Differences Across First District Banks in Operational Efficiency

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Economists devoted little attention to differences across banks in operational efficiency until about 15 years ago, when banks began to fail with increasing frequency. Some economists (for example, Bennett 1986, Davis 1986, Kaufman 1991) attributed the rising failure rate in part to intensified competitive pressures generated by deregulation and technological innovation. According to this view, stiffer competition disciplined inefficient institutions viable only in a simpler, more protected environment. If this hypothesis is correct, and a significant number of banks are still inefficiently managed, then further deregulation and technological change could "shake up and shake out" the banking industry. Concern over this possibility has spurred efforts to estimate the dispersion among banks in operational efficiency.

Using data from 1985 through 1993, this study evaluates the extent to which operational efficiency—efficiency in the use of inputs—varies within the First Federal Reserve District. This type of efficiency, often referred to as "X efficiency," is one of three types. The other two are economies of scale (efficiency from operating at optimal size) and economies of scope (efficiency from optimal diversification of outputs). Economists have generally found few economies of scale or scope in banking.[1]

This study relies on methodologies developed and applied by other economists who have examined X efficiency in banking. Unlike most other studies that have addressed this issue, however, this study focuses on dispersion in efficiency within a region rather than the nation as a whole.[2] This subnational focus is appropriate because the characteristics of an efficient bank may differ by region. For example, an operational strategy that may be efficient in the Midwest may not be efficient in the East, where institutional, legal, and regulatory environments are different (Evanoff and Israilevich 1991). Furthermore, some banking markets may be national, others regional or local. Consequently, while a bank in Massachusetts may be inefficient relative to one in Missouri, the two banks may not compete with each other in any market. In evaluating a bank's ability to withstand increased competitive pressure, one should compare the bank's operational efficiency with that of its most efficient competitors. In some markets, such as those for lending to mid-sized businesses, the competitors of Massachusetts banks are limited mostly to New England institutions (see Dunham 1986 and Tannenwald 1994).

The article begins with a discussion of the problems inherent in measuring variation among banks in X efficiency. It goes on to describe the principal strategies that economists have devised to resolve these dilemmas. The methodologies used in this study are then presented, along with empirical results. The next section interprets these results and critiques the study's methodologies. The final section summarizes and draws policy conclusions.

Unlike most studies that have examined X efficiency in banking, this study focuses on dispersion in efficiency within a region rather than the nation as a whole.

The study finds substantial dispersion in X efficiency among First District banks. The characteristics of this dispersion have changed over time, however. Differences in X efficiency between the most and least efficiently managed banks have widened. The least efficient banks have fallen further and further below prevailing efficiency standards. By contrast, differences between the most efficiently managed banks and banks exhibiting an average degree of efficiency have narrowed. One interpretation of this narrowing gap is that the difficulties experienced by the District's banks during the late 1980s and early 1990s taught the majority of bank managers a painful but effective lesson on the importance of managing inputs efficiently.

However, the article points out several anomalies in the empirical results that raise doubts about the validity of the methodologies commonly used in measuring X efficiency in banking. Consequently, the article concludes that measures of bank efficiency need further development before one can rely on them with confidence.

I. Problems Inherent in the Measurement of Bank Efficiency

Efficiency is the ratio of a system's effective or useful output to its total input. In order to evaluate the efficiency of a machine or a business, one must identify and measure its inputs and outputs and determine its minimum input/output ratio. Engineers are usually able to satisfy these requirements in measuring the efficiency of a machine. For example, the fuel efficiency of an automobile is measured by the number of miles traveled per gallon of fuel consumed. Given the characteristics of the automobile, the fuel utilized, and the environment in which the vehicle operates, engineers can deduce the maximum possible number of miles per gallon from laws of mechanics and physics.

Measuring the efficiency of a bank is more difficult for several reasons. First, a bank's inputs and outputs are hard to identify; indeed, they can be one and the same. For example, demand and retail time and savings deposits are inputs in that they are important sources of funds used to finance loans. At the same time, according to a national survey (Board of Governors 1992), almost one-half of the operating expenses incurred by U.S. commercial banks are devoted to servicing checking and savings accounts, functions viewed by depositors as outputs.

Second, like many businesses, banks have several inputs and outputs whose quantities are difficult to compare. Banks provide loans, checking accounts, and savings accounts; manage custodial accounts; lease equipment; underwrite securities; and provide a host of other financial services. In so doing, they utilize labor, land, machinery and equipment, and deposits. Since the measures used to gauge the volume of these outputs and inputs are not comparable, analysts of bank efficiency measure total bank output and input in terms of their monetary value. Monetary values, however, reflect price as well as quantity.

Third, the minimum input/output ratio that a particular bank *could* achieve is difficult to determine objectively. No laws of bank operations exist, parallel to laws of mechanics and physics, to enable an expert to deduce a bank's maximum attainable performance ("best practice"). Rather, economists must infer best

[1] See Evanoff and Israilevich (1991), Clark (1988), and Mester (1987) for surveys of studies estimating economies of scale and scope in banking. More recent estimates can be found in Mester (1994a and 1994b) and Berger and Humphrey (1991).

[2] The only other study of dispersion in X efficiency within a region is Mester's study for the Third District (Mester 1994a and 1994b).

Table 1
Dispersion in X Efficiency among First District Banks, Measured in Terms of Interquartile Differences in Average Total Cost (ATC)[a]

	1985 to 1989		
Mean ATC, by ATC Quartile	Banks with Total Assets Less than $100 Million	Banks with Total Assets between $100 Million and $300 Million	Banks with Total Assets Greater than $300 Million
First ATC Quartile (Lowest Cost)	.078	.078	.082
Fourth ATC Quartile (Highest Cost)	.102	.100	.109
Percentage Difference between Mean ATC of First and Fourth ATC Quartiles[b]	31%	28%	33%
	1990 to 1993		
Mean ATC, by ATC Quartile	Banks with Total Assets Less than $100 Million	Banks with Total Assets between $100 Million and $300 Million	Banks with Total Assets Greater than $300 Million
First ATC Quartile (Lowest Cost)	.072	.069	.073
Fourth ATC Quartile (Highest Cost)	.121	.107	.122
Percentage Difference between Mean ATC of First and Fourth ATC Quartiles[b]	68%	55%	67%

[a]Average total cost (ATC) = ratio of total cost to total assets. Total cost includes interest on time certificates of deposit of $100,000 or more; interest on other deposits; interest on deposits in foreign offices, Edge Act and Agreement subsidiaries, and in International Banking Facilities (IBFs); expense of federal funds purchased and securities sold under agreements to repurchase in domestic offices of the bank money; interest on mortgage indebtedness and obligations under capitalized leases; interest on notes and debentures subordinated to deposits; salaries and employee benefits; expenses of premises and fixed assets; and other noninterest expense.

[b]{(Mean ATC, Fourth Quartile − Mean ATC, First Quartile)/Mean ATC, First Quartile} * 100

Source: Federal Insurance Deposit Corporation, *Reports on Condition and Income*, and author's calculations.

practice by observing the input/output ratios of actual banks.

Precisely how to infer best practice is unclear. One cannot simply pick banks with the highest value of output per dollar of input, because this ratio is partially determined by factors other than efficiency, such as output mix and input and output prices. Banks with a low input/output ratio may have access to unusually cheap labor and office space or specialize in types of loans that are especially inexpensive to originate. The method used to identify efficient banks must control for such factors. The problem is comparable to the need to control for differences in speed, temperature, weight, and road conditions in determining the maximum possible fuel efficiency of an automobile.

As an illustration of the problem, suppose that best practice banks in the First District were identified as those with a relatively low ratio of total cost to total assets, or average total costs (ATC). One could divide the District's banks into size groups, rank banks within each size group in order of increasing ATC, divide each group into ATC quartiles, and designate banks exhibiting best practice as those in the first (lowest) ATC quartile. To estimate the difference between best practice and worst practice, one could compare the mean ATCs for the first and fourth quartiles. Table 1 shows such comparisons for three size groups and two time periods, 1985 to 1989 and 1990 to 1993. The revealed interquartile differences are large, especially in the later time period. Among large banks (those with more than $300 million in assets), the mean ATC for the fourth quartile was 67 percent higher than the mean ATC for the first quartile in the 1990 to 1993 period.

This difference could reflect factors other than X efficiency, such as differences in the price of inputs. Large banks in the fourth ATC quartile paid an average interest rate of 6.0 percent on small time and savings deposits during the 1990 to 1993 period. The comparable average interest rate for the first quartile was only 3.7 percent. Large fourth-quartile banks paid an average interest rate of 9.4 percent on purchased funds, while their first-quartile counterparts paid an average rate of only 4.8 percent. These large differences in the price of funds, not differences in X efficiency, may have been responsible for the interquartile difference in average ATC among large banks between 1990 and 1993.

II. Alternative Methods of Determining "Best Practice"

The three most prevalent methods for identifying best practice are the data envelopment analysis approach (DEA), the stochastic econometric frontier approach (SEFA), and the thick frontier approach (TFA).[3]

Data Envelopment Analysis Approach (DEA)

Under this approach, a sample of banks is, in effect, divided into subsamples that produce the same level and mix of outputs and face similar input prices.[4] In each subsample, the bank that incurs the lowest total cost is deemed to exemplify best practice for that subsample. The best practice banks form an efficiency frontier that "envelops" other banks in the sample and can be used to evaluate a bank's X efficiency.

A simplified hypothetical example, limited to a sample of banks producing only one output and using only one input, is presented in Figure 1. Each point on line AA* represents the bank using the least amount of input at its level of output. Banks lying within the AA* frontier are X inefficient; their degree of inefficiency is measured by their distance from the frontier.

The DEA approach makes no attempt to distinguish between banks that are on the frontier because they are truly the most efficient and those whose total costs are depressed by other factors not held constant by sample stratification. As a result, the approach tends to produce upwardly biased estimates of dispersion in X efficiency. Other approaches attempt to eliminate such bias in their estimates of the efficiency frontier.

Stochastic Econometric Frontier Approach (SEFA)

In this approach, regression techniques are used to estimate a model in which total cost is assumed to be a function of several variables, including input prices and the level and mix of outputs. A graphic version of a simple cost model, in which total cost varies only with the level of a single output, is shown in Figure 2. Banks' predicted total costs, given their level of output, forms line BB*.

According to SEFA, the cost model is assumed to represent best practice. Consequently, if the model controlled perfectly for all cost determinants except X efficiency, a bank whose observed cost equaled its predicted value would exhibit best practice. A bank's relative X efficiency could be measured by the degree to which its actual cost exceeded its predicted value. By assumption, a bank's actual cost could not be less than its predicted value.

In fact, some cost determinants other than X efficiency cannot be controlled for because they are unknown or impossible to measure. The SEFA approach assumes that these cost determinants generate random errors in prediction, distributed according to a normal or bell-shaped curve. By contrast, errors generated by X efficiency are assumed to be distributed according to a one-sided "half-normal" pattern.[5] Given the different statistical properties of these two distributions, one can distinguish deviations of actual from predicted cost attributable to X efficiency from those attributable to other factors. Critics of the SEFA approach present empirical evidence suggesting that predictive errors attributable to variation in X efficiency are not in fact distributed according to a half-normal pattern. (See, for example, Berger and Humphrey 1991.)

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[3] See Evanoff and Israilevich (1991); Berger (1993); Berger, Hunter, and Timme (1993); and Mester (1994a and 1994b) for other descriptions and comparisons of these approaches.

A fourth, recently developed approach to the measurement of X efficiencies in financial institutions is the "distribution-free" approach, developed by Berger (1993). According to this approach, a cost function is estimated for a sample of financial institutions for each of several years. (For example, Berger and Humphrey (1991) estimate such a function for a constant nationwide sample of bank holding companies each year between 1980 and 1990.) Each bank holding company's average residual over the entire time period is then compared with the comparable average residual for each bank holding company within its peer group. The bank holding company with the lowest average residual is considered to exhibit best practice for the peer group. The key assumption implicit in this approach is that random error averages out over time.

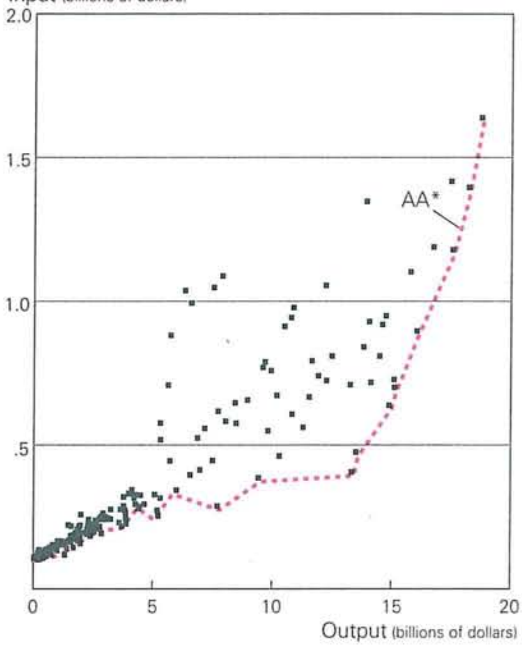
Yet another approach, recently applied by Akhavein, Swamy, and Taubman (1994), is capable of estimating a unique efficiency frontier for each bank in a sample. The approach is based on a general fixed-coefficients profit function that relaxes many of the arbitrary assumptions required in other approaches.

[4] Although output prices should also be controlled for, prices of most banking outputs are difficult to observe. For example, in making loans, banks often tailor the terms of each loan to the characteristics of the borrower, such as profitability, size, and volume of debt outstanding. The terms of each loan involve many variables, such as interest rate, maturity, down payment, and collateral, so that measuring the price of any particular type of loan is extremely difficult.

[5] Most observations in a half-normal distribution are clustered at or near one extreme value. The further one moves away from this extreme, the lower the probability of finding an observation. A detailed description of the statistical properties of a half-normal distribution is presented in Mester (1994a and 1994b).

Figure 1

The Data Envelopment Analysis Approach to Analyzing Differences across Banks in X Efficiency

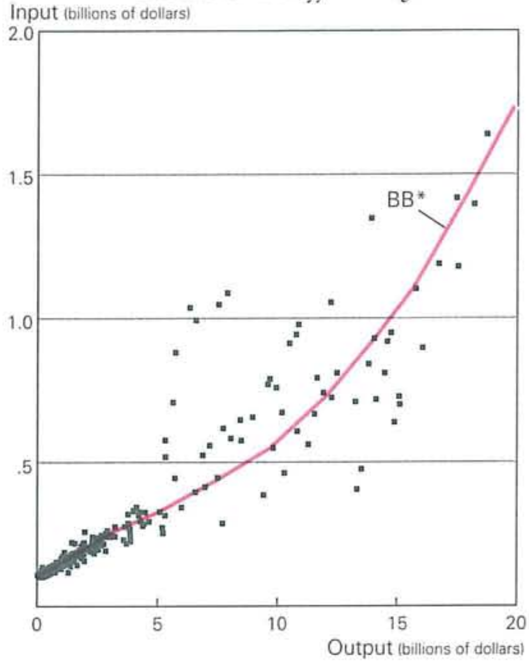


Note: The observations in this figure consist of a pooled cross-section time series sample of First District commercial banks spanning the years 1985 through1993. The cross-sectional sample from each year includes all Bank Insurance Fund (BIF)-insured banks domiciled within the First District in that year except 1) banks created de novo within the previous two years or operating in less than seven of the ten years from 1984 through 1993; 2) banks whose deposits-to-assets ratio was less than 0.15; and 3) banks whose total output exceeded $20 billion. The rationale for exclusions 1) and 2) is given in Section III of the text. Banks with more than $20 billion in annual output were distant outliers. The vertical axis measures a composite input consisting of the sum of employee compensation, expense of fixed assets, interest expense of small time and savings deposits, and interest expense of all purchased funds. The horizontal axis measures a composite output consisting of demand deposits, small time and savings deposits, real estate loans, commercial and industrial loans, and consumer installment loans. The total number of observations (1,315) appears much smaller than the actual number because so many of them are clustered in the lower left corner of the figure.

Source: Federal Deposit Insurance Corporation, *Reports on Income and Condition*, and author's calculations.

Figure 2

The Stochastic Econometric Frontier Approach to Analyzing Differences across Banks in X Efficiency



Note and Source: See Figure 1.

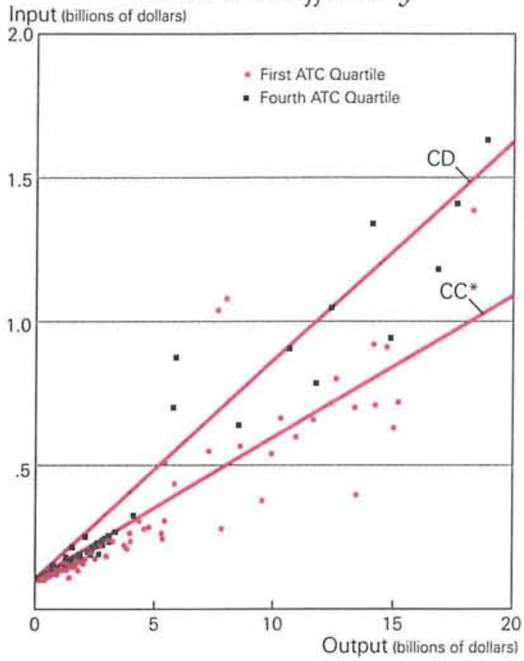
The Thick Frontier Approach (TFA)

The thick frontier approach, pioneered by Berger and Humphrey (1991), borrows elements from both DEA and SEFA. Like SEFA, TFA embraces the assumption that deviations of actual from predicted total cost are attributable to random error as well as X efficiency. Like DEA, TFA assumes that best practice is exhibited by a subset of banks. Specifically, TFA assumes that, on average, banks with relatively low average cost (total cost/total assets) set the standard for operational efficiency against which other banks should be measured. Practitioners of TFA have usually identified low-average-cost banks as those in the lowest average-cost quartile within their size group. TFA defines best practice by estimating a total cost function from a subsample limited to these banks. Although observed total costs within this sample still deviate from their predicted values, these deviations are assumed to result solely from random error.

TFA is illustrated in Figure 3. CC* is a total cost function fitted to the observed total cost of banks in the lowest average-cost quartile in their size groups, represented by circles. Among these low-cost banks, few exhibit total costs that exactly equal their pre-

Figure 3

The Thick Frontier Approach to Analyzing Differences across Banks in X Efficiency



Note and Source: See Figure 1.

dicted values (in other words, fall on line CC*). Predictive errors are assumed to be random. Thus, banks below and above CC* are not assumed to be "superefficient" and "inefficient," respectively; rather, their deviations are attributed exclusively to random error. The term "thick frontier" comes from TFA's usage of all the low-average-cost firms to identify best practice, including those with observed total costs above and below predicted values.

For comparative purposes, a total cost function estimated for banks in the highest average cost quartile in their size group (represented by squares in Figure 3) is also drawn in Figure 3. This fitted line, CD, represents worst practice. As explained in the next section, a comparison of the two functions reveals the degree to which banks within a given sample vary in X efficiency.[6]

III. Methodology and Results

This study uses two of the widely used standard methodologies described above to measure variation in X efficiency among First District banks between 1985 and 1993. TFA is used to estimate the difference in X efficiency between the District's "best practice" and "worst practice" banks. Estimates are performed for two time periods, 1985 to 1989 and 1990 to 1993. A hybrid of TFA and SEFA is used to estimate the difference in X efficiency between the District's best practice and average practice banks for each year between 1985 and 1993. (Sample sizes are too small to permit annual estimation of the range of efficiency between best and worst practice institutions.)

Both sets of estimates utilize the categorization of inputs and outputs in the study by Bauer, Berger, and Humphrey (1993). Four inputs and five outputs are identified. Inputs include labor, land and physical capital, interest paid for purchased funds, and interest paid on demand and retail time deposits. The five outputs include three types of loans and two types of deposits. The loan categories are real estate, commercial and industrial (including construction and land development), and consumer. The deposit categories are demand deposits and retail time and savings.

The sample of banks in each year includes all Bank Insurance Fund (BIF)-insured banks domiciled within the First District with the following exceptions: 1) Banks created de novo within the previous two years or operating in fewer than seven of the ten years from 1984 through 1993. In general, banks incur atypical start-up costs in the first several years of their existence that are difficult to control for. 2) Banks whose deposits-to-assets ratio was less than 0.15. Since these institutions either are trust companies or function like them, factors affecting their total costs are different from those influencing the total costs of banks.

Use of Cost Functions to Compare Dispersion in X Efficiency: 1985 to 1989 and 1990 to 1993

As explained in the previous section, the numerous studies that have used the TFA approach determine best practice by estimating a cost function from a sample of banks ranking low in average cost compared to other banks of similar size. Next, these

[6] TFA does not permit one to estimate the relative X efficiency of a particular bank because, within the lowest and highest ATC quartiles, differences in X efficiency are assumed away.

Table 2
Difference between Best Practice and Worst Practice Banks, First District, by Size Group
Percent of Average Total Cost

	Banks with Total Assets Less than $100 Million	Banks with Total Assets between $100 Million and $300 Million	Banks with Total Assets Greater than $300 Million
1985 to 1989	25	7	21
1990 to 1993	45	34	51

Note: Figures are the estimated percentage increase in total costs that best practice banks would experience if their x efficiency deteriorated to worst practice. See Appendix for methodological details.
Source: Federal Insurance Deposit Corporation, *Reports on Condition and Income*, and author's calculations.

studies determine worst practice by estimating the same function from a sample of institutions ranking high in average cost compared to other banks of similar size. Then, the studies estimate how much a representative best practice bank would raise its predicted total cost by downgrading its X efficiency to worst practice. This is accomplished by comparing the bank's total cost predicted from the best practice model with that predicted from the worst practice model.

In order to implement this strategy, two samples of banks were created by pooling data for 1985 through 1989 and for 1990 through 1993, respectively. Banks in each pooled data set were divided into three size groups and, within each size group, into ATC quartiles, just as they were in the comparisons presented in Table 1. All banks ranking in the lowest quartile within their size group were assumed to exhibit best practice, all banks ranking in the highest quartile to exhibit worst practice.

In most studies following the TFA approach, translog cost models are estimated for the best practice and worst practice subsamples, respectively. In translog cost models, explanatory variables interact in complex ways to influence total cost. The influence of each variable is assumed to depend on both its own value and that of each other cost determinant included in the model. For example, according to the translog form, the impact of an additional dollar of real estate loans on total cost partially depends on the volume of each of the outputs because diversification of output can affect economies of scope. The impact of an increase in real estate loans is also assumed to depend in part on the cost of labor (as well as the cost of other inputs), since the provision of real estate loans may be more or less labor-intensive than that of other outputs.

In a translog cost function, total cost is also partially determined by the square of each cost factor. Inclusion of squared terms reflects the assumption that the relationship between a given cost determinant and total cost may be nonlinear, that is, it may vary with the determinant's value. For example, as a bank's loan portfolio expands, it may experience decreasing average cost because of economies of scale. At some point, diseconomies of scale set in, causing average cost to increase with further loan growth. Many relationships between outputs and costs follow this "U-shaped" pattern.

Some economists (for example, Mitchell and Onvural 1992 and McAllister and McManus 1993) have questioned whether translog functions accurately reflect how input prices, output mix, and other factors interact to determine a bank's total cost. These economists are particularly skeptical of the accuracy of translog cost functions when they are estimated from samples of banks exhibiting wide variation in values of cost determinants. Despite these limitations, this study follows the common practice of using the translog form.

The estimated translog cost models (described in the Appendix and presented in Appendix Tables 1 and 2) were used to evaluate "X efficiency gaps"—percentage increases in average total cost that representative best practice banks would suffer if their X efficiency deteriorated to worst practice.[7] The results of this evaluation are presented in Table 2. A comparison of Table 2 with Table 1 yields at least one noteworthy difference and one similarity. For each

[7] For each size group, the representative best practice bank possessed the mean value among banks in the lowest ATC quartile for each variable in the cost function.

size group in each time period, the efficiency gap reported in Table 2 is smaller than the comparable ATC interquartile difference reported in Table 1. Thus, controlling for factors other than efficiency narrows the interquartile gaps. As in Table 1, interquartile differences are narrower during the 1985 to 1989 period, when the efficiency gap ranged between 7 percent and 25 percent, than during the 1990 to 1993 period, when they ranged between 34 percent and 51 percent.[8]

Estimates of Annual Efficiency Gaps between Best Practice and Average Practice

Given the limitations of available data, the ability to evaluate dispersion in X efficiency on an annual basis is more limited than over the longer time periods used for Table 2. Consequently, differences between best practice and average practice were estimated for each year instead of differences between best practice and worst practice. In order to measure differences between best practice and worst practice, one must be able to estimate cost functions from 25-percent subsamples of First District banks. As alluded to in the previous section, the population of First District banks is too small to support such quartile-specific estimates on a year-by-year basis.

As noted above, annual differences between best practice and average practice were estimated with a hybrid of the standard SEFA and TFA methodologies employed by other economists. As in SEFA, a translog cost function was estimated with banks drawn from all ATC quartiles. However, contrary to standard SEFA methodology, the estimated cost function was not assumed to represent best practice. The predictive errors attributable to all variables not included in the cost model, including X efficiency, were assumed to be random and, therefore, to have an expected value of zero. Consequently, the cost model provided estimates of what each bank's total cost would be under the assumption that it exhibits average practice.

It was assumed, as in the TFA approach, that banks in the lowest ATC quartile in their size group exhibit best practice. An ATC dummy variable was included in the cost model, assigned a value of 1 if a bank was in the lowest ATC quartile and 0 if it was not. The coefficient on this dummy variable indicates by what percentage a bank would increase its total cost if its level of X efficiency deteriorated from best practice to average practice.

The estimated coefficients on the ATC dummies for the years 1985 through 1993, expressed in percentage terms, range from −4 percent (1991 and 1993) to −14 percent (1986) (Figure 4 and Appendix Table 2). This range includes the −8 percent point estimate made by Mester (1994a and 1994b) for Third District Banks in 1992. The coefficients tend to get smaller over time, suggesting that differences between best practice and average practice in the First District narrowed over the 1985 to 1993 period. The difference, −4 percent, is statistically significant in 1991 and insignificant in 1993. This trend contrasts with the widening gap over the same time period between best practice and worst practice (Table 2).

IV. Interpretation of Results

Two interpretations of these diverging trends are offered here. According to one, these trends reflect a "shake-up and shakeout" of New England's banking industry, in which increasing deregulation and cyclical shocks have compelled most institutions to manage their inputs more efficiently, while some have been too burdened by problem loans to do so. According to the other interpretation, these diverging trends are spurious empirical results reflecting flaws in estimation procedures.

The "Shake-Up and Shakeout" Interpretation

The results presented in the previous section are consistent with the theory that deregulation and severe financial stress have compelled First District banks as a whole to manage their inputs more efficiently. From 1978 through 1982, several federal laws broadened the competitive interface between banks and other financial institutions.[9] In addition, the New

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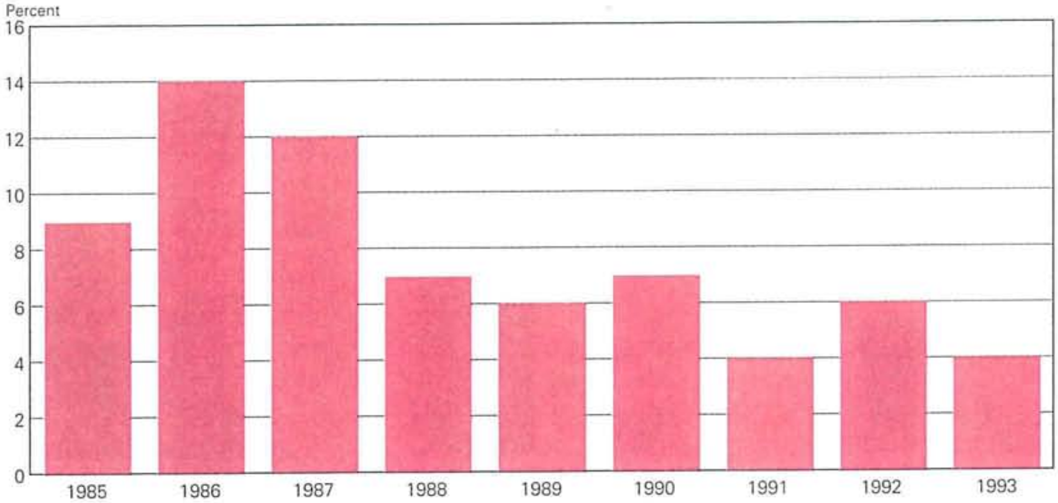
[8] The 7 percent estimate for the efficiency gap among First District banks in the $100 million to $300 million range is considerably narrower than the comparable gap found by Bauer, Berger, and Humphrey (1993) in the United States for 1985 to 1988, using TFA. Precise comparisons with their findings are difficult because they used eight size groups instead of three. They found efficiency gaps for this four-year period averaging 21 percent in the $100 million to $200 million asset range, and 19 percent for the $200 million to $300 million range. Their estimated efficiency gaps for banks in the $300 million to $10 billion range were similar to the 21 percent reported in Table 2 for First District banks in the $300 million plus group. They found much larger efficiency gaps (well over 40 percent) for banks with total assets exceeding $10 billion.

[9] For example, the Financial Institutions Regulatory and Interest Rate Control Act of 1978, the International Banking Act of 1978, the Depository Institutions Deregulation and Monetary Control Act of 1980, and the Garn–St Germain Depository Institutions Act of 1982. See Spong (1994) for an overview of U.S. bank regulatory policy.

Figure 4

X Efficiency Gaps: Best Practice vs. Average Practice, 1985 to 1993, First District Commercial Banks



Note: Figures indicate percentage increase in total costs that best-practice banks would experience if their x efficiency deteriorated to average practice. They are identical to the coefficients on the ATC dummy variable in the cost function presented in Appendix Table 1.

Source: Federal Deposit Insurance Corporation, *Reports on Income and Condition*, and author's calculations.

England states passed interstate banking bills over the course of the 1980s that increased the geographic dispersion of bank holding companies.[10] In theory, intensified competitive pressures created by these various deregulatory measures could have forced First District banks to become more X efficient. The full impact of these pressures may not have been felt until the late 1980s, after banks had sufficient time to adjust to their less regulated environment. This theory is consistent with the narrowing gap between best practice and average practice between 1985 and 1993.

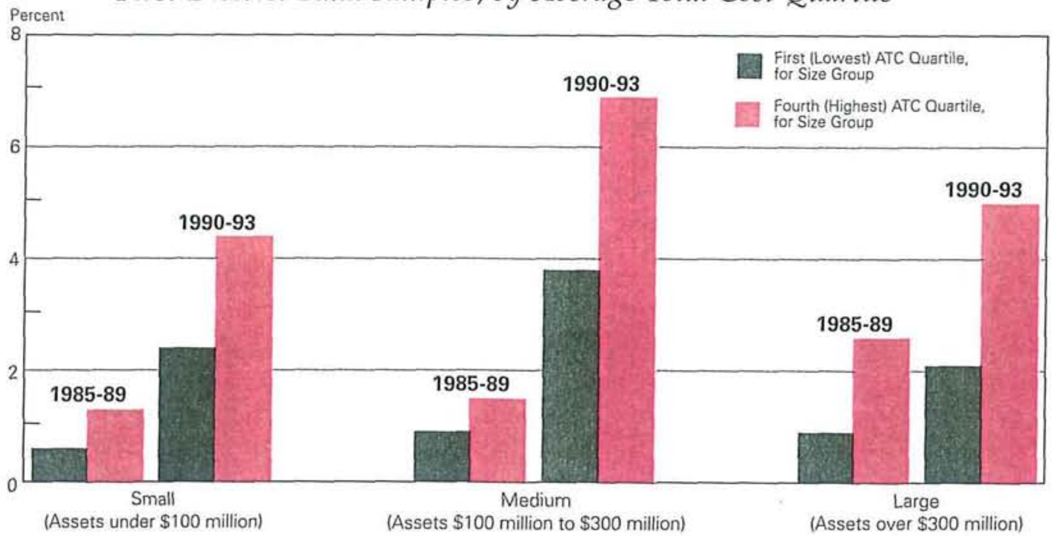
In addition, New England's banking industry was subject to severe financial stress during the late 1980s and early 1990s. As a result, many banks experienced a sharp rise in their ratio of nonperforming loans to total assets. This shock theoretically could have provided an additional incentive for the average bank to enhance X efficiency. Those institutions experiencing the sharpest deterioration in their loan portfolios, however, generally were subject to the most severe regulatory discipline and therefore cut their lending more sharply than the banking industry as a whole. They were compelled to allocate staff and to hire consultants to cope with their financial problems, with little or no additional output to show for it. In theory, these requirements could have caused their X efficiency to decline relative to best practice. Thus, while increasingly intense competition and financial stress may have induced the majority of banks to become more X efficient, the same factors may have so damaged some banks that they could not become more efficient. Instead, these institutions were forced to cut output and to cope with their acute financial difficulties, sacrificing X efficiency in the process.

Consistent with this theory is the correlation between the rising incidence of problem loans and the widening gap in mean ATC between the first and fourth ATC quartiles, demonstrated in Figure 5. In all three size categories, and in both the 1985 to 1989 and 1990 to 1993 time periods, nonperforming loans as a percentage of total assets is larger for the highest ATC quartile than for the lowest ATC quartile. The difference in this percentage between ATC quartiles is significantly larger in the later time period for all three size groups.

[10] These changes in interstate banking laws and regulations within the region are discussed in Syron (1984) and Dunham and Syron (1984).

Figure 5

Nonperforming Loans as a Percentage of Total Assets, First District Bank Samples, by Average Total Cost Quartile



Source: Federal Deposit Insurance Corporation, *Reports on Income and Condition*, and author's calculations.

The "Spurious Results" Interpretation

The trends reported in Figure 4 and Appendix Tables 1 and 2, although consistent with the "shake-up and shakeout" theory, may be spurious. Several troubling characteristics of the annual estimated cost models displayed in Appendix Table 2 raise doubts about the trends' statistical validity. First, the coefficients on several variables fluctuate widely from year to year. For example, as shown in Row 4, the coefficient on the volume of small time and savings deposits (LDTS) plummets from 0.966 in 1987 to −1.010 in 1988, climbs to −0.395 in 1989, climbs further to 0.010 in 1990, falls back sharply to −0.820 and −0.853 in 1991 and 1992, respectively, and then plummets to −3.575 in 1993. Several of the coefficients on other variables in the cost function exhibit extreme intertemporal volatility, as do the coefficients estimated from pooled cross-section time series data for 1985 to 1989 and 1990 to 1993 (Appendix Table 1). Such volatility is difficult to explain and therefore casts doubt on the accuracy of the estimated coefficients.[11]

Another disturbing characteristic of the coefficients is their sensitivity to slight changes in data samples. As stated in Section III, all banks not present for at least seven years between 1984 and 1993, de novo banks, and banks with a ratio of deposits to assets of less than 0.15 were excluded from the samples used to estimate the cost functions. In each year, a few banks had a ratio of deposits to assets of less than 0.15 but met the other two criteria for inclusion. When these banks were included in the samples, the estimates of the coefficient on the ATC dummy variable changed dramatically and the tendency of the coefficient's absolute value to fall over time vanished. Such sensitivity to slight changes in sample definition

[11] The intertemporal volatility of the coefficients may be symptomatic of the biases inherent in the translog functional form, mentioned in Section III of the text.

The intertemporal volatility of the coefficients is not the same as the total elasticities of cost with respect to cost determinants. Each determinant appears in several different terms in the cost function: a linear term, a squared term, and several interaction terms. In the theory, intertemporal variation in the coefficients on some terms could offset the variation in the coefficients on others, resulting in little variation over time in the total impact of each determinant.

To explore this possibility, the total elasticity of total cost with respect to each of the five outputs in the model was evaluated at the mean value for each output, using the annual cost model estimates. The results, presented in the Appendix, suggest a substantial amount of year-to-year variation in total cost elasticities with respect to various outputs.

Table 3
Percentage of Banks in the Lowest-Cost ATC Quartile Two Years in a Row, 1985 to 1993

Pairs of Consecutive Years (1)	Number of Banks in Sample Present in Both Years of Pair (2)	Banks in Lowest-Cost ATC Quartile for Their Size Group Present in Both Years of Pair, as a Percentage of Banks in Lowest-Cost ATC Quartile in First Year of Pair (3)
1985–86	173	20.2
1986–87	176	28.4
1987–88	178	30.3
1988–89	178	23.6
1989–90	178	21.3
1990–91	151	18.5
1991–92	136	21.3
1992–93	128	39.1

Note: Calculations reported in column (3) are based on banks present in both years of pair.
Source: Federal Deposit Insurance Corporation, *Reports on Condition and Income*, and author's calculations.

suggests problems with the underlying data, the cost function, or both.

An especially troubling indication of methodological problems is the large year-to-year variation in the identity of banks in the lowest-cost ATC quartile for each size group. According to the thick frontier approach, banks possessing this characteristic are assumed to exhibit best practice. Given this assumption, one would expect the identity of best practice banks to exhibit some intertemporal stability. At a minimum, one would expect at least one-half of all banks in the lowest-cost ATC quartile for their size group in a given year to be in the lowest-cost ATC quartile for their size group in the following year. According to Table 3, however, the average annual rate of turnover in banks ranking in the lowest-cost ATC quartile for their size group far exceeds 0.5. Column 1 lists all pairs of consecutive years during the sample period, 1985 to 1993. Column 2 reports the number of banks present in the sample in both years. Column 3 reports, for this subsample, the percentage of all banks in the lowest-cost ATC quartile for their size group in the first year of the pair of years that is also in the lowest-cost ATC quartile for their size group in the second year. For example, in 1985–86, 20 percent of the banks present in both 1985 and 1986 and in the lowest-cost ATC quartile for their size group in 1985 were also in the lowest ATC quartile for their size group in 1986. This percentage varies between 19 percent and 40 percent, suggesting turnover rates roughly between 0.6 and 0.8.

V. Summary and Conclusions

Measures of dispersion among banks in X efficiency have many potential applications. They can assist in the identification of banks vulnerable to competitive pressures generated by further deregulation and technological change. In so doing they can help regulators choose where to channel their scarce resources, especially those devoted to improving bank management. They can assist in the evaluation of potential efficiency gains or losses resulting from bank mergers.[12]

This article develops estimates of the dispersion in X efficiency among First District banks between 1985 and 1993. It shows evidence that, over time, the average First District bank has realized an increasing percentage of its potential X efficiency. In 1993, the last year studied, the gap between best practice and average practice banks within the District was statistically insignificant. By contrast, the gap in efficiency between the most and least efficient banks has widened considerably, suggesting the presence of a group of banks quite vulnerable to further competitive pressure. The advent of unlimited interstate branching could be a source of such pressure in the near future.

However, methods for estimating interbank differences in X efficiency are still in the developmental stage. The cost functions at the heart of these efficiency estimates are unstable over time, casting doubt on their accuracy. Key assumptions underpinning some of these methods are not supported by empirical evidence. Estimates of differences among banks in X efficiency need further refinement before they can be used confidently as public policy indicators.

[12] This potential application of measures of X efficiency has already been demonstrated in several studies. See Wall, Srinivasan, Narayanan, and Takeda (1994) for such a study and a review of previous such studies.

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Appendix

Translog Cost Model

The formal translog cost model estimated in this study (Appendix Tables 1 and 2) can be written as:

$$lnTC = \alpha + \sum_{i=1}^{5}\beta_i \, lnY_i + 1/2 \sum_{i=1}^{5}\sum_{j=1}^{5}\delta_{ij} \, lnY_i \, lnY_j$$

$$+ \sum_{k=1}^{4}\gamma_k \, lnP_k + 1/2 \sum_{k=1}^{4}\sum_{n=1}^{4}\gamma_{kn} \, lnP_k \, lnP_n$$

$$+ \sum_{i=1}^{5}\sum_{k=1}^{4}\rho_{ik} \, lnY_i \, lnP_k + \epsilon \qquad (1)$$

$$S_k = \alpha_k + \sum_{n=1}^{4}\gamma_{kn} lnP_n + \sum_{i=1}^{5}\rho_{ik} \, lnY_i + \Psi_k, \quad k = 1,2,3,4 \qquad (2)$$

where:

- TC = real total cost (interest and operating costs deflated by the GNP deflator). As is standard in banking studies, cost figures do not include loan losses. They are instead effectively treated as a decline in revenue, since the rates charged on loans include premia to cover the expected value of these losses;
- Y_i = real value of output i: 1) demand deposits, 2) small time and savings deposits, 3) real estate loans, 4) commercial and industrial loans, and 5) installment loans;
- P_k = real price of input k: 1) labor, 2) physical capital, 3) interest rate on small time and savings deposits, and 4) interest rate on purchased funds;
- S_k = cost share of input k, which equals $\partial lnTC/\partial lnP_k$ from equation (1) plus an error term;
- ϵ, Ψ_k = error terms.

The standard symmetry and linear homogeneity in input price restrictions are imposed in estimation, as are the Shephard's Lemma cross-equation restrictions. One of the share equations is dropped to avoid singularity. Estimates of the parameters for the share equations are available from the author upon request.

Methodology for Computing Difference between Best Practice and Worst Practice Banks, as Reported in Table 2

Following the methodology of Berger (1993), the differences reported in Table 2 for each time period were computed according to the following formula:

$$INEFF = (AC^{Q4} - AC^{Q4*})/AC^{Q4}$$

AC^{Q4} was calculated in the following manner: 1) the average values of all cost determinants in the cost model were computed for banks in the lowest average cost (ATC) quartile; 2) using the model estimated with the lowest ATC quartile data, total cost was estimated for a hypothetical bank exhibiting these average values for the cost determinants; 3) this total cost estimate was divided by the average value for total assets for lowest quartile banks, to arrive at predicted ATC for the hypothetical low AC bank.

AC^{Q4*} was calculated in the same manner, except estimated total cost was derived from the cost model estimated from the highest ATC quartile.

Analysis of Total Impact of Output Variables on Total Cost

As mentioned in footnote 11, simulations were performed to evaluate the elasticity of total cost with respect to each of the five outputs in the cost model at the output's mean value. For each of the five outputs in each year, the observation with the mean value for that output was identified. It was then assumed that the value of that output increased by 10 percent. The resulting percentage increases in predicted cost, based on the annual estimated cost functions (Appendix Table 2), were divided by 10 to arrive at the estimated elasticities. The results are reported in Appendix Table 3. Note the sharp, difficult-to-explain jumps in the cost elasticity with respect to demand deposits from 1988 to 1989, consumer installment loans from 1992 to 1993, and small time and savings deposits from 1991 to 1992 and from 1992 to 1993.

Appendix Table 1

Total Cost Function, Estimated from Pooled, Cross-Section Time Series Data, 1985–89 and 1990–93[a]

Line	Variable[b]	Definition	First ATC Quartile 1985–1989 Coefficient	First ATC Quartile 1985–1989 Standard Error	First ATC Quartile 1990–1993 Coefficient	First ATC Quartile 1990–1993 Standard Error	Fourth ATC Quartile 1985–1989 Coefficient	Fourth ATC Quartile 1985–1989 Standard Error	Fourth ATC Quartile 1990–1993 Coefficient	Fourth ATC Quartile 1990–1993 Standard Error
1	INTERCEPT		−7.688931	.435160**	−2.417944	1.015545*	−2.739171	.593205**	.242356	.783426
	Output Variables:									
2	LDDD	Demand deposits	.031399	.113486	.876433	.226216**	.600413	.137288**	.276690	.102950**
3	LDTS	Small time & savings deposits	1.475004	.158898**	.309359	.367604	.730481	.237018**	2.201001	.232851**
4	LDRE	Real estate loans	−.284770	.083589**	−.261039	.173051	−.039043	.170376	−2.099448	.175245**
5	LDCI	Commercial & industrial loans[c]	.096250	.056879	−.305873	.139975*	−.549310	.145005**	.797676	.153188**
6	LDIN	Consumer installment loans	−.246265	.096940*	.289798	.212053	−.028881	.121908	−.430759	.139782**
	Factor Price Variables:									
7	LW1	Price of labor[d]	−.287748	.048815**	−.311337	.072206**	.030809	.059419	−.107262	.083997
8	LW2NE	Price of capital[e]	1.399268	.072455**	.734793	.085243**	.792558	.083455**	.138539	.109650
9	LW3	Price of small time and savings deposits[f]	−.474727	.054225**	.246831	.071944**	−.371273	.071572**	.297317	.094263**
10	LW4	Price of purchased funds[g]	−.273586	.062815**	−.340573	.083470**	.095811	.064687	.342812	.090721**
	Interaction Terms:									
11	DDDD	(LDDD×LDDD)/2	.235639	.019736**	.210973	.056195**	.017054	.006277**	.004439	.004075
12	DDTS	(LDDD×LDTS)/2	−.087717	.052741	.137036	.088951	−.100440	.039013*	−.105303	.034312**
13	DDRE	(LDDD×LDRE)/2	−.105514	.030255**	−.301139	.071142**	−.031826	.031241	−.218577	.035509**
14	DDCI	(LDDD×LDCI)/2	−.035724	.028537	−.074710	.062607	.101471	.036067**	.337200	.038867**
15	DDIN	(LDDD×LDIN)/2	−.135842	.031018**	−.170975	.049162**	.019657	.023017	−.107050	.010039**
16	TSTS	(LDTS×LDTS)/2	−.145665	.019116**	−.293619	.058397**	−.054308	.027460*	−.129617	.021965**
17	TSRE	(LDTS×LDRE)/2	.341397	.025262**	.345778	.082747**	−.030698	.061845	.124290	.020594**
18	TSCI	(LDTS×LDCI)/2	−.055175	.034624	.177107	.096191	.221418	.064775**	−.023768	.035442
19	TSIN	(LDTS×LDIN)/2	.152935	.045862**	−.050227	.116522	.082090	.029389**	.160587	.023006**
20	RERE	(LDRE×LDRE)/2	−.063056	.005944**	.051941	.048491	.142312	.032883**	.238423	.019002**
21	RECI	(LDRE×LDCI)/2	.014861	.019962	−.093891	.068919	−.144734	.027459**	−.165670	.017746**
22	REIN	(LDRE×LDIN)/2	−.154927	.031624**	.066934	.051399	−.052956	.033788	−.002082	.013623
23	CICI	(LDCI×LDCI)/2	−.000365	.002662	.009272	.009403	−.021485	.034377	−.062210	.011555**
24	CIIN	(LDCI×LDIN)/2	.065707	.022943**	−.035913	.039374	−.063982	.031467*	.000373	.011317
25	ININ	(LDIN×LDIN)/2	.001038	.012279	.058217	.025190*	−.022805	.017905	−.002048	.008361
26	W1W1	(LW1×LW1)/2	.085582	.010453**	.045132	.009722**	.033019	.010248**	.088821	.012061**
27	W1DD	LW1×LDDD	.068195	.005991**	.046690	.010115**	.028703	.003758**	.030465	.004931**
28	W1TS	LW1×LDTS	−.079940	.008153**	−.065353	.015619**	−.021053	.006667**	−.020084	.008362*
29	W1RE	LW1×LDRE	−.016636	.002994**	−.013646	.005306*	−.027532	.005002**	−.041824	.006123**
30	W1CI	LW1×LDCI	.002697	.002379	.012062	.003474**	.006420	.004943	.005475	.005160
31	W1IN	LW1×LDIN	.011903	.005268*	.007600	.006491	−.013931	.004916**	−.005047	.004514
32	W2NEW2NE	(LW2NE×LW2NE)/2	−.104211	.010985**	−.109397	.010538**	−.091988	.012531**	−.047605	.015441**
33	W2NEDD	LW2NE×LDDD	−.118682	.006527**	−.135239	.010609**	−.042559	.005514**	−.037353	.006519**

Appendix Table 1 continued

Total Cost Function, Estimated from Pooled, Cross-Section Time Series Data, 1985–89 and 1990–93[a]

			First ATC Quartile				Fourth ATC Quartile			
			1985–1989		1990–1993		1985–1989		1990–1993	
Line	Variable[b]	Definition	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
34	W2NETS	LW2NE×LDTS	.020375	.008758*	.078589	.016267**	−.041561	.009530**	−.007667	.010669
35	W2NERE	LW2NE×LDRE	.020560	.003227**	.001701	.005558	.033664	.007300**	.054622	.007852**
36	W2NECI	LW2NE×LDCI	.000399	.002566	.006060	.003649	−.007250	.007216	−.007152	.006589
37	W2NEIN	LW2NE×LDIN	.039037	.005709**	.015688	.006813*	.027383	.007157**	−.011003	.005886
38	W3W3	(LW3×LW3)/2	.006825	.009459	.071183	.008114**	−.006181	.011621	.035926	.014406*
39	W3DD	LW3×LDDD	.015468	.007585*	.034258	.011404**	−.008204	.005964	−.011533	.007691
40	W3TS	LW3×LDTS	.088903	.010091**	.039905	.017925*	.064858	.010300**	.020676	.012417
41	W3RE	LW3×LDRE	−.007830	.003804*	.005517	.005998	.007527	.007928	.005196	.009116
42	W3CI	LW3×LDCI	−.003105	.003049	−.020449	.003978**	−.005467	.007835	−.000198	.007737
43	W3IN	LW3×LDIN	−.043067	.006374**	−.014957	.007465*	.003477	.007705	.026071	.006812**
44	W4W4	(LW4×LW4)/2	−.072243	.018040**	−.216562	.012637**	−.174553	.030836**	.016782	.013341
45	W4DD	LW4×LDDD	−.013833	.028505	.060135	.042656	.151961	.026964**	−.131672	.020484**
46	W4TS	LW4×LDTS	.106709	.036102**	−.199818	.071397**	−.142365	.043322**	.182103	.026829**
47	W4RE	LW4×LDRE	−.034205	.011054**	.172209	.055651**	.097839	.032084**	−.223630	.028637**
48	W4CI	LW4×LDCI	.006172	.013975	−.030529	.011479**	−.040065	.026280	.259198	.028899**
49	W4IN	LW4×LDIN	−.061396	.021400**	.001153	.028434	−.076316	.026412**	−.087291	.028791**
50	W1W2NE	(LW1×LW2NE)/2	.046016	.005825**	.100970	.005828**	.079195	.007015**	.087266	.007167**
51	W1W3	(LW1×LW3)/2	−.118908	.008478**	−.087607	.008174**	−.057579	.010490**	−.015831	.012272
52	W1W4	(LW1×LW4)/2	.012751	.005370*	.011836	.007416	.037324	.007390**	.016290	.009305
53	W2NEW3	(LW2NE×LW3)/2	.083989	.010218**	−.018444	.009493	.006196	.011699	−.067309	.012521**
54	W2NEW4	(LW2NE×LW4)/2	−.030435	.005772**	−.020352	.008082*	−.095086	.010856**	−.056254	.011497**
55	W3W4	(LW3×LW4)/2	.001039	.006503	.016137	.008452	.016045	.011157	.033776	.013253*
		R-Square	.9991		.9976		.9971		.9981	
		Observations	214		152		211		154	

*Significant at the .05 level or greater.

**Significant at the .01 level or greater.

[a]The dependent variable is total cost defined as the sum of employee compensation, expense of fixed assets, interest expense of small time and savings deposits, and interest expense of all purchased funds.

[b]All variables are in natural log form and have been deflated by the Boston Consumer Price Index (annual).

[c]Includes construction and land and farmland loans.

[d]Price of labor is defined as employee compensation divided by the number of full-time employees.

[e]Price of capital is defined as the value of non-residential office space divided by the square footage of non-residential office space, multiplied by 1,000.

[f]Price of small time and savings deposits is defined as interest expense on small time and savings deposits divided by small time and savings deposits.

[g]Price of purchased funds is defined as interest expense of federal funds purchased and securities sold, time certificates of deposit of $100,000 or more, demand notes issued to the U.S. Treasury on other borrowed money, and deposits in foreign offices divided by the stock of federal funds purchased and securities sold, time certificates of deposit of $100,000 or more, demand notes issued to the U.S. Treasury on other borrowed money, and deposits in foreign offices.

Note: The division of several of the interaction terms by 2, although counterintuitive, is a characteristic of a cost function derived from a translog production function. See Varian (1993) for a formal derivation.

Source: U.S. Bureau of Labor Statistics; FW Dodge Division, McGraw-Hill, Inc., *Dodge Construction Potentials Bulletin*; Federal Deposit Insurance Corporation, *Reports on Condition and Income*; and author's calculations.

Appendix Table 2

Estimated Total Cost Functions, 1985 through 1993, Annual Data[a]

Line	Variable[b]	Definition	1985 Coefficient	1985 Standard Error	1986 Coefficient	1986 Standard Error	1987 Coefficient	1987 Standard Error	1988 Coefficient	1988 Standard Error	1989 Coefficient	1989 Standard Error
1	Q	Lowest average total cost dummy variable	−.088234	.017278**	−.135761	.015280**	−.122548	.015046**	−.066129	.014967**	−.064024	.014262**
2	INTERCEPT		−6.285675	.694998**	−8.085702	.701716**	−4.777063	.715260**	−2.669158	.878994**	−1.553787	.686011*
	Output Variables:											
3	LDDD	Demand deposits	.820573	.152089**	.050892	.130553	.775379	.186618**	.450070	.210608*	.629440	.194766**
4	LDTS	Small time & savings deposits	1.594516	.273504**	1.568488	.203796**	.965896	.160444**	−1.009896	.322820**	−.394831	.256854
5	LDRE	Real estate loans	−.473943	.156009**	−.004174	.143998	.135174	.112679	.483476	.140249**	.593105	.134626**
6	LDCI	Commercial & industrial loans[c]	−.410284	.152338**	−.164831	.069945*	−.445574	.129025**	.625560	.181512**	−.109468	.120931
7	LDIN	Consumer installment loans	−.456364	.174712*	−.177418	.178972	−.557707	.172635**	.281770	.174488	.050592	.153067
	Factor Price Variables:											
8	LW1	Price of labor[d]	−.069614	.068807	.020401	.068377	.185615	.084069*	.138329	.072471	.211487	.070176**
9	LW2NE	Price of capital[e]	.969905	.099497**	1.021682	.100133**	.684118	.128749**	.604218	.134727**	.413370	.098483**
10	LW3	Price of small time and savings deposits[f]	−.369697	.084262**	−.572411	.076459**	−.322830	.083859**	−.622062	.088606**	−.171619	.081828*
11	LW4	Price of purchased funds[g]	−.061189	.085516	.060656	.091279	−.093806	.112533	.759030	.183784**	.093525	.085090
	Interaction Terms:											
12	DDDD	(LDDD×LDDD)/2	.255217	.033050**	.030033	.014470*	.001562	.005237	.002851	.005861	.002171	.005767
13	DDTS	(LDDD×LDTS)/2	−.402646	.067460**	−.008556	.043866	−.185117	.051228**	.019333	.061265	.043229	.050825
14	DDRE	(LDDD×LDRE)/2	−.151291	.022606**	.088103	.046848	−.117266	.038908**	−.202004	.035545**	−.251086	.033391**
15	DDCI	(LDDD×LDCI)/2	.041853	.037392	−.008460	.027011	.306330	.034498**	.202459	.037252**	.255778	.031310**
16	DDIN	(LDDD×LDIN)/2	.021250	.063896	−.009597	.029151	.044553	.022746	−.007841	.025755	−.079763	.024636**
17	TSTS	(LDTS×LDTS)/2	−.063228	.037044	−.028431	.028733	.029664	.022495	−.027319	.032348	−.039303	.020574
18	TSRE	(LDTS×LDRE)/2	.327448	.059767**	−.147098	.063757*	−.055408	.041094	.154449	.048941**	.235143	.032373**
19	TSCI	(LDTS×LDCI)/2	.034600	.055053	−.015008	.042575	−.059705	.048295	−.080713	.052295	−.137591	.042059**
20	TSIN	(LDTS×LDIN)/2	.105960	.048035*	.070916	.083878	.185542	.036250**	.096944	.037373*	.118457	.031670**
21	RERE	(LDRE×LDRE)/2	−.081513	.019022**	.055862	.019669**	.065890	.015942**	.053137	.030718	.052386	.015009**
22	RECI	(LDRE×LDCI)/2	.044098	.015732**	−.032488	.016458	−.029443	.020889	−.070904	.035332*	−.049224	.017506**
23	REIN	(LDRE×LDIN)/2	−.050596	.043776	.002377	.049531	.101536	.039931*	−.033788	.040260	−.126515	.019148**
24	CICI	(LDCI×LDCI)/2	−.030871	.012470*	.023742	.005786**	.013178	.015361	.018279	.019567	.006086	.005269
25	CIIN	(LDCI×LDIN)/2	.029324	.047689	.059813	.023956*	−.191023	.041487**	−.077936	.033852*	−.008428	.023440
26	ININ	(LDIN×LDIN)/2	−.059766	.023807*	−.070019	.024958**	−.067102	.018489**	−.006659	.022044	.025497	.017832
27	W1W1	(LW1×LW1)/2	.065996	.012474**	.056736	.012774**	.024218	.015915	.074776	.013137**	−.013710	.011082
28	W1DD	LW1×LDDD	.043763	.004916**	.025599	.004832**	.021128	.005209**	.026932	.004601**	.022444	.004507**
29	W1TS	LW1×LDTS	.002595	.007997	.024452	.008604**	.017209	.009748	−.035006	.008425**	−.028999	.007822**
30	W1RE	LW1×LDRE	−.032890	.003595**	−.040262	.003950**	−.028313	.005638**	−.020171	.005156**	−.012668	.004296**
31	W1C1	LW1×LDCI	−.009379	.003805*	.009014	.002773**	−.007557	.005163	.003607	.005288	.004906	.003410
32	W1IN	LW1×LDIN	−.018766	.007205*	−.028169	.007237**	−.014917	.006891*	.005482	.005718	−.003386	.005211
33	W2NEW2NE	(LW2NE×LW2NE)/2	−.060504	.016073**	−.030233	.016020	−.021135	.019723	.074408	.024918**	−.048402	.013922**

Appendix Table 2 continued

Estimated Total Cost Functions, 1985 through 1993, Annual Data[a]

Line	Variable[b]	Definition	1985 Coefficient	1985 Standard Error	1986 Coefficient	1986 Standard Error	1987 Coefficient	1987 Standard Error	1988 Coefficient	1988 Standard Error	1989 Coefficient	1989 Standard Error
34	W2NEDD	LW2NE×LDDD	−.089840	.006512**	−.044386	.006484**	−.041255	.007133**	−.035616	.006401**	−.038524	.006742**
35	W2NETS	LW2NE×LDTS	−.058555	.009895**	−.073670	.011027**	−.060489	.012538**	−.009122	.011488	−.018219	.011560
36	W2NERE	LW2NE×LDRE	.057442	.004642**	.046662	.005231**	.035591	.007644**	.025434	.007145**	.012556	.006409
37	W2NECI	LW2NE×LDCI	−.006371	.005015	.000344	.003655	.001986	.007026	−.017524	.007354*	.006429	.005072
38	W2NEIN	LW2NE×LDIN	.075916	.009338**	.039994	.009763**	.034371	.009044**	.009505	.007877	.004300	.007720
39	W3W3	(LW3×LW3)/2	−.022196	.014751	−.060199	.012707**	−.015371	.013895	−.048763	.013558**	−.005995	.012308
40	W3DD	LW3×LDDD	.018726	.006649**	−.002595	.005276	.005679	.005796	−.008571	.006492	−.001589	.007796
41	W3TS	LW3×LDTS	.053235	.010187**	.049583	.009234**	.045812	.010377**	.057554	.011537**	.055255	.013459**
42	W3RE	LW3×LDRE	−.011143	.004763*	.002079	.004299	−.002747	.006266	−.000896	.007269	−.001569	.007513
43	W3CI	LW3×LDCI	.014817	.005193**	−.008140	.003026**	.005807	.005762	.009078	.007430	−.010186	.005921
44	W3IN	LW3×LDIN	−.038289	.009439**	−.002178	.007881	−.012230	.007306	−.008305	.007845	.008838	.008878
45	W4W4	(LW4×LW4)/2	−.163431	.035315**	−.156798	.028155**	−.180233	.042888**	−.155428	.055615**	−.048409	.025661
46	W4DD	LW4×LDDD	.065579	.035441	.157308	.026883**	.220631	.044201**	.118683	.055172*	.107484	.048973*
47	W4TS	LW4×LDTS	−.031905	.053694	−.219697	.036850**	−.186634	.040827**	−.578142	.137102**	−.239169	.070839**
48	W4RE	LW4×LDRE	.000658	.014114	.048209	.011889**	.134446	.027021**	.187017	.067435**	.176733	.025387**
49	W4CI	LW4×LDCI	−.040884	.030143	.030141	.014820*	−.108994	.022434**	.173468	.039455**	.027380	.026053
50	W4IN	LW4×LDIN	.004034	.059054	−.012413	.041800	−.059602	.041273	.094214	.053919	−.071604	.038025
51	W1W2NE	(LW1×LW2NE)/2	.031644	.009931**	.012257	.009906	.033113	.009590**	−.012625	.010931	.093929	.007044**
52	W1W3	(LW1×LW3)/2	−.078156	.012522**	−.059560	.012347**	−.032737	.015013*	−.062130	.012009**	−.007604	.010678
53	W1W4	(LW1×LW4)/2	.040681	.009341**	.040745	.008959**	.052024	.008267**	.005598	.011137	.068085	.008856**
54	W2NEW3	(LW2NE×LW3)/2	.066130	.014737**	.067371	.015495**	.017331	.017988	.084183	.015904**	−.061687	.011374**
55	W2NEW4	(LW2NE×LW4)/2	−.091564	.012317**	−.085845	.012016**	−.098691	.011129**	−.060557	.015672**	−.080349	.013151**
56	W3W4	(LW3×LW4)/2	.021456	.012308	.014998	.009526	.020105	.008967*	.040818	.014782**	−.024694	.014273
		R-Square	.9975		.9979		.9978		.9975		.9978	
		Observations	173		176		177		179		182	

Appendix Table 2 continued

Estimated Total Cost Functions, 1985 through 1993, Annual Data[a]

Line	Variable[b]	Definition	1990 Coefficient	1990 Standard Error	1991 Coefficient	1991 Standard Error	1992 Coefficient	1992 Standard Error	1993 Coefficient	1993 Standard Error
1	Q	Lowest average total cost dummy variable	−.068997	.013741**	−.043448	.015990**	−.059684	.018924**	−.036306	.021999
2	INTERCEPT		−.748082	.648064	−.489340	.684615	−.281838	.880114	−4.755886	1.289112**
	Output Variables:									
3	LDDD	Demand deposits	.045503	.151201	.192089	.129884	.656033	.179967**	.557617	.204695**
4	LDTS	Small time & savings deposits	.009599	.215478	−.820308	.208502**	−.852535	.242043**	−3.575209	.570827**
5	LDRE	Real estate loans	.642559	.129970**	.609869	.138355**	.117245	.147129	−2.644577	.236153**
6	LDCI	Commercial & industrial loans[c]	−.397316	.124502**	−.030446	.113177	.115122	.132588	−.395634	.158664*
7	LDIN	Consumer installment loans	.328220	.164892*	.694437	.141483**	.641608	.164858**	.024405	.207168
	Factor Price Variables:									
8	LW1	Price of labor[d]	.148715	.073965*	−.024186	.077300	.037533	.082059	−.248337	.103067*
9	LW2NE	Price of capital[e]	.336451	.101737**	.439741	.110382**	.449154	.120736**	.661014	.109901**
10	LW3	Price of small time and savings deposits[f]	.204825	.077652**	.022491	.090489	.062106	.098373	.211241	.102603*
11	LW4	Price of purchased funds[g]	−.379981	.095036**	.123907	.115326	−.097585	.131608	−.247837	.130252
	Interaction Terms:									
12	DDDD	(LDDD×LDDD)/2	.020514	.003727**	.014419	.004514**	.012626	.005907*	−.014460	.006682*
13	DDTS	(LDDD×LDTS)/2	.311361	.047001**	.028965	.047027	.031482	.045755	.227882	.062343**
14	DDRE	(LDDD×LDRE)/2	−.272805	.035119**	−.062256	.025047*	−.163414	.030996**	−.472020	.048091**
15	DDCI	(LDDD×LDCI)/2	.014686	.029354	.004522	.029194	.049197	.040423	.196397	.051271**
16	DDIN	(LDDD×LDIN)/2	−.133637	.020178**	.013000	.023723	.017256	.026322	.000471	.031541
17	TSTS	(LDTS×LDTS)/2	−.136998	.016990**	−.090230	.019642**	−.030466	.030099	−.152629	.048529**
18	TSRE	(LDTS×LDRE)/2	.233261	.035281**	.120436	.020181**	.312487	.028552**	.208148	.048450**
19	TSCI	(LDTS×LDCI)/2	.068044	.050389	.210735	.039140**	.097376	.052354	.078201	.068712
20	TSIN	(LDTS×LDIN)/2	−.028174	.034585	.098438	.034263**	.029153	.043254	−.186578	.084481*
21	RERE	(LDRE×LDRE)/2	.062456	.018270**	.089573	.016893**	−.043189	.022312	.127143	.043235**
22	RECI	(LDRE×LDCI)/2	−.106189	.022581**	−.160992	.023778**	−.026448	.026389	−.075687	.046968
23	REIN	(LDRE×LDIN)/2	−.109124	.019946**	.162370	.027131**	−.154784	.036571**	.129912	.050882*
24	CICI	(LDCI×LDCI)/2	.018912	.003923**	.003893	.004109	.028214	.005956**	.003899	.010438
25	CIIN	(LDCI×LDIN)/2	.022578	.024332	−.090479	.018250**	−.192304	.023039**	−.106726	.018964**
26	ININ	(LDIN×LDIN)/2	.083081	.010927**	.029436	.011590*	.066401	.013281**	.055501	.021601*
27	W1W1	(LW1×LW1)/2	−.015858	.012183	.012844	.012794	−.011263	.011570	.078889	.013967**
28	W1DD	LW1×LDDD	.022794	.004350**	.020940	.005094**	.019438	.005697**	.015181	.006091*
29	W1TS	LW1×LDTS	−.020438	.008165*	−.004513	.009396	−.018925	.010788	−.021372	.013401
30	W1RE	LW1×LDRE	−.022340	.004566**	−.036534	.004978**	−.027025	.005684**	−.034566	.007863**
31	W1C1	LW1×LDCI	.001405	.003442	.005253	.003781	.005427	.004232	.017227	.004645**
32	W1IN	LW1×LDIN	.002583	.004597	.004797	.004672	.009111	.005360	−.000841	.006487
33	W2NEW2NE	(LW2NE×LW2NE)/2	−.047115	.014200**	−.074514	.016487**	−.051169	.017031**	−.092201	.014545**

Appendix Table 2 continued

Estimated Total Cost Functions, 1985 through 1993, Annual Data[a]

Line	Variable[b]	Definition	1990 Coefficient	1990 Standard Error	1991 Coefficient	1991 Standard Error	1992 Coefficient	1992 Standard Error	1993 Coefficient	1993 Standard Error
34	W2NEDD	LW2NE×LDDD	−.033032	.006412**	−.023691	.006659**	−.032104	.006664**	−.033583	.005750**
35	W2NETS	LW2NE×LDTS	−.039239	.011607**	−.043873	.011604**	−.021498	.012311	−.031124	.012484*
36	W2NERE	LW2NE×LDRE	.030422	.006603**	.038610	.006309**	.040793	.006553**	.059242	.007291**
37	W2NECI	LW2NE×LDCI	.011773	.004954*	.010587	.004818*	−.003320	.004866	−.011427	.004342*
38	W2NEIN	LW2NE×LDIN	−.000396	.006590	−.014377	.006006*	−.016496	.006234**	−.005570	.006070
39	W3W3	(LW3×LW3)/2	.044443	.012570**	−.024293	.017682	−.023242	.014560	.025328	.015055
40	W3DD	LW3×LDDD	−.003905	.006668	−.011516	.007078	−.004970	.007762	.005352	.007419
41	W3TS	LW3×LDTS	.062656	.012315**	.044503	.012554**	.050413	.014487**	.046252	.016334**
42	W3RE	LW3×LDRE	−.002781	.007047	.005123	.006848	−.003328	.007630	−.007122	.009547
43	W3CI	LW3×LDCI	−.013236	.005273*	−.014800	.005197**	−.006094	.005765	−.013491	.005658
44	W3IN	LW3×LDIN	.003858	.006885	.013953	.006328*	.006502	.007279	.012082	.007899
45	W4W4	(LW4×LW4)/2	−.060473	.023165*	−.173519	.044259**	−.077872	.041060	−1.288E-05	.035087
46	W4DD	LW4×LDDD	−.042398	.037741	.054621	.030215	.074791	.054349	−.020768	.062123
47	W4TS	LW4×LDTS	.056065	.044894	−.293065	.052808**	−.016287	.081000	.716109	.112858**
48	W4RE	LW4×LDRE	.155863	.028170**	.197301	.029182**	.006706	.036810	−.589564	.082297**
49	W4CI	LW4×LDCI	−.077799	.029807*	.009498	.023824	.062454	.019220**	.044434	.023741
50	W4IN	LW4×LDIN	−.091975	.045605*	.042724	.040918	−.123512	.040847**	−.142696	.036326**
51	W1W2NE	(LW1×LW2NE)/2	.101562	.006515**	.098144	.006869**	.087983	.007459**	.067501	.007971**
52	W1W3	(LW1×LW3)/2	−.002681	.011529	.009524	.012375	−.047291	.011985**	−.082455	.012188**
53	W1W4	(LW1×LW4)/2	.055422	.007647**	.026861	.009912**	.027967	.010267**	−.009707	.012076
54	W2NEW3	(LW2NE×LW3)/2	−.100904	.012102**	−.079209	.012961**	−.033038	.013690*	.009875	.012116
55	W2NEW4	(LW2NE×LW4)/2	−.054202	.010126**	−.093591	.012835**	−.059711	.012171**	−.066571	.011623**
56	W3W4	(LW3×LW4)/2	.001815	.010751	.024042	.013549	.020264	.013967	.083896	.014589**
		R-Square	.9976		.9981		.9976		.9971	
		Observations	184		158		141		132	

*Significant at the .05 level or greater.

**Significant at the .01 level or greater.

[a]The dependent variable is total cost defined as the sum of employee compensation, expense of fixed assets, interest expense of small time and savings deposits, and interest expense of all purchased funds.

[b]All variables except lowest average total cost dummy variable are in natural log form and have been deflated by the Boston Consumer Price Index (annual).

[c]Includes construction and land and farmland loans.

[d]Price of labor is defined as employee compensation divided by the number of full-time employees.

[e]Price of capital is defined as the value of non-residential office space divided by the square footage of non-residential office space, multiplied by 1,000.

[f]Price of small time and savings deposits is defined as interest expense on small time and savings deposits divided by small time and savings deposits.

[g]Price of purchased funds is defined as interest expense of federal funds purchased and securities sold, time certificates of deposit of $100,000 or more, demand notes issued to the U.S. Treasury on other borrowed money, and deposits in foreign offices divided by the stock of federal funds purchased and securities sold, time certificates of deposit of $100,000 or more, demand notes issued to the U.S. Treasury on other borrowed money, and deposits in foreign offices.

Note: The division of several of the interaction terms by 2, although counterintuitive, is a characteristic of a cost function derived from a translog production function. See Varian (1993) for a formal derivation.

Source: U.S. Bureau of Labor Statistics; FW Dodge Division, McGraw-Hill, Inc., *Dodge Construction Potentials Bulletin*; Federal Deposit Insurance Corporation, *Reports on Condition and Income*; and author's calculations.

Appendix Table 3

Elasticity of Total Cost with Respect to Each of Five Outputs, Evaluated at Output Mean

	1985	1986	1987	1988	1989	1990	1991	1992	1993
Real Estate Loans	−.1	0	0	.1	0	0	.2	0	−.2
Demand Deposits	.1	.1	0	.1	.6	0	.1	0	−.1
Small Time and Savings Deposits	1.1	.9	.9	.9	1	.7	.6	.9	1.3
Commercial and Industrial Loans	0	0	0	−.1	.2	.1	.1	0	0
Consumer Installment Loans	−.1	−.1	0	0	0	.2	0	.1	1

Note: See appendix text for methodological details.
Source: Same as for Appendix Tables 1 and 2.