benefits of the transaction service offered to the customer equals the marginal cost of financial capital to the lender, and is simply one point on the NS curve (point D).

The Production Function

The FI produces transaction deposits with the aid of physical factors of production, labor, capital (buildings, computers), land, materials, etc. For simplicity, there is only 1 composite factor, k, with a unit cost of \$W. The marginal cost schedule for supplying transaction output is shown in Diagram 2a. Similarly, the processing of loans involves physical inputs and its supply schedule is depicted in Diagram 2b. Both these schedules are determined jointly due to inseparable production functions involving transray economies of scale. The MC function for loans is not a conventional function for its assumes that as the level of loans is expanded so is the level of financial capital. The production function for loans is described as

$$L = \min[D, g(k)]$$

where g(k) is the physical production function linking the volume of loans to the value of physical inputs. Thus loans are produced with both deposits (financial capital) and physical inputs. The actual marginal cost of producing one dollar of loans is equal to the addition of the MC(D) and MC(L) schedules to the NSD(i - P) shown in Diagram 3. This schedule has been derived under the condition of the critical financial intermediation balance sheet restriction, namely, that D = L, in our simple exposition. If the FI is a price taker in the loan market, it will face a perfectly elastic supply curve at the prevailing market rate, r, as indicated in Diagram 3. Equilibrium is established at point E and DD* = L* is the optimal level of the balance sheet. The optimal condition for equilibrium is that

$$r \geqq MC(L) + MC(D) + (i - P)$$

The optimal level of deposits and loans for any financial intermediary depends on the yield on loans, costs of inputs, customer valuation of transaction services and the rate of time preference. Shifts of any of these components will shift the equilibrium point E.

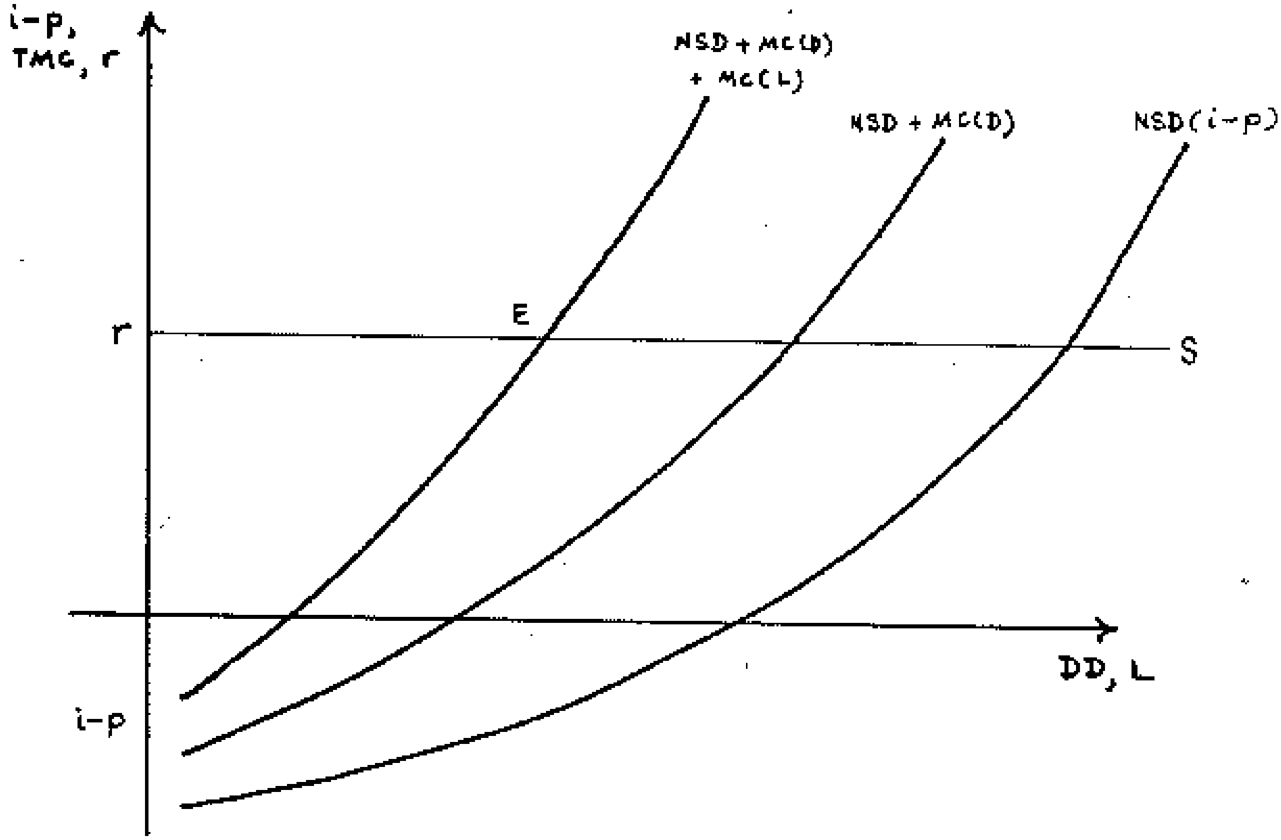
The above exposition can be easily extended to include multiple earning assets and other banking output activities such as leasing, deposit boxes and trusts.

An important implication of the above theory is that unless banks expand into nonbanking activity such as brokerage or trusts, then the elasticity of substitution between financial capital and computers and/or labor will be zero for a given quality of services.[5]

III. Econometric Methodology

We estimate a flexible cost function for a multiproduct banking firm. We posit a priori restrictions so as to establish consistency between a well-behaved production function and the dual cost system.

Diagram 3



EQUILIBRIUM FOR THE FI

Moreover following Christianson, Jorgensen and Lau (1973) we utilize Shephard's Lemma and estimate the translog cost function together with the share equations utilizing Zellner's seemingly unrelated equations (SUR). This system is then estimated together with the cross equation restrictions implied by Shephard's Lemma and Linear Homogeneity in prices.[6] From the above system we can derive economies of scope and multiproduct scale economies. In addition, we can estimate specific scale economies as well as elasticities of substitution between the inputs in the model. The above procedure is carried out for each quartile in our four annual samples.[7]

The system to be estimated is as follows:

$$(1) \qquad LTC = \alpha_0 + \sum_i^4 \alpha_i LX_i + \sum_i^3 \beta_i LP_i + \tfrac{1}{2} \sum_i^4 \sum_j^4 \alpha_{ij} LX_i LX_j + \sum_i^4 \sum_j^3 \gamma_{ij} LX_i LP_j$$

$$+ \tfrac{1}{2} \sum_i^3 \sum_j^3 \beta_{ij} LP_i LP_j + \delta_1 TNO + \delta_2 ALNS + \delta_3 ADEPS + V$$

$$(2)\text{-}(3) \qquad S_i = \beta_i + \sum_{j=1}^{3} \beta_{ij} LP_j + \sum_{j=1}^{4} \gamma_{ij} LX_j + U_i$$

where:

where:	LTC	is the log of total costs
	LP_1	log of interest on available funds
	LP_2	log of wages
	LP_3	log of computer rental
	LX_1	log of deposits
	LX_2	log of loans
	LX_3	log of investments
	LX_4	log of fee-based banking activity

TNO	number of banking offices
ALNS	log of average loan size
ADEPS	log of average deposits
S_1	share of interest in total costs
S_2	share of wages in total costs
V, U_1, U_2	random disturbances with covariance matrix Σ.

It is quite evident that the share equations involve no loss in degrees of freedom. Only two share equations are estimated since adding a third would lead to singularity in the error covariance matrix.

The main justification for specification of the translog equation (1) is that deposits appear as an output -- transaction services -- whereas the interest on available funds appears as an input -- price -- the rental cost of financial capital. This is the rationale for including both deposits and interest rates in this dual specification. We have also added three extra terms to control for number of branches, average loan size and average deposit size.[8] The above specification also includes a computer rental variable LP_3.

Economies of Scale

In the multiproduct banking firm economies of scale are estimated utilizing Baumols Ray Average Costs. Intuitively, we ask the question of whether or not an equiproportionate increase in all outputs (LX_1, LX_2, LX_3 and LX_4) would lead to a less than proportionate increase in total costs. If such is the case, we have declining ray average costs which imply economies of scale. Ray average costs of the multiproduct bank are defined as

$$(4) \qquad RAC(\underline{X}) = \frac{TC(\underline{X})}{\Sigma X_i} = \frac{C(k\underline{X}^{\circ})}{k}$$

where $k\underline{X}^{\circ} = \underline{X}$ and $\Sigma X_i^{\circ} = 1$. This is the standard average cost of the composite commodity whose unit is the vector $\underline{X}^{\circ} = [X_1^{\circ}, X_2^{\circ}, X_3^{\circ}, X_4^{\circ}]$. To test for declining ray average costs (with respect to composite output), substitute $X_i = kX_1$ for i = 2,3,4 into the translog equation and differentiate with respect to X_1. The solution is,

$$(5) \qquad \frac{\partial LTC}{\partial L\underline{X}} = \sum_{i=1}^{4} \alpha_i + \sum_{i=1}^{4}\sum_{j=1}^{4} \alpha_{ij} LX_j + \sum_{i=1}^{3}\sum_{j=1}^{4} \gamma_{ij} LP_i$$

if $\frac{\partial LTC}{\partial \underline{X}} \leq 1$, economies of scale exist.

Moreover, specific economies of scale or elasticities of costs with respect to outputs can be computed by differentiating (1) with respect to LX_j for j = 1,4. This yields

$$(6) \qquad \frac{\partial LTC}{\partial LX_j} = \alpha_j + \sum_{i=1}^{4} \alpha_{ij} LX_i + \sum_{i=1}^{3} \gamma_{ij} LP_i \qquad \text{for } j = 1,2,3,4.$$

One can observe that

$$(7) \qquad \frac{\partial LTC}{\partial L\underline{X}} = \sum_{j=1}^{4} \frac{\partial LTC}{\partial LX_j}$$

so that the sum of specific scale economies must equal the overall scale economies defined by declining ray average costs. In the estimation procedure, we calculate $\partial LTC/\partial L\underline{X}$ at the mean of each quartile, where each quartile is estimated independently each year.[9]

Economies of Scope

Economies of scope or jointness in production is said to exist between any two outputs i and j if $\partial TC/\partial X_i \partial X_j < 0$. This is a sufficient condition to insure that $TC(0,X_j) + TC(X_i,0) \geq TC(X_i,X_j)$.[11] Denny and Pinto (1978) have shown that the sufficient condition for cost complementary is that

$$\frac{\partial^2 LTC}{\partial LX_i LX_j} + \left(\frac{\partial LTC}{\partial X_i}\right)\left(\frac{\partial LTC}{\partial X_j}\right) < 0.$$

In terms of translog specification (1) the above condition can be approximated around the mean of each variable to

(9) $$\alpha_i \alpha_j + \alpha_{ij} < 0 \qquad \text{for all } i,j \quad i \neq j.$$

If (9) holds, economies of scope are said to exist. We estimate (9) for each pair of outputs.

Elasticities of Substitution and Derived Demand Elasticities

Allen's partial elasticities of substitution are calculated as follows,

$$\sigma_{ij} = [\beta_{ij} + S_i S_j]/S_i S_j \qquad \text{for } i \neq j$$

and

$$\Omega_j = [\beta_{jj} + S_j(S_j - 1)]/S_j$$

where σ_{ij} is the elasticity of substitution between i and j and Ω_j is the derived demand elasticity for input j with respect to price j. It should be noted that a necessary condition for the Hessian matrices' eigenvalues to be nonnegative (to insure concavity of the cost function) is that $\Omega_j < 1$ for all j.

Other Tests

Further restrictions on the translog technology in (1) can be imposed to test for homotheticity, homogeneity, and separability. The homogeneity postulate is satisfied if $\Sigma \beta_i = 1$, $\sum_i \beta_{ij} = \sum_j \beta_{ij} = 0$ and $\sum_i \gamma_{ij} = 0$. We estimate the system (1), (2) and (3) imposing the above homogeneity system. Equation (1) can also be tested for a Cobb-Douglas or CES specification. In the Cobb-Douglas case, all the second order terms should be zero. A weaker case is that of homotheticity where each α_{ij} and γ_{ij} should be zero. F tests can be performed to test for these restrictions.

We also tested the null hypothesis that technological and cost parameters differed across quartiles. For his purpose the unrestricted sum of squared residuals (allowing parameters to differ across quartiles) was compared to the sum of squared errors of restricted system using an F statistic. This was calculated spearately for each year, 1979-1982.

Finally, our theory of financial intermediation expressed earlier, suggests that interest costs should be included in total costs and that an interest yield should be included in the cost function as a price of inputs. Many researchers have not pursued this specification. We thus estimated the system without interest costs and an interest rate and compared this set of regressions to the original regressions.

We now turn to a description of our data and our preliminary empirical findings.

IV. The Data and their Measurement

Data used in this study are from the Federal Reserve Functional Cost Analysis program from the years 1979 through 1982. After preliminary screening, 623 banks were included in the sample ranging in deposit size from a minimum of about $6 million to a maximum of $2.6 billion in 1982. The mean deposit size was $141 million. The major advantage of this sample is that it presents cost estimates that are based on a standardized procedure for measurement while its major disadvantage is that it is biased downward by size and does not include any of the nation's largest banks. Another disadvantage is that different banks may participate in the FCA program each year and the individual banks cannot be identified to track a year to year common bank sample. For this reason we divided the banks into quartiles or deciles in order to measure economies of scale and scope by bank size groups.

A. Total Costs (TCI). To measure economies of scale, we chose to include the total costs of inputs used to provide the various outputs of the banks. These include wages and salaries of officers and employees, interest paid to attract funds, and the actual or estimated cost of on-premise or off-premise computer expense. We differed from other studies in two significant respects. We included interest costs because we believed them to be a legitimate input whose costs are both significant in size and apt to differ among banks. On the other hand their inclusion raises the question of endogeneity as an independent variable in the regression equation, resulting in possible biased estimates. Other researchers, with the exception of Murray and White, have excluded interest and concentrated on operating costs alone. On the other hand, others have included costs of supplies, materials and related expenses to specific outputs included in their equations. We have not, believing that they are not of great importance to scale and scope economies. Because of our interest in measuring the impact of computer technology on scale and scope economies, we included estimates of computer expense in total costs.

B. Outputs. Four logs of outputs were included in our regression equations:

DEP - total deposits include demand deposits and time deposits, including certificates of deposit, $100,000 and over

LOAN - loans outstanding include real estate loans made and serviced, commercial, consumer, construction, agricultural and other loans

INV - investments include short-term money market instruments and long-term securities held

NBNK - non-balance sheet expense items (NBE) include safe deposit, trust, data services, and other agency expenses.

C. Input Prices. The logarithmic prices of labor, financial capital and computer capital were included:

INT - interest cost of available funds was measured by dividing interest costs incurred on deposits and borrowings during the year by the average amount outstanding during the year

WAGE - the average wages per employee (including officers but not directors) was calculated by dividing the aggregate wages paid during the year by the average number of officers and employees on the payroll during the year

RENT - the average annual computer rental value per CPU hour at prime time rates was provided by taking the bank's estimate of the current equivalent market monthly rental price for its on-premise mainframe computer multiplied by twelve divided by the reported average weekly number of CPU hours multiplied by 52.

These estimates of average computer rental prices were available only for banks with on-premise mainframes. For other banks, the mean rental value per CPU hour by asset size decile for reporting banks was assigned to other individual banks groups by asset size decile so that banks not reporting estimated computer rental values were assigned an estimate that was identical to the mean rental value of the reporting banks in the corresponding size decile.

D. Other Variables. The average size of loans and the average deposit size were included to permit measurement of scale and scope economies in terms of the number of accounts rather than dollar volume.

AVLOAN - the dollar value of the average loans outstanding during the year divided by the average number of loan accounts during the year

AVDEP - the dollar value of the average of deposits outstanding during the year divided by the average number of deposit accounts during the year

OFFICE - the total number of full service, limited service offices and paying and receiving stations

Since the focus of this study was to investigate the impact of computer technology upon scale and scope economies, only banks that utilized computers were included in the sample. Specifically, the questionnaire permitted classification of the number of responding banks into three groups in each year:

Computer Status	1982	1981	1980	1979
Both on- and off-premise	240	184	174	153
On-premise only	84	79	75	103
Off-premise only	299	349	401	463
Neither	2	4	3	11
Total Reporting Answers	625	616	653	730
Banks not Reporting Answers	238	180	171	142
Total Reporting Banks	863	796	824	872

By deducting the "neither" category from the total of banks reporting answers to the computer status question, the sample of banks in our investigation was derived. Of these banks, the number of banks providing estimates of computer current market rental rates were included in a separate sample whose numbers are shown below:

Bank Samples	1982	1981	1980	1979
All Bank Sample	623	612	650	719
Computer Bank Sample	270	203	214	223

For more explicit information on the computation of the variables see Appendix 1, Translog Data Variables.

V. Empirical Findings

Table 1 reports the description of data in the on-premise computer sample, while Table 2 describes the pooled on premise and off premise computer sample. Deposit size ranges from 5.8 million to $2.6 billion, while total costs range from about $½ million to $310 million per annum. One also notes the high standard deviation of the computer rental rates in both samples. The average wage rate in both samples around $18,000 per annum seems reasonable.

Table 3 reports the simultaneous regression coefficients in equations (1), (2) and (3), in each the quartile for 1982 and table 4 reports the entire sample in 1979, 1980, 1981 and 1982. In all cases the goodness of fit is unsurprisingly high. The simultaneous generalized least square regression with Shephard's cross equation restrictions improves the fit considerably, when all these systems are compared to either linear or non-linear OLS. One notes immediately that aggregation of the data leads to lower standard errors on the parameters, due to the larger population size in the 1982 sample. Furthermore by inspection of table 3 the coefficients appear to be quite different across quartiles. To test this proposition formally, we estimated F statistics in each year. The sum of squared residuals in the restricted regression of equation 1 was calculated under the assumption that the coefficients were equal in each quartile. The F statistics are reported in Table 5. In each year, we find that the hypothesis of equality in parameters across quartiles is rejected at high confidence intervals, greater than 99% in all the years. We thus conclude that the production function parameters vary with bank size and that aggregation of quartiles will bias measures of scale and scope parameters.

Again by inspection of tables 3 and 4 one notes that many of the interaction terms are significantly different from zero, perhaps, due to scope economies. After imposing linear homogeneity on costs with respect to prices, we tested whether the production function could be represented by homothetic technologies. The dual of the C.E.S. production function requires that each of the parameters α_{ij} and γ_{ij} be restricted to zero. The Cobb Douglas (a special case of the C.E.S.) must also have (in addition to the above, C.E.S. restrictions) β_{ij} equal to zero (i.e., all the interaction terms are not significantly different from zero). The F statistics for each quartile and year 1979-1982 for the pooled on premise and off premise computer sampler are shown in Table 6. In the aggregate samples, the C.E.S. specification is rejected at the 1% level of significance in all four years. In 1981, C.E.S. is rejected at the 1% level in all quartiles, 3 out of 4 quartiles in 1980 and 1982 and only once in 1979. The Cobb Douglas specification cannot be rejected at 5% in the second quartile of 1979 and at 1% in the second quartile of 1982. In 75% of the samples, the C.E.S. as technology is rejected, and in only one case, we could not reject a Cobb Douglas specification at a 5% level of significance. Rejecting Cobb-Douglas and C.E.S. implies that cost complementarities in the production of multiple products are present. This obviously has serious ramifications for the optimal scale of bank production as well as the variety of products due to scope economies.

Economies of Scale

Table 7 describes ray average costs (measured at the mean of each sample) for the pooled computer sample for each quartile and aggregate each year, 1979-1982. In the aggregate samples of 1979 and 1982, one cannot reject the hypothesis that there are constant returns to scale. But in 1980 and 1981, one can significantly reject the absence of scale economies.

When the data is split into quartiles, there are significant economies of scale in the first two quartiles in all years and during 1980 and 1981 there are significant scale economies in the fourth quartile (largest asset size). We also find no significant diseconomies of scale in any of the samples throughout the four years. These findings sharply contradict the findings of previous researchers [Gilligan et al. and Benston et al.], who have used aggregate data and found no economies of scale beyond banks with $50 million in deposits and moreover, have found diseconomies in large banks. The fact that the degree of scale economies depends nonmonotonically on bank size is consistent with our earlier hypothesis (i.e., table 6) that production functions differ with size. In all the four years, scale economies are largest in the second quartile -- .91 in 1979, .84 in 1980, .76 in 1981 and .91 in 1982.

Table 8 describes the specific scale economies or the decomposition of ray average cost elasticities into activities. Fee-based banking activity appears to contribute substantially to scale economies in all the years and across all quartiles. One would suspect that banks in this size group have not expanded their nonbanking activities to the same extent as the large money market banks, since the banking deregulation bills in the eighties. In order to compete against the bigger banks, they will have to expand this activity. Overall during 1980-1982, credit expansion is the most costly for banks, although for very small banks in the first quartile, deposit expansion is far more expensive than loan expansion, during each year 1979-1982. Money market activity (investments) is the cheapest source of potential bank activity expansion in aggregate and quartile data over all the years.

Economies of Scope

Table 9 describes measures of scope economies in each quartile in the pooled sample. In table 10 we perform F-statistic tests where the null hypothesis is no scope economies for any pair of the four outputs. We significantly reject the nonlinear restriction imposed by zero scope economies. This is true for all quartiles and years. Table 10 presents a test for the aggregate sample in 1982.[13] The above finding is consistent with Gilligan, Smirlock and Marshall (1984), and Gilligan and Smirlock (1984) covering the years 1973-1978 who also found significant scope economies.

Examination of table 9 shows that scope economies are strongest between deposits and investment as well as deposits and loans. There are also scope economies between nonbank activity and all the others as evidenced by the negative signs in columns 4, 5 and 6. We were however surprised to find strong scope diseconomies between Loans and Investment in all years over all quartiles. There does appear to be a lessening amount of scope economies for both loan-deposits and loan-investments.

The Deposit-Investment aggregate scope coefficient declines from 8.4 to 2.5 over the 1979-1982 period and from 11.7 to 2 for Deposit-Loans over the same period. One should note, however, that the pattern of scope economies is not monotonic. In fact from 1980 to 1981 both scope coefficients increased, rather than decreased. More research will have to focus on the source of scope economies.

The above findings suggest that strong jointness in production does exist for banks confirming the earlier findings of Gilligan et al. with a 1978 sample and Gilligan and Smirlock (1984) in their sample covering the years 1973 to 1977.

The Substitutability of Computers in Banks

Tables 11 and 12 summarize our findings on the elasticity of substitution between all inputs as well as elasticities of derived demand. In many cases the signs are wrong -- for example, the elasticity of financial capital with respect to interest costs and labor with respect to wages are of the wrong sign. There appears to be much multicollinearity in the estimated system. A rise in yields could well be reflecting a rise in asset earnings, thus producing the wrong sign. Still one of our predictions was that financial capital would be a relatively poor substitute for labor or capital due to the balance sheet restriction or limitational input effect. This seems to be borne out by the data, where the elasticity of substitution between computers and labor is far greater than between financial capital and the physical inputs.

Two elasticities seem reasonable and are generally significant throughout all quartiles and aggregates in each year. These are the own elasticity of computers and the elasticity of substitution between labor and computers. The elasticity of substitution is relatively large in the aggregate sample -- in 1982 it was 2.92 in the on premise sample and 1.8 in the pooled sample with the exception of 1980, the elasticity of substitution in the aggregate samples and 1982 quartiles was not less than unity. Among larger size banks the data of 1982 confirm that on-premise computer banks tend to displace labor more than off-premise computer banks. The on-premise elasticity of substitution is 2.92 (significant at the 1% level) as opposed to 1.8 for the pooled sample. The derived demand elasticity for computers has been relatively small and stable from 1979-1982. In 1982, this value was -.35 and -.38 in the on premise and pooled sample respectively.

Interest Rates and Measurement Error

With the exception of Murray and White (1983), most empirical studies have excluded interest rates from the cost function. Often total costs have included interest expenses, while the interest rate is excluded from the list of independent variables. If interest rates are correlated across banks (and there is every reason to believe they are), the estimates will be biased and inefficient. If, however, one excluded interest costs in the total costs variable and interest rates as an input price, would the results we have shown here be significantly different?

In Table 13 we reestimate scale economies without interest expenses and an interest rate. In the aggregate sample, it appears that there are significant scale economies in each year. Moreover, the scale economies after 1979 were more pronounced, being as low as .42 in 1980-3rd quartile. We simply note that ray average costs (and the regression parameters more generally) are sensitive to interest rate specifications. Earlier work ignoring interest costs (the most important component of banking costs) cannot be robust.

VI. Conclusions

This is an embryonic stage in our attempt to understand how technology and deregulation would affect the dynamic structure of the banking system. To do this we presented a simple theory of how financial intermediation interacts with physical production. This led us to the conclusion that as long as banks choose differential liability portfolios, exclusion of interest yields from the dual cost function is a serious empirical misspecification. Moreover, in previous empirical studies interest costs are often included in total costs and thus leaving out an interest rate in the dual specification would again bias the results, if interest costs are correlated across banks. We have shown that banking cost functions are very sensitive to interest rate specification.

A major innovation of this study is to include a computer rental term in our econometric model. This enabled us to estimate both the derived demand elasticity for computers as well as the elasticity of substitution between computers and labor from 1979-1982. While the computer price elasticity is inelastic, the substitutability -- particularly of on-premise computer banks -- is very high. Any reduction in computer rental rates relative to wages would lead to significant adjustments in the banking labor force. An implication of this is that the introduction of microcomputers, a close substitute for on-premise computers, could lead to serious employment reductions.

In contrast to some other studies we estimated individual equations for each quartile between 1979 and 1982. We found that technology parameters vary significantly within bank size and across time, with no apparent pattern. While aggregate data tended to support earlier studies showing economies of scale for small banks and diseconomies for large banks, our disaggregated panel data show a remarkably different result. We find declining ray average costs for both small and big banks, once each quartile is estimated independently. Thus aggregation of data may understate true scale economies.

Significant economies of scope always prevail for deposits and investments and for deposits and loans, throughout all samples. There also appears to be scope economies between nonbank activity and with deposits, investments and loans. With recent deregulation of certain banking product lines and strong specific scale economies for "off balance sheet" bank activity, as well as scope economies, one would suspect that the system will evolve into a highly efficient supermarket system. Our findings support the hypothesis that efficiency can only be achieved by increasing banking concentration and expanding product variety. With the advent of the new telecommunication technology, interstate banking restrictions and regulations, which explicitly prevent an integration of traditional commercial banking and nonbanking activity -- such as brokerage and investment banking -- will restrict the realization of significant economies of scale and scope.

Footnotes

[1]Even if no scale or scope economies exist on the supply side, scope economies on the demand size could induce greater concentration.

[2]See Gilligan et al. (1983) for a similar finding using 1978 FCA data.

[3]For example Longbrake and Haslem (1965), Koot (1978), Murray and White (1980) and more recently the replacement of the Cobb-Douglas production function with generalized (Translog) cost function models, for example, Benston, Hanweck and Humphrey and Gilligan et al.

[4]An exception is Murray and White (1983) who study small scale credit unions in Canada.

[5]This has immediate implications for bank deregulation outcomes. In a free supermarket system, banks could expand output in brokerage and investment banking activity without the banking deposit restriction.

[6]See Christianson et al. (1973) for a comparison between ordinary least squares estimates and SUR estimates. In the banking area, the above system has been estimated by Humphrey (1981) and Murray and White (1983).

[7]Pooled cross section-time series was ruled out at this stage since strict confidentiality by the Fed is maintained about bank participants in each sample.

[8]Different levels of these variables could also affect the parameter estimates. Gilligan et al. and Benston et al. have estimated separate equations for branch versus unit banks.

[9]In comparing our estimates with Gilligan et al. one should note that they implicitly assume stability of parameters across quartile size.

[10]See, for example, Baumol (1977).

[11]See Murray and White (1983) for a derivation of (9). In their models all variables are standardized around their mean values. In terms of estimation, equation (1) in our model would be identical to theirs, except for the intercept term.

[12]A monotonic relationship might exist, however, on an intra-quartile basis that is between banks with the same parameters.

[13]An F test is valid here since we ignore the share equations. In many of the cases the nonlinear algorithm did not converge after 3000 iterations! In the tests of table 10, convergence was achieved.

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TABLE 1

Description of Data for On Premise Computer Banks, 1982

	N	Mean[a] Deposit Volume	Mean[a] Annual Wage Rate	Mean[a] Computer Rental Rate	Average[a] Loan Size	Average[a] Deposit Size	Mean[a] Total Costs
1st Quartile	67	$ 38M (14.3)	$17,987 (3,530)	$ 30 (116)	$ 8,739.40 (4,787)	$3,133 (1,135)	$ 4M (1.6)
2nd Quartile	68	$ 86.3M (14.3)	$18,046 (2,108)	$ 33.8 (57.1)	$ 8,518.70 (3,451)	$3,137 (667)	$ 9.3M (1.7)
3rd Quartile	68	$150M (30.9)	$17,945 (2,298)	$ 43.5 (68)	$11,018 (8,278)	$3,531 (827)	$17M (3.9)
4th Quartile	67	$523M (398)	$18,090 (2,302)	$111 (138)	$ 8,225 (6,920)	$3,615 (1,552)	$60M (46)
1982 Sample	270	$225M (32)	$18,017 (2,604)	$ 54 (105)	$ 9,130 (6,216)	$3,354 (1,114)	$22.5M (3.1)

[a]Standard deviation in parentheses

Range for Sample

	Minimum	Maximum
Deposits	$8M	$2,650M
Loans	$3M	$1,855M
Total Costs	$.6M	$ 310M

Table 2

Description of Data for Pooled on Premise and Off Premise Computers, 1982
(standard deviations in parentheses)

Asset Size Group (low to high)	No. of Banks	Mean Deposit Volume[a]	Mean Annual Wage Rate	Mean Computer Rental Rate	Average Loan Size	Average Deposit Size	Mean Total Costs[a]
Group #1	155	$30.1 (13.1)	$18,061 (3,446)	$26.4 (76.4)	$8,311 (3,766)	$2,979 (1,010)	$3.2 (1.4)
Group #2	156	64.1 (22.4)	18,019 (2,594)	28.5 (38.0)	8,767 (3,576)	3,191 (814)	6.8 (2.5)
Group #3	157	111.0 (41.3)	18,128 (2,320)	39.8 (46.0)	10,333 (6,277)	3,456 (725)	12.4 (5.0)
Group #4	155	359.1 (331.1)	18,371 (2,717)	100.1 (98.4)	10,982 (11,926)	3,861 (1,620)	41.0 (38.3)
All Banks	623	140.8 (210.6)	18,145 (2,795)	48.6 (75.1)	9,600 (7,280)	3,372 (1,144)	15.8 (24.3)

[a]millions of dollars

Range for Sample[a]	Minimum	Maximum
Deposits	5.8	2,650.4
Loans	2.8	1,855.5
Total Costs	.7	310.5

Table 3[a]

DEP. VARIABLE
LOG TOTAL COSTS

SEEMINGLY UNRELATED REGRESSION COEFFICIENTS FOR 1982[b]

INDEPENDENT VARIABLES	Transcendental Logarithmic Equation[c] 1st quartile	2nd quartile	3rd quartile	4th quartile	pooled sample
CONSTANT	.64 (5.47)	16.2 (29.4)	42.1 (31.2)	-1.48 (4.17)	8.42** (1.06)
DEP	-1.58 (2.3)	-8.3 (6.6)	-5.9 (3.9)	-1.09 (-.61)	-.36 (.53)
LOAN	1.98 (1.41)	5.6 (3.6)	.52 (2.7)	1.097 (1.18)	.44 (.31)
INV	1.76 (1.02)	2.8 (.24)	2.62 (1.85)	2.38** (.7)	1.09** (.2)
NBNK	-.12 (.13)	-.15 (.27)	.68** (.28)	-.53** (.18)	-.13** (.05)
INT	2.44** (.22)	1.9** (.27)	2.7** (.3)	2.26** (.21)	2.55** (.08)
WAGE	-1.3** (.22)	-.88** (.26)	-1.58* (.27)	-1.24** (.22)	-1.4** (.07)
RENT	-.48** (.2)	.77 (.56)	-.71 (.54)	-.14 (.17)	-0.05 (0.05)
DEP^2	2** (.66)	4** (1.5)	3.76** (.73)	1.71** (.49)	1.88** (.23)
$LOAN^2$	.65** (.22)	1.48** (.41)	1.19** (.29)	.64** (.19)	.67** (.08)
INV^2	.47** (.11)	.81** (.18)	.78** (.14)	.39** (.05)	.52** (.03)
$NBNK^2$	-.001 (.003)	-.003 (.004)	.01 (.004)	-.00 (.007)	.001 (.001)
LOAN·DEP	-1.12** (.38)	-2.7** (.78)	-1.9** (.45)	-.94** (.29)	-1.02** (.14)
INV·DEP	-.91** (.26)	-1.9** (.53)	-1.6** (.31)	-.8** (.17)	-.9** (.09)
NBNK·DEP	-.04 (.04)	.05 (.05)	.059 (.04)	.01 (.04)	-.04** (.01)

Table 3 (continued)

INDEPENDENT VARIABLES	1st quartile	2nd quartile	3rd quartile	4th quartile	pooled sample
LOAN·INV	.44** (.15)	1.03** (.3)	.77** (.22)	.33** (.12)	.4** (.06)
LOAN·NBNK	.03 (.02)	.03 (.03)	-.01 (.02)	-.02 (.03)	.02** (.009)
INV·NBNK	.01 (.01)	.02 (.02)	.02 (.01)	.03 (.02)	(.02)** (.007)
DEP·INT	-.11** (.04)	.01 (.03)	-.03 (.03)	-.03 (.03)	-.06** (.016)
DEP·WAGE	.128 (.04)	-.005 (.04)	.03 (.03)	.02 (.03)	.055** (.016)
DEP·RENT	.09 (.07)	-0.08 (.09)	-0.03 (.09)	.1* (.05)	.082** (.024)
LOAN·INT	.08** (.02)	.02 (.02)	.002 (.02)	.02 (.02)	.037** (.01)
LOAN·WAGE	-.08** (.02)	-.02 (.02)	0.00 (0.02)	.002 (.02)	-.03** (.009)
LOAN·RENT	-.03 (.04)	.004 (.05)	.067 (.055)	-.06* (.027)	-.04** (.01)
INV·INT	.1** (.01)	.04** (.02)	.05** (.015)	.03* (.01)	.05** (.007)
INV·WAGE	-.09** (.02)	.05** (.02)	-0.05 (.01)	-.02* (.01)	-0.05** (.007)
INV·RENT	.04 (.03)	.04 (.04)	-0.003 (.03)	-.03 (.02)	-.04** (.01)
NBNK·INT	-.01** (.003)	.02** (.002)	-.009** (.002)	-.01** (.004)	-.08** (.001)
NBNK·WAGE	.01** (.003)	.02** (.001)	.009** (.002)	.009** (.004)	.012** (.001)
NBANK·RENT	-.005 (.004)	.006 (.004)	.004 (.005)	-.001 (.007)	.002 (.88)
INT^2	.22** (.01)	.18** (.01)	.16** (.15)	.14** (.016)	.18** (.006)

Table 3 (continued)

INDEPENDENT VARIABLES	1st quartile	2nd quartile	3rd quartile	4th quartile	pooled sample
$WAGE^2$	.16** (.01)	.16** (.01)	.14** (.01)	.1** (.02)	.15** (.006)
$RENT^2$	.02** (.006)	.007 (.007)	.002 (.002)	-.003 (.006)	.003* (.001)
WAGE·RENT	-.003 (.004)	-.008** (.003)	.004 (.003)	.00 (.004)	.00 (.002)
WAGE·INT	.2** (.01)	-.188* (.01)	-.15** (.01)	-.11** (.02)	-.16** (.006)
INT·RENT	-.028* (.005)	-.004 (.003)	.01 (.003)	-.01** (.004)	-.018* (.002)
AVLOAN	-.01 (.01)	.006 (.009)	.001 (.007)	-.018* (.006)	-.001 (.003)
AVDEP	-.2** (.01)	-.027 (.015)	-.02 (.015)	.04** (.01)	-.02 (.006)
OFFICE (TNO)	.002 (.002)	0.000 (.015)	.002 (.0009)	.0009** (.00026)	-.00037* (.00018)
WEIGHTED R^2	.978	.93	.936	.987	.9946
N =	154	156	155	156	121

[a]Standard error in parentheses

[b]This is the pooled on premise and off premise computer sample

**Significant in 2 tailed test at 1% level

*5% level of significance

[c]All variables are in logs with the exception of OFFICE

[d]The share equations can be derived from the above regressions

Table 4[a]

SEEMINGLY UNRELATED REGRESSION COEFFICIENTS 1979-1982

DEP. VAR. COSTS IND. VARIABLES	Transcendental Logarithmic Equation[c] TOTAL 1979	1980	1981	1982
CONSTANT	12.9** (1.1)	9.048* (1.12)	3.75** (1.34)	8.42** (1.06)
DEP	-3.58** (.9)	.078 (.748)	-1.7** (.74)	-.36 (.53)
LOAN	2.61** (.55)	.21 (.43)	.91** (.41)	.44 (.31)
INV	1.97** (.33)	-.85** (.28)	1.8** (.32)	1.09** (.2)
NBNK	-.11* (.054)	-.14** (.05)	.01 (.07)	-.13** (.05)
INT	2.8** (.08)	2.69** (.079)	2.31** (.08)	2.55** (.08)
WAGE	-1.82** (.086)	-1.45** (0.086)	-.39** (.076)	-1.4** (.07)
RENT	.02 (.07)	-.108** (.07)	.09 (.06)	-.05 (.05)
DEP^2	2.6** (.51)	1.21** (.29)	1.62** (.34)	1.88** (.23)
$LOAN^2$	.97** (.18)	.43** (.098)	.55** (.11)	.67** (.08)
INV^2	.49** (.07)	.45** (.05)	.5** (.05)	.52** (.03)
$NBNK^2$	.004* (.002)	.003 (.002)	.007** (.002)	.001 (.001)
LOAN·DEP	-1.5** (.3)	-.62** (.17)	-.79** (.2)	-1.2** (.14)
INV·DEP	-1.01** (.19)	-.68** (.12)	-.79** (.14)	-.9** (.09)
NBNK·DEP	.06** (.026)	-.04* (.02)	-.04* (.025)	-.04** (.01)

Table 4 (continued)

IND. VARIABLES	1979	1980	1981	1982
LOAN·INV	.497**	.25**	.26**	.4**
	(.122)	(.07)	(.09)	(.06)
LOAN·NBNK	.04**	.029*	.01	.02**
	(.02)	(.014)	(.01)	(.069)
INV·NBNK	.02**	.02**	.017	.02**
	(.01)	(.009)	(.011)	(.007)
DEP·INT	-.12**	-0.06**	-.06**	.06**
	(.02)	(.019)	(.025)	(.016)
DEP·WAGE	.136**	.08**	.06**	.055**
	(.024)	(.02)	(0.018)	(.08)
DEP·RENT	.027	.21**	.049	.082**
	(.047)	(.03)	(.028)	(.024)
LOAN·INT	.087**	(.05**	.047**	.037**
	(.015)	(.01)	(.015)	(.01)
LOAN·WAGE	-.089**	-.04**	-.028**	-.03**
	(.015)	(.01)	(.01)	(.009)
LOAN·RENT	-.032	-.14	-.039**	-0.04**
	(.03)	(.02)	(.016)	(.01)
INV·INT	.069**	.05**	.059**	.05**
	(.009)	(.007)	(.01)	(.007)
INV·WAGE	-.07**	-.05**	-.049**	-.05**
	(.009)	(.007)	(.008)	(.007)
INV·RENT	.005	-.067**	-.023	-.04**
	(.018)	(.013)	(.013)	(.01)
NBNK·INT	-.014**	-.01**	-.012**	-.01**
	(.001)	(.001)	(.002)	(.001)
NBANK·RENT	-.001	.002	.006**	.002
	(.003)	(.002)	(.002)	(.88)
INT^2	.21**	.21*	.23**	.18**
	(.006)	(.007)	(.008)	(.006)
$WAGE^2$	.17**	.145**	.03**	.15**
	(.006)	(.07)	(.006)	(.006)

Table 4 (continued)

IND. VARIABLES	1979	1980	1981	1982
$RENT^2$	.006**	.01**	.02**	.003**
	(.002)	(.002)	(.003)	(.001)
WAGE RENT	-.005**	.006**	-.005**	.00
	(.002)	(.002)	(.001)	(.002)
WAGE INT	-.188**	-.187**	-.15*	-.16**
	(.005)	(.005)	(.005)	(.006)
INT·RENT	-.008**	.02**	-.029**	-.01**
	(.002)	(.002)	(.002)	(.002)
AVLOAN	-.007	-.01**	-0.002	-.001
	(.004)	(.004)	(0.004)	(.003)
AVDEP	-0.02**	-.015*	.004	-.02
	(.007)	(.007)	(.007)	(.006)
OFFICE (TNO)	-.0003	-.0005	0.00	.00037*
	(.0003)	(.0003)	(.0003)	(.00018)
WEIGHTED R^2	.9943	.9931	.9933	.9946
N =	716	649	608	621

[a]Standard error in parenthesis

[b]**1% significance; **5% significance

Table 5

Structural Stability Across Bank Size

	F Statistic	DF	Probability $(X \geq F)$
1979	1.73218**	(123,540)	0.99982
1980	2.00972**	(123,480)	0.999999
1981	5.42579**	(123,436)	0.99999
1982	1.93041**	(123,452)	0.9999

**Significant at 1% level. The critical F value at 1% for all samples is approximately 1.4.

Table 6[a]

Testing for C.E.S. and Cobb Douglas Specification[b]

SAMPLE	Degrees of Freedom	C.E.S. F Statistic	Degrees of Freedom	Cobb Douglas F Statistic
1979-1	18,144	1.475	21,144	2.198*
2	18,148	.8247	21,148	1.7
3	18,148	2.798**		
4	18,148	1.825	(21,148)	2.62**
All	18,684	5.896**		
1980-1	18,129	1.285	(21,129)	8.2**
2	18,131	2.3896*	(21,131)	3.25**
3	18,131	3.78**		
4	18,130	3.178**		
All	18,617	7.89**		
1981-1	18,118	4.606**		
2	18,120	3.055**		
3	18,121	3.837**		
4	18,121	4.393**		
All	18,576	34.1**		
1982-1	18,122	3.87**		
2	18,124	1.258	(21,124)	1.97*
3	18,123	4.52**		
4	18,124	4.30**		
All	18,589	13.7**		

[a]Null hypothesis is that the relevant parameters be set equal to zero. ** is a rejection of the null at the 1% level of significance, while * is a rejection at the 5% level of significance; but not at 1%.

[b]If the C.E.S. is rejected, then the Cobb Douglas will also be rejected, thus we do not show Cobb Douglas F statistics in these cases.

Table 7

ESTIMATES OF RAY ECONOMIES OF SCALE[A]

Sample: pooled off premise and on premise banks with linear homogeneity imposed

SAMPLE	RAY ECONOMIES OF SCALE ESTIMATE (RES)	STANDARD ERROR	t-STATISTIC (Null: RES = 1)
1979-I	.918*	.021	4.26
II	.906*	.026	3.55
III	.986	.022	0.58
IV	.987	.011	1.85
1979	.997	.005	.65
1980-I	.943*	.02	2.89
II	.836*	.034	4.79
III	1.04	.037	-1.08
IV	.967*	.011	3.03
1980	.98*	.005	3.15
1981-I	.902*	.024	4.07
II	.759*	.041	17.3
III	.985	.023	0.65
IV	.972*	.01	2.86
1981	.967*	.006	5.67
1982-I	.918*	.019	4.26
II	.906*	.026	3.55
III	.986	.023	0.58
IV	.982	.01	1.78
1982	.996	.005	.65

[A]The t-statistics test the null hypothesis that RES = 1. * is a 2-tailed test rejection of null at 1% significance and ** 5% significance.

Table 8

SPECIFIC SCALE ECONOMIES (SUR)

(LINEAR HOMOGENEITY IMPOSED)

	ON PREMISE COMPUTER SAMPLE				ON PREMISE AND OFF PREMISE COMPUTER SAMPLE			
	Deposits	Loans	Investment	Non Banking	Deposits	Loans	Investment	Non Banking
1982 Q1	.56	.25	.13	.02	.58	.23	.13	.02
Q2	.08	.46	.29	.04	.21	.41	.28	.03
Q3	.14	.46	.33	.02	.17	.47	.3	.02
Q4	.33	.36	.19	.06	.27	.4	.24	.04
All	.34	.40	.22	.04	.32	.39	.24	.03
All(UR)	.36	.39	.21	.04	.34	.39	.23	.02
1981 Q1	.76	.11	-.13	.1	.59	.28	.16	.03
Q2	.29	.37	.23	.04	.34	.36	.22	.04
Q3	-.05	.56	.34	.01	.28	.36	.20	.03
Q4	.41	.28	.21	.03	.58	.14	.21	.02
All	.27	.4	.21	.06	.39	.33	.21	.04
All (UR)	.27	.41	.2	.05	.35	.36	.21	.04
1980 Q1	.81	.02	.04	.05	.8	.06	.065	.023
Q2	.28	.41	.32	.01	.43	.39	.21	.02
Q3	.21	.44	.19	.005	.25	.43	.22	.03
Q4	.22	.46	.19	.06	.28	.44	.18	.05
All	.31	.43	.19	.04	.5	.27	.17	.04
All(UR)	.33	.41	.19	.03	.056	.24	.15	.03
1979 Q1	.46	.26	.14	.02	.73	.16	.06	.02
Q2	.52	.28	.13	.05	.57	.25	.1	.03
Q3	.32	.41	.18	.01	.33	.4	.18	.03
Q4	.32	.36	.21	.05	.35	.36	.21	.04
All	.5	.29	.15	.04	.52	.29	.14	.04
All (UR)	.53	.27	.14	.04	.52	.29	.14	.04

All(UR) - This sample does not impose linear homogeneity.

Table 9

Economies of Scope on Premise and Off Premise Banks
Unrestricted (UR) and Linear Homogeneity (LH) Imposed

		Deposits Loans		Deposits Investment		Loans Investment		Loans Non Bank		Non Bank Investment		Deposits Non Bank	
		UR	LH	UR	LH	UR	LH	UR	LH	UR	LH	UR	LH
1982 -	1	-4.1	-18.1	-3.5	-15.5	3.9	10.6	-.21	-.06	-.20	-.07	.14	.09
-	2	-49.6	-59.6	-25.2	-33.8	16.8	21.4	-.8	-.8	-.41	-.45	1.2	1.3
-	3	-5.0	5.3	-17.1	-7.2	2.1	-.78	.36	-.93	1.8	.7	-4.1	-3.2
-	4	-2.1	-5.9	-3.4	-8.0	2.9	6.3	-.6	-1.2	-1.2	-1.7	.6	1.4
-	All	-1.2	-2.0	-1.3	-2.5	.9	1.5	-.03	-.05	-.11	-.11	0	.06
1981 -	1	-2.1	-7.5	-.9	-2.2	.9	1.8	.01	-.02	-.01	-.01	.03	.01
-	2	2.3	-36.4	-13.2	-36.8	-2.1	40.2	.67	-4.3	-2.5	-4.4	3.2	3.8
-	3	1.3	3.2	.8	1.5	5.3	3.4	-1.0	-.7	.67	-.37	-.5	-.8
-	4	-3.8	-.75	-9.6	-11.3	3.5	5.2	-.4	-.4	-1.0	-.56	1.1	.8
-	All	-2.3	-4.5	-3.9	-5.6	1.9	3.4	.03	.04	.04	.04	-.07	-.07
1980 -	1	-3.0	-17.7	-2.3	-9.8	1.3	6.1	.01	.17	.12	.10	-.16	-.28
-	2	-781.8	-474.1	-419.9	-301.0	314.3	262.5	-15.3	-8.5	-8.2	-5.4	20.5	9.8
-	3	-47.4	-6.2	-4.1	-4.3	.71	8.6	3.97	2.67	-.03	1.7	-12.2	-.86
-	4	-2.9	-3.4	-4.3	-4.2	1.9	2.3	-.28	-.36	-.50	-.52	.60	.62
-	All	-.6	-.25	-.61	-.73	.43	.40	0	0	-.10	-.09	-.06	-.03
1979 -	1	-25.1	-27.2	-13.7	-14.5	9.0	9.3	-.07	-.06	-.03	-.02	.09	.07
-	2	4.6	-6.2	1.6	-.9	1.7	3.0	-1.2	-1.8	-.41	-.3	-1.0	.6
-	3	-.97	-7.9	-9.8	-6.7	2.6	2.4	.35	.30	.39	.27	-1.7	-.99
-	4	-1.5	-1.4	-.33	-.51	.74	.80	-.14	-.16	-.28	-.25	-.22	-.12
-	All	-10.8	-11.7	-8.1	-8.4	5.6	5.9	-.24	-.24	-.19	-.17	.31	.31

Table 10

Significance of Economies of Scope 1982
Pooled Sample

(Nonlinear Least Squares)

	F Statistic
1,2 Deposit Loans	582.59**
1,3 Deposit Invest	582.44**
1,4 Deposit Non Bank	589.45**
2,3 Loans Inv.	344.8**
2,4 Loans Non Bank	49.6**
3,4 Invest Non Bank	59.6**

**Significant at 1% significance (Critical F value is 2.01). These were estimated using nonlinear least squares. The maximum number of iterations allowed was 3,000.

TABLE 11

Elasticities of Substitution (SUR) and Own Elasticities 1982

(linear homogeneity imposed)
(standard (approximate) error in parentheses)

	On Premise Computer Banks			All Computer Banks		
	Financial Capital	Labor	Computer	Financial Capital	Labor	Computer
Q1						
Financial Capital	.004	.002	-.48	.05**	-.23**	-.27
	(.04)	(.18)	(.4)	(.02)	(.08)	(.22)
Labor		-.04	1.32		.14**	1.45*
		(.13)	(1.28)		(.06)	(.76)
Computer			.09			-.09
						.10
Q2						
Financial Capital	.06*	-.41*	.65*	.04*	-.23*	.30
	(.03)	(.21)	(.34)	(.02)	(.09)	(.21)
Labor		.32	.32		.18*	.37
		(.17)	(1.4)		(.07)	(.86)
Computer			-.58**			-.31**
			(.15)			(.07)
Q3						
Financial Capital	-.001	.056	-.69	.02	.11	.18
	(.03)	(.17)	(.44)	(.02)	(.1)	(.23)
Labor		-.09	3.54		.06	2.6*
		(.14)	(2.29)		(.08)	(1.07)
Computer			-.08			.61**
			(.17)			(.07)

TABLE 11 (cont'd)

	On Premise Computer Banks			All Computer Banks		
	Financial Capital	Labor	Computer	Financial Capital	Labor	Computer
Q4						
Financial Capital	-.02 (.04)	.13 (.21)	-.65 (.5)	-.03 (.02)	.20 (.11)	-.28 (.27)
Labor		-.15 (.16)	3.67 (2.09)		-.20* (.09)	2.5* (1.2)
Computer			-.23 (.19)			-.25** (.08)
All (LH)						
Financial Capital	.03** (.01)	-.16 (.07)	-.28 (.15)	.03** (.008)	-.17** (.04)	.05 (.1)
Labor		.09* (.05)	2.92** (.59)	.1**	.1** (.03)	1.8** (.4)
Computer			-.35** (.7)			-.38** (.08)

TABLE 12

Elasticities of Substitution (SUR) and Own Elasticities (LH)
Pooled on Premise and Off Premise Computer Banks
(standard error in parenthesis)

	FINANCIAL	LABOR	COMPUTER
1979			
Financial	.003 (.009)	-.03 (.03)	.23** (.09)
Labor		-.001 (.026)	1.05** (.25)
Computer			-.43** (.03)
1980			
Financial	.02 (.008)	-.09** (.03)	-.07 (.06)
Labor		.045* (.027)	.71** (.21)
Computer			.11** (.03)
1981			
Financial	-.04** (.006)	.17** (.03)	.16** (.04)
Labor		(-.19) (.03)	1.006** (.15)
Computer			-.31** (.032)
1982			
Financial	.03** (.008)	-.178* (.04)	.05** (.10)
Labor		.105** (.03)	1.8* (.4)
Computer			-.38** (.04)

Table 13

Scale Economies without Interest Costs

	Q1	Q2	Q3	Q4	ALL
1982	.75* (.09)	.81** (.07)	.44** (.16)	.98 (.39)	.89* (.023)
1981	.59* (.18)	.53** (.14)	.85 (.15)	.81** (.08)	.80** (.03)
1980	1.037 (.103)	.775 (.52)	.42** (.13)	.79** (.05)	.89** (.03)
1979	.83 (.11)	1.036 (.11)	.915 (.15)	.98 (.04)	.91** .024

LH not imposed [Off Premise and On Premise Pooled]

Null: No scale economies

*Reject Null at 2 tailed 5% t = 1.98

**Reject Null at 2 tailed 1% t = 2.61

APPENDIX

TRANSLOG DATA VARIABLES*

TCI - total costs of inputs: wages (35+36+37), interest (174+291+292+293+294+295+380+381+382+383), computer rental (1079 times twelve)]

SI - interest share of TCI: interest (see TCI component)/TCI

SW - wage share of TCI: wages (see TCI component)/TCI

DEP - total deposits:
146+147+148+149+150+151+262+263+264+265+266+365

LOAN - dollar value of average loans outstanding: see numberator of average loan size

AVLOAN - average loan size: dollar value of average loans outstanding (476_531+532+533+534+626+688+689+690+691) divided by the average number of loan accounts (478+536+537+538+539+631+692+693+694+695)

AVDEP - average deposit size: total deposits (see TDEPS) divided by the average number of deposit accounts (152+153+154+267+269+270+271)

INV - average annual bank investments in U.S. securities (422), tax-exempt securities and loans (423), other investments (424), federal funds sold (425), other liquidity loans (426), trading account secur-ities (427) and purchased real estate mortgage loans not being serviced (477)

WAGE - wages per employee (including officers but not directors): aggregate salaries (35+36+37)/number of employees (31+32)

INT - interest cost of available funds (%): interest cost (174+291+292+293+294+295+380+381+382+383)/available funds (146+147+148+149+150+151+262+263+264+265+266+363+364+365+366)

RENT - average annual computer rental value per CPU hour, prime shift only: annual computer rental value (1079 times twelve)/annual number of CPU hours (1080 times fifty-two)

OFFICE - total number of bank offices: full service, limited service offices and paying and receiving stations (84)

NBNK - non-balance sheet expenses: safe deposit (932), nonbanking functions (agency activities, 1038), trust department (980), data services (1078)

*Numbers shown in parentheses are variable numbers assigned by the Federal Reserve Functional Cost Analysis in its Schedule Reference Listing (SRL) of items on the data tape.