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Financial Strategies of Top-Performance Banks in the Eleventh District

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The early 1980s have been a difficult economic period in the Eleventh Federal Reserve District for both businesses and banks. Energy and agricultural businesses in the District have been rocked by commodity price declines. In addition, the semiconductor and other electronic industries have been in a temporary slump. Finally, the supply of commercial space has increased relative to present demand, placing downward pressure on rents and creating financial stress in the real estate development industry. All these factors have had an adverse effect on Eleventh District banks. Troubled energy, real estate, and agricultural loans have depressed earnings at District banks relative to other banks. In 1985 the average return on assets at District banks, at slightly over one-half of 1 percent, was significantly lower than the average at banks in the rest of the nation.

Despite these problems, some banks in the Eleventh District performed extremely well. When ranked by return on assets for 1985, the top 10 percent of District banks had an average return on assets that was equal to the average for the top 10 percent of banks elsewhere in the nation.

The focus of this article is to determine if the top-performance banks followed specific financial strategies and, if so, whether these strategies differed from those of other District banks. The study compares a series of financial ratios constructed from the balance sheets, income statements, and reports of off-balance-sheet activity for both top-performance and low-performance banks in the District. Two financial strategies were observed among top-performance banks: a commercial real estate strategy and a conservative strategy. In addition, there was one group of top performers whose superior performance appeared to be more directly related to the ability of their management to control expenses and seemed to be relatively unrelated to any particular financial strategy.

Defining strategies and top performance

A financial strategy for the purposes of this study is the collection of management decisions about asset and liability distribution, reserve management, capital position, growth, and off-balance-sheet activity.[1] These are the decisions modeled in most of the literature concerning bank behavior because they are under bank management's control.

Of course, many other decisions made by bank management affect performance directly. The most obvious decisions not included in financial strategy are decisions about the use of real resources, such as land, labor, and physical capital. Other important decisions, such as credit policy, are not fully reflected in the above listing of financial strategy decisions. Since these decisions are crucially important to performance, ratios measuring management's ability to limit loan losses and control expenses also are examined. These variables are not included in the analysis of financial strategy but are included in the final analysis of what is important in determining top performance.

Determining superior strategies by measuring performance is not a trivial matter, primarily because performance is a function of factors other than just strategy. The relationship between strategy and performance begins with a forecast of the future business environment. Given this forecast, a financial strategy could be formulated that would maximize the gains to the bank. Finally, the strategy must be executed. The execution of the strategy within the actual business environment will determine the performance.

Low performance can result from several factors. First, the forecast of the business environment could be wrong and, consequently, produce a bad strategy. Second, even if the forecast were correct, a strategy inappropriate to the forecast could produce low performance. Finally, no matter how superior the strategy and the forecast, if the plan cannot be executed properly, low performance can result. For example, assume that one aspect of execution can be viewed as the ability of bank management to make good credit decisions. If the forecast and strategy suggest that a particular industry will sustain rapid and profitable growth, poor execution could result in lending to the few firms in that industry that will perform poorly in spite of the health of their industry.

This article examines the financial strategies of top-performance banks. In order to maximize the effect of financial strategy on performance in this research, performance was measured over a five-year period.[2] By measuring performance over an extended period, the effects of random errors in forecasts or deviations from normal execution will be minimized.

The return on assets over the period from 1981 to 1985 was chosen as the measure of performance for this research. This performance measure is easily computed for all banks. Return on assets is closely but not perfectly related to performance.[3] Bank management can affect the return on assets in any given period through a variety of decisions. Changes in accounting methodology, decisions to record nonrecurring income, and decisions about the provision for loan losses will all have an impact on return on assets. Calculating the return on assets over a five-year period helps to minimize these effects of management decisions. The possible effects of manipulation of the performance measure were further reduced by calculating the return on assets as net income before extraordinary items divided by total assets. The timing as to when extraordinary income is reported is, to some extent, at the discretion of bank management. Consequently, such income is often recorded in years of otherwise poor financial performance as bank management tries to boost earnings.

A final concern in measuring performance was the effect of bank size on return on assets. Small banks often serve a much different market than do large banks. To minimize this problem, the banks were separated into three size categories. Small banks had total assets of at least $25 million and less than $100 million. Midsize banks had total assets greater than or equal to $100 million and less than or equal to $250 million. Large banks had total assets in excess of $250 million.

Thus, a bank was defined as a top performer if its annualized return on assets from 1981 to 1985 would rank it in the top 10 percent of the banks in its size category. There were 64 small top-performance banks, 23 midsize top-performance banks, and 7 large top-performance banks.

While the analysis to be presented will show the relationship between strategy and performance, it is impossible to determine future successful strategies from an analysis of past successful strategies. A financial strategy is based on a specific forecast of the future business environment, and as the forecast changes, so must the strategy. Consequently, a low-performance bank cannot expect superior performance to result from mimicking the strategy of a top-performance bank. Mimicking the past behavior of successful banks implicitly assumes that the business environment will not change. Whenever the business environment changes, a bank mimicking strategies that were successful in the past will be implementing the wrong strategy.

Methodology for financial analysis

The methodology of the research was designed to determine how top-performance banks responded with regard to four strategic decisions. The first issue was the investment strategy. Specifically, did these banks target their asset holdings into particular types of loans or securities? In addition, what strategies did top-performing banks follow to manage credit and liquidity risk? Second, what strategy did such banks use in funding their asset holdings? Third, did total asset growth differ between top-performance and low-performance banks, and was asset growth a component of their strategy? The fourth and final strategic issue was whether the top-performance banks undertook more, or less, off-balance-sheet activity than low-performance banks.[4]

These four strategic issues were chosen either because of their importance to income generation through the traditional business of banking or because of their importance given the deregulation that has occurred in the banking industry. The investment and funding strategies are most directly related to financial intermediation, the traditional business of banking. In addition, funding strategies have had to adapt to removal of interest rate ceilings on deposits. Banks now have a greater ability to attract various types of deposits. Another aspect of the adaptation is the increased use of service charges on deposit accounts in an effort to generate income to cover the expenses of check clearing and processing. As a result, noninterest income has increased in importance as a source of revenue. The removal of interest rate ceilings also increased the ability of many banks to fund more rapid growth; hence, the rate of growth as a component of financial strategy was examined. Furthermore, deregulation has reduced the spread between the return on assets and the cost of funds. Banks have responded by exploring new sources of revenue. One such source is off-balance-sheet activity.

The investment strategy of top-performing banks was determined by examining the percentage of total assets placed in ten different types of earning assets. These ten categories include eight categories of loans and two categories of securities. The loan categories are commercial and industrial, commercial real estate, residential real estate, foreign real estate, consumer, and agricultural loans; loans to depository institutions; and lease financing receivables. The first category of securities includes U.S. Treasury bills and notes and obligations of other U.S. Government agencies. These securities have essentially no credit risk and are highly liquid. The second category includes all remaining securities, primarily municipal bonds. Although these securities are liquid, they do bear some credit risk. In addition, income from securities in the second category is usually exempt from federal taxes. An eleventh ratio, interest income from loans in proportion to total income, was used to measure the importance of lending activity in generating income.

The investment strategy also covers the bank's decision about the risk-return trade-off. Four ratios were examined to determine the willingness of top banks to bear liquidity and credit risk. The ratios of the two types of securities to total assets measured the share of assets placed in relatively risk-free and highly liquid assets. The third ratio was the ratio of interest income from securities to total income, and the fourth ratio was interest income from loans to total income. These two ratios measured the overall importance of loans, the relatively riskier asset, in generating income.

The funding strategy of top banks was the second strategic issue. Sources of funds were broken down into five categories: transaction deposits, savings and small time deposits, large time deposits, foreign deposits, and borrowed funds. These categories were measured in proportion to total assets.

Overall growth of total assets was the third strategic issue. Deregulation removed some of the barriers to growth, especially for the smaller banks. Consequently, the growth in assets over the past five years was included as a variable to determine if top-performing banks were growing at a more rapid or less rapid rate than other banks.

Finally, the fourth strategic issue was to determine if top banks were offering off-balance- sheet services to generate noninterest income. Two different measures of off-balance-sheet activity were used. One was the ratio of loan commitments, lease commitments, and letters of credit to total assets. The other was the ratio of commitments on forward, future, and option contracts to total assets. The reason for splitting the off-balance-sheet activity into two ratios was that the first ratio represents off-balance-sheet activity that is closely related to the traditional business of banking. The second ratio measures exposure in the financial markets for forwards, futures, and options. This type of financial intermediation is not a traditional activity for bankers, and heavy exposure suggests a strategy of aggressive expansion and diversification into new lines of business. The ratio of noninterest income to total income was also examined as corroborating evidence to determine if off-balance-sheet activity was an important source of revenue. Of course, noninterest income is affected by other factors too, such as service charges.

Multiple successful strategies

Once the sample of top banks had been determined, there was no reason *a priori* to assume that all the banks were conducting similar strategies. To determine if there was more than one successful strategy, a cluster analysis was conducted. Cluster analysis organizes the observations, in this case the top banks, into highly similar groups, or clusters. The procedure calculates the distances between all the data points. It then groups the data points into clusters so as to minimize distances between observations within a cluster and to maximize the distances between different clusters. (For a more detailed description of cluster analysis, see the accompanying box.)

The number of clusters needed to describe the data determines the number of top-performance strategies. Several

Cluster Analysis

Cluster analysis sorts undifferentiated data into similar groups, or clusters. Similarity is measured by the Euclidean distance from each observation to the center of its cluster. Mathematically, the dispersion of all observations can be summarized as dispersion of observations within a cluster and dispersion of clusters. Since the total dispersion of all observations is fixed, any reduction in dispersion within a cluster increases the separation between clusters. Any methodology that iteratively places observations in clusters until each observation is closer to its own cluster center than to any other cluster center is equivalent to minimizing the trace of the within-cluster dispersion matrix. An example of an algorithm used to make these cluster assignments is given here.

This example uses a sample of four observations labeled points *A*, *B*, *C*, and *D*, and each observation consists of two variables, *x* and *y*. The cluster analysis will group the data into two clusters, and the radius, the minimum distance between clusters, is set at 3. The number of clusters and the length of the radius are determined by the researcher.[1]

The first step in the analysis is to set initial cluster seeds. These seeds are the first approximations of the centers of the clusters. The first observation, *A*, becomes the first cluster seed. The second observation, *B*, is a distance of 2.88 from the initial seed. Since the distance is less than the radius, point *B* is grouped into the first cluster. The distance between the third observation, *C*, and the initial seed, point *A*, is 4.24. Since this distance exceeds the radius, point *C* is chosen as the second cluster seed.

After the initial cluster seeds have been set, each observation is assigned to the cluster whose cluster seed is closest. Point *A* is the cluster seed chosen for cluster 1 and, hence, is assigned to cluster 1. Point *B* is 2.88 distance from point *A* and 5.10 distance from point *C*; consequently, it is assigned to cluster 1. Point *C* is the chosen cluster seed for cluster 2, so it is assigned to cluster 2. Observation *D* is 12.00 from cluster 1's initial seed and 9.49 from cluster 2's initial seed; therefore, it is assigned to cluster 2.

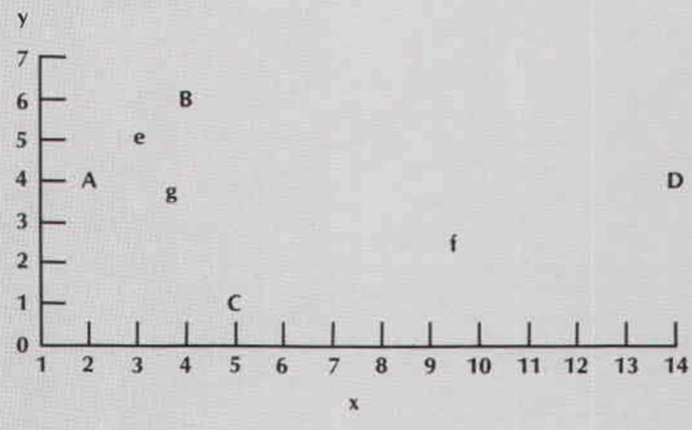
The third step in the cluster analysis is to calculate cluster means. These means then become the new cluster seeds, and the process of assigning observations to clusters is repeated. Point e represents the new cluster seed for cluster 1, and point *f* is the cluster seed for cluster 2.

Observations *A* and *B* are closer to point e than point *f*, so they are assigned to cluster 1. Observation *C* is 4.47 from point e and 4.74 from point *f*; therefore, observation *C* is reassigned to cluster 1. Observation *D* is closer to point *f* than point e, so it remains in cluster 2.

In the next and final iteration, the cluster seeds would be point g (the cluster mean of points *A*, *B*, and *C*) and point *D*, a single-observation cluster. The process of reassigning observations to clusters produces no changes in the composition of the clusters. Consequently, the cluster means would not change. The cluster analysis separated the four observations *A*, *B*, *C*, and *D* into two clusters. The first cluster contained the observations *A*, *B*, and *C*, and the second cluster consisted of the single observation *D*.

1. To eliminate the problem of differences in units, it is typical in cluster analysis to normalize all the variables. For ease of exposition, normalization was not done in this example.

Example of Cluster Analysis



cluster analyses were conducted, varying the number of possible clusters from two through seven. The results of the analysis indicated that there were two clusters for the small top-performance banks, three for the midsize top-performance banks, and only one for the large top-performance banks. The choice of the number of clusters was primarily based on maximizing the cubic clustering criterion, a measure of the separation between clusters.[5]

The results of the cluster analysis in separating the financial strategies for midsize and small banks are presented in Charts 1 and 2.[6] Each strategy was named for its most dominant feature in comparison with the low-performance banks. The two top-performance strategies determined by the cluster analysis were a commercial real estate strategy and a conservative strategy. In addition, there was a group of midsize top-performance banks that followed a financial strategy highly similar to the financial strategy of the low-performance banks. This group of top-performance banks is described as following no distinct financial strategy. The financial ratios for all the top-performance banks are reported by strategy and bank size in the Appendix.

The different strategies were quite distinct among the midsize banks, while a high degree of variation among the small top-performing banks resulted in some overlap of strategies. The financial strategies for the midsize top-performance banks are plotted in Chart 1. The separation of the three clusters indicates the sharp differences between the financial strategies. Chart 2 depicts the two financial strategies for the small top-performance banks. These two strategies are not sharply separated. It is likely that there is a great deal of variation in financial ratios within each strategy for the small banks.

Financial strategies compared between top- and low-performance banks

The crucial question, however, is whether the financial strategies of these top-performance banks differ from the financial strategies of low-performance banks. To answer this question, a sample of low-performance banks in the District was constructed, and a comparison of top-performance and low-performance banks was made. These low-performance banks had annualized rates of return on assets that were below the median return on assets for all banks in the District over the same five-year period used to define the top banks. The reason for choosing banks in the 50th percentile or lower as the low-performance banks was to ensure that the top banks with successful strategies were compared with low-performance banks whose strategies were substantially less effective. Using the 50th percentile as a cutoff also guaranteed that the number of observations would be large.[7]

Chart 1
Financial Strategy Clusters for Midsize Banks

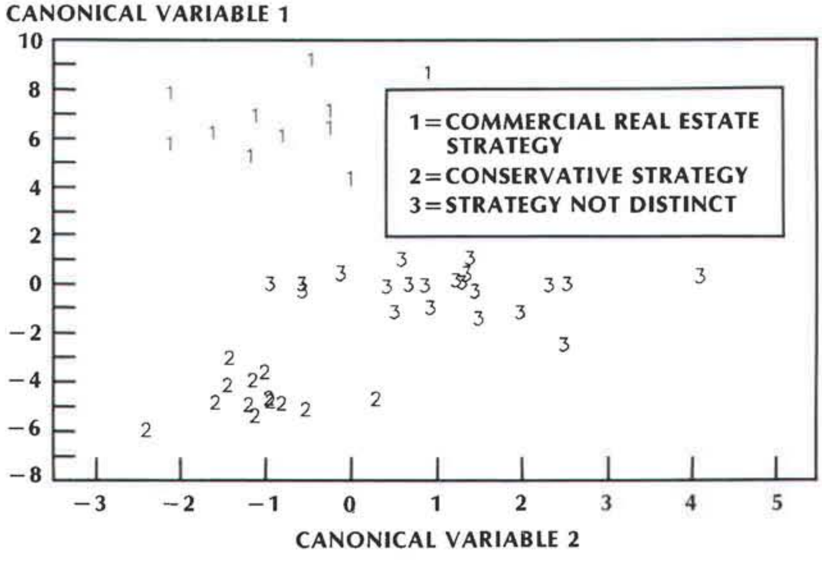
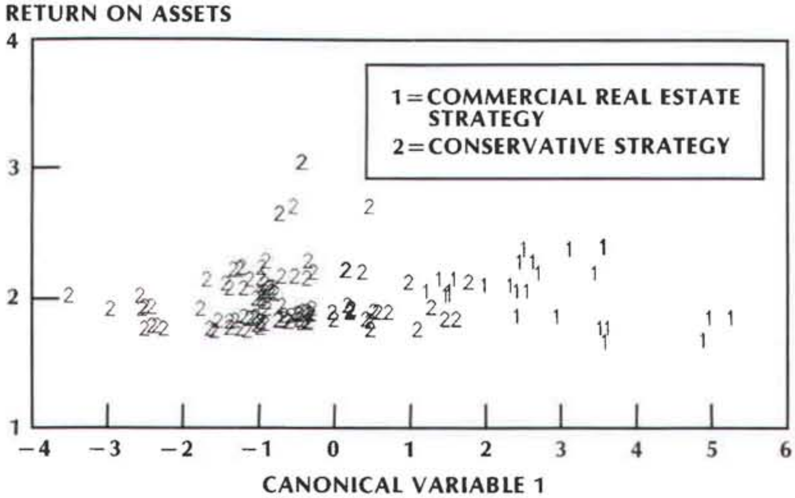


Chart 2
Financial Strategy Clusters for Small Banks



The differences between top-performance and low-performance banks were measured by a difference-of-means test. The various combinations of strategies and size groups were tested separately in comparison with a sample of low-performance banks of similar size. A *t* test was calculated for each of the 22 financial ratios. The differences and the results of the *t* tests are reported in Table 1. In the remaining discussion, top-performance banks will be referred to by their type of strategy. Hence, any reference to a specific strategy bank implies that it is a top-performance bank.

Commercial real estate strategy. Some top-performance banks in all three size categories pursued a strategy that included, among other things, significantly greater lending to the commercial real estate industry. The differences in financial ratios for such banks compared with the low-performance group are reported in the first three columns of Table 1. These banks offset the increased commercial real estate lending with a decrease in commercial and industrial loans. Their asset portfolios also show relatively greater lending to consumers, significantly greater in the case of small and large banks pursuing this strategy.

Not only are these banks lending relatively more to commercial real estate and consumers; some of the banks are also growing at rapid rates. The average small bank following this financial strategy increased its total assets by 96.3 percent over the five-year period from 1981 to 1985. Similarly, total assets at the midsize banks grew 113.8 percent. Both of these growth rates are well over 2 1/2 times the growth rate at their low-performance counterparts. Surprisingly, the large banks following the commercial real estate strategy have recorded only modestly faster growth than their low-performance counterparts, and the difference was not statistically significant.

The banks following a commercial real estate strategy also invest more heavily in non-U.S. Government securities. For the most part, these securities are municipal bonds. Such bonds offer liquidity and have some tax advantages. The income earned is exempt from federal taxes.[8] Consequently, the investment in these securities may be an effect of top performance rather than a cause. Top-performance banks have greater incomes and, therefore, greater incentives to conserve income from the effects of taxation. The converse is true for low-performance banks.

It is difficult to judge whether these banks are taking on greater credit risks than are their low-performance counterparts. These facts are known. They invested more in other securities that do have some risk of default. The midsize and large banks also have higher loan-to-asset ratios than their comparison groups. The midsize and large banks following this strategy have a higher ratio of earning assets to total assets than the low-performance banks in similar size groups. It is clear that a greater percentage of their total assets are exposed to some degree of default risk; however,

Table 1
DIFFERENCES IN FINANCIAL RATIOS BETWEEN TOP-PERFORMANCE AND LOW-PERFORMANCE BANKS

	Financial strategies and bank sizes					
	Commercial real estate			Conservative		Not distinct
	Small	Midsize	Large	Small	Midsize	Midsize
	As percent of total income					
Sources of income						
Loan income	-5.8**	0.0	-1.7	-10.4**	-4.7	-2.4
Security income	2.4	1.4	5.4	9.9**	6.4**	6.2*
Other interest income	3.4	-.3	1.6	-.9	-1.5	-1.4
Noninterest income	1.7	.8	-2.7	1.0	.4	-.7
	As percent of total assets					
Asset composition						
Loans						
Commercial and industrial	-3.6*	-6.5**	-7.0**	-4.1**	-2.5	1.8
Commercial real estate	3.4*	6.8**	7.4**	-2.5**	1.4	.2
Residential real estate	-1.6	-2.2	-.1	-2.3**	-.8	-1.8
Foreign real estate	.0	.0	.0	.0	.0	.0
Consumer	2.6*	2.3	4.6*	-.1	-1.2	-1.2
Agricultural	-3.9**	-.3	-1.1	.0	-1.4*	-.8
Depository institutions	-.2**	1.8	2.6	.5	1.2	-.2**
Lease financing	.2	-.1	.4	.1*	.0	.1
Securities						
U.S. Government	-3.1	-.2	2.8	4.7**	-1.1	4.5
All other	6.2**	1.7	4.5**	7.1**	10.3**	2.6*
Liability composition						
Deposits						
Transaction	4.0**	-.8	-.5	1.6**	2.2**	.4
Savings and small time	-3.8**	1.9	16.4**	-2.9**	-.1	-1.0
Large time	-2.0	-1.1	-4.5	-2.4**	-3.5**	.2
Foreign	.0	.0	-3.7	.0	.0	.0
Borrowed funds	.1	-.6	-8.8**	-.4**	-1.6**	-1.4**
Off-balance-sheet activity						
Commitments on loans, leases	.5	.1	-15.0**	-.6	1.1	1.0
Commitments on forwards, futures, options	-.1**	.0	-1.3	.0	.0	.0
Asset growth						
Percent change in total assets from 1981 to 1985	61.1**	70.1**	9.8	7.2**	-21.2**	17.1**

* Significant at the .10 level.
** Significant at the .05 level.

this exposure does not necessarily imply a higher expected level of defaults. Their net chargeoffs to total loans are significantly lower than similar ratios at low-performance banks.

The banks following a commercial real estate strategy appear to have no common strategy with regard to funding their asset portfolio. The small banks following this strategy have significantly higher transaction deposits and significantly lower savings and small time deposits. The midsize banks reported no significant differences in their funding strategy compared with the midsize low-performance banks.

The funding strategy of large top-performance banks appears to have taken advantage of deposit deregulation to build stable funding sources that would lower liquidity risks. At the large top-performance banks, savings and small time deposits relative to total assets were significantly higher than at large low-performance banks. This category of deposits includes money market deposit accounts and money market certificates. These relatively stable deposits were used in place of more volatile and expensive sources of funds. As a share of total assets, borrowed funds were significantly lower at large top-performance banks, and large time deposits, a traditional source of funds for large banks, were also lower, though not significantly.

Finally, off-balance-sheet activity was not a source of higher profits for the banks following the commercial real estate strategy. There was little difference in the off-balance-sheet activity between top-performing and low-performing banks in the small and midsize categories. The small commercial real estate banks did have significantly less committed in forwards, futures, and options, but the difference was small in magnitude. The large top-performing banks had significantly smaller off-balance-sheet commitments, relative to total assets, than large low-performing banks. The large banks also had lower noninterest income, but this difference was not significant.

Conservative strategy. The second financial strategy for top performance was a relatively conservative strategy. The strategy appears to reduce both credit and liquidity risks. In the sample, there were both small and midsize banks that followed this strategy. The differences between their financial ratios and those of the low-performance banks are reported in the fourth and fifth columns of Table 1.

The asset distribution and the sources of income indicate that these conservative banks invest more heavily in lower-risk securities and relatively less in loans that have a higher probability of default. In addition, securities have a much greater degree of liquidity.

The sources of income give a clear indication of this strategy. The interest and fee income from securities is a significantly higher proportion of total income at the conservative banks compared with low-performance banks in similar size classes. Conversely, the interest and fee income from loans relative to total income is less at the conservative banks, significantly so in the case of small banks.

The differences in the sources of income are mirrored in the differences in the asset distribution. The ratio of securities to total assets is approximately 50 percent higher at the conservative banks than at the low-performance banks. The decision to hold a greater proportion of total assets in securities dictates that a lower proportion of assets be placed in other assets—in particular, loans. The loan-asset ratio of the small conservative banks was 8.4 percentage points lower than the same ratio at the low-performance banks. Commercial and industrial loans, commercial real estate loans, and residential real estate loans in proportion to total assets were all significantly lower at the small conservative banks. At the midsize conservative banks, the loan-asset ratio was 3.3 percentage points lower than the ratio for their low-performance counterparts. Relatively less lending in proportion to total assets occurred in several specific loan categories, but only agricultural lending to total assets was significantly lower.

The funding strategy of the conservative banks also indicates a strategy designed to reduce liquidity risks. The use of large time deposits and borrowed funds was significantly less at the conservative banks. These banks funded their asset portfolios with significantly greater transaction deposits. In addition, total liabilities funded a smaller share of total assets at these conservative banks, indicating that a greater proportion of such assets are funded with capital or subordinated debt.[9]

The differences in asset growth, while significant, were far less dramatic at the conservative banks than at the banks that pursued the commercial real estate strategy. At the small conservative banks, the growth in assets was 42.4 percent over the five-year period, compared with 35.2 percent at the small low-performance banks. In contrast to all the other categories of top-performing banks, total assets at the midsize conservative banks grew significantly less than at the midsize low-performance banks. Total assets rose 22.4 percent at these banks, roughly one-half the increase at the midsize low-performance banks.

No distinct financial strategy. A group of midsize top-performance banks appears to be following the same financial strategy as the low-performance banks. There were few important differences between the financial ratios of these top-performance banks and the low-performance banks.

The differences in the financial ratios are reported in the sixth column of Table 1. These banks have a small but significant difference in loans to depository institutions as a proportion of total assets, and they fund a lower proportion of their portfolio with borrowed funds than do low-performance banks. The growth rate of assets was significantly higher at the top-performance banks. These differences, however, appear to be too small in magnitude to account for the banks' superior performance. The differences in their holdings of securities and the income generated from securities are more likely an effect, rather than a cause, of top performance.

The ability to separate different strategies depends on the degree of disaggregation in the data. It is possible that the 22 financial ratios used to specify strategies are inadequate for determining the differences in the case of banks with no distinct strategy. If a financial strategy involved lending to a specific industry, this difference might not reveal itself because all commercial and industrial loans are aggregated in the Report of Condition.

Controlling expenses and loan losses at top-performance banks

A superior financial strategy, however, is not the only means of achieving top performance. The relationship between strategy and performance depends on the ability of bank management to execute the strategy. Poor execution is a potential cause of poor performance, regardless of the superiority of the financial strategy. The converse may also be true—that superior execution may produce top performance even when the financial strategy appears to be no different from the financial strategy of the low-performance banks.

Previous economic research investigating the causes of bank profitability has found that the ability to control expenses is an important explanatory factor.[10] Controlling costs is not considered a financial strategy decision within the context of the bank modeling literature. It is, however, an example of the importance of execution in determining financial performance.

To determine if management's ability to execute was responsible for the top performance, several ratios measuring its ability to control expenses and loan losses were examined relative to those of the low-performance banks. Two ratios were used to measure the cost of funds: the average cost of deposits and the average cost of large time deposits. The average cost of deposits is affected by the funding strategy. The average cost of large time deposits measures the bank's ability to obtain funds at the lowest cost. The cost of the large time deposits may be affected by the timing of the acquisition of large time deposits, as in periods of low interest rates, or by the maturity of the large time deposits acquired. This cost measure will also be affected by other factors, such as risk premiums. Noninterest expense as a percentage of total assets is a measure of total cost control over real resources.

The ability of bank management to control loan losses was measured by two ratios. First, the ratio of net chargeoffs to total loans was used as a measure of present credit problems. Second, the ratio of nonaccruing loans to total loans was used as a measure of future loan losses. The second measure could be used to determine if bank management was only postponing taking loan losses.

Regardless of their individual financial strategies, all the top-performance banks were superior in their ability to manage expenses and loan losses. The differences in the expense ratios are reported in Table 2. All the top-performance banks were significantly better than the low-performance banks at controlling loan losses and other credit problems. In four out of six cases, the top-performance banks had a significantly lower cost of funds, and in five of the six cases, the noninterest expenses were significantly lower. With regard to the cost of large time deposits, which might be considered the marginal cost of funds for these banks, only two types of top-performing banks had a lower cost and one group of the top-performing banks had a significantly higher cost of large time deposits.

The midsize banks that followed no distinct financial strategy were superior to low-performance banks in all five of the expense-control ratios. Their credit-quality ratios were significantly lower, indicating that these banks are superior at controlling loan losses. Their average cost of funds was significantly lower than for the low-performance banks, and their marginal cost of funds was significantly lower, which was true at only one other group of top-performance banks. Finally, the difference in their noninterest cost ratio was not only significant, but it also indicated that no other group of top-performance banks was more effective in controlling noninterest costs.

Of course, these results may be seen as tautological. Since the performance measure is essentially income less expenses divided by total assets, anything that lowers expenses will be associated with higher returns. The expense ratios used do not measure management intentions but actual outcomes. If the outcomes were random, then the idea that strategy has any relationship to performance would be severely questioned. While this matter cannot be dismissed, there is some evidence that expense-control ratios are not always the most important criterion in determining performance.

Overall measure of differences between top- and low-performance banks

While the above tests report differences in specific financial and expense ratios, an overall measure of the differences between the top-performance banks and the low-performance banks is needed. The overall measure of difference used was Wilks' lambda, generated by discriminant analysis. Discriminant analysis seeks to determine the most efficient method of distinguishing two groups of data; in this case, the two groups are top-performance banks and low-performance banks. Methodologically, discriminant analysis examines all the variables and separates from these variables a subset of variables that has the greatest ability to discern the correct group membership of any particular observation.

The degree of separation between the two groups is directly related to the ability of the discriminant analysis to assign membership to the groups correctly, and this ability is measured by Wilks' lambda. Wilks' lambda measures the proportion of residual variation (to the total variation) remaining when the discriminant analysis is completed. Thus, the Wilks' lambda statistic ranges in value from 0 to 1. A value of zero for Wilks' lambda indicates that the discriminant function explains all the variation between the groups and there is no residual variation remaining. A value of 1 would indicate that the discriminant function was unable to explain any of the variation between groups.[11]

Discriminant analysis was also used to determine the importance of the expense ratios in separating the top-performance banks from low-performance banks. The first discriminant analysis used only the 22 ratios defining financial strategies. A second discriminant analysis was performed using the 5 expense ratios in addition to the 22 financial ratios. Any large decrease in the Wilks' lambda between these two analyses would indicate that the expense ratios were important in separating the top-performance banks from low-performance banks.

The results of the discriminant analysis indicate that financial strategy is important in differentiating between top-performance and low-performance banks. For some of the top-performance banks, inclusion of the expense-control ratios increased the ability of the discriminant analysis to distinguish the top- from low-performance banks. The results for the discriminant analysis are reported in Table 3.

When financial strategy only was considered, the analysis was able to discriminate the top-performance banks from low-performance banks with success in all cases. The Wilks' lambdas were significantly less than 1 in all cases. The large top-performance banks following the commercial real estate strategy were most distinguishable from the low-performance banks in their size category. The Wilks' lambda of 0.4122 indicates that more than half of the total variation was explained.

The midsize top-performance banks classified as having no distinct strategy had the highest Wilks' lambda, indicating relatively less differentiation between their financial strategy and the strategies of midsize low-performance banks. This result is in agreement with the *t* tests, which showed only minor differences in financial strategy between these banks and their low-performance counterparts. In addition, the most important variable in discriminating between these top-performance banks and the low-performance banks was the ratio of interest income from securities to total income. This ratio reflects heavy investment in other securities. It is likely that the heavy investment in other securities is the result of investment by highly profitable banks in tax-exempt securities to avoid taxes. Consequently, a large part of the discrimination between these two groups may be based on a variable that is a result of top performance and not a cause of top performance.

In the second discriminant analysis, where financial strategy was combined with measures of management's ability to control expenses, there was little improvement in the ability of the discriminant analysis to separate top-performance banks following either commercial real estate or conservative strategies from low-performance banks. Among the five groups of banks, three cases resulted in little or no decline in Wilks' lambda. In the remaining two cases, the actual magnitude of the decline was notable, but the percentage increase in the explained variation was relatively small.

The midsize top-performance banks that followed no distinct strategy reported a moderate decline in Wilks' lambda on the basis of the discriminant analysis using both financial and expense ratios. The value of Wilks' lambda declined 0.0323. Furthermore, the average cost of funds and the ratio of noninterest expenses to total assets were more important variables in discriminating between the groups than the ratio of interest income from securities to total income. These results suggest that bank management's ability to control expenses was an important determinant in achieving top performance for such banks.

Conclusion

The above analysis describes the successful financial strategies of the top-performance banks in the Eleventh District from 1981 to 1985. The analysis, which was conducted for

Table 2
EXPENSE RATIOS FOR TOP-PERFORMANCE BANKS

	Financial strategies and bank sizes					
	Commercial real estate			Conservative		Not distinct
	Small	Midsize	Large	Small	Midsize	Midsize
	Means					
Cost of funds (Percent)	5.8	6.3	6.7	6.5	6.8	6.5
Cost of large time deposits (Percent)	8.6	8.4	9.2	9.0	10.3	8.5
Noninterest expenses as percent of total assets	3.1	2.5	2.2	2.9	2.6	2.4
Net chargeoffs as percent of total loans	.5	.4	.5	.6	.8	.5
Nonaccruals as percent of total loans	.6	.5	1.3	.6	1.4	.7
	Differences from low-performance banks (Percentage points)					
Cost of funds	-1.1**	-.5**	.3	-.4**	-.1	-.3*
Cost of large time deposits	-.8	-1.1*	-.1	-.4	.8*	-1.0**
Noninterest expenses as percent of total assets	-.3	-.8**	-.4*	-.5**	-.7**	-.8**
Net chargeoffs as percent of total loans	-1.2**	-1.3**	-.9**	-1.1**	-.9**	-1.1**
Nonaccruals as percent of total loans	-1.4**	-2.0**	-2.2**	-1.4**	-1.1**	-1.8**

* Significant at the .10 level.
** Significant at the .05 level.

Table 3
RESULTS OF DISCRIMINANT ANALYSIS EXPRESSED BY WILKS' LAMBDA

	Financial ratios	Financial and expense ratios	Change
Commercial real estate strategy			
Small banks	.7877	.7877	.0000
Midsize banks	.8108	.8106	-.0002
Large banks	.4122	.3447	-.0675
Conservative strategy			
Small banks	.5927	.5716	-.0211
Midsize banks	.7550	.7550	.0000
Strategy not distinct			
Midsize banks	.8691	.8368	-.0323

three size classes of banks, was based on a comparison of banks with high returns on assets with a sample of low-performance banks. There were two distinct successful financial strategies: commercial real estate and conservative. In addition, there was a group of banks that did not use a distinct financial strategy but appeared to achieve top performance through a strategy of controlling expenses.

High-quality credit management appears to be a necessary condition for superior performance. Regardless of strategy, top-performance banks in the District had significantly lower loan losses. These findings suggest that even an optimal financial strategy cannot overcome bad credit decisions and the resulting large loan losses.

In addition, high-quality management is sufficient for superior performance. The banks with no distinct financial strategy were top performers primarily because of their ability to control expenses. This result also indicates that it is possible to avoid high loan losses even when lending in a troubled economy.

Financial strategies do appear to be effective in generating high returns. Most banks classified as top performers had distinct financial strategies. These strategies must be considered within the business environment at the time. The conservative financial strategy appeared to be entirely appropriate for an economy that was in a downturn. The commercial real estate strategy was a success during the 1981-85 period, which included a construction boom. This success, however, may fade over the next year or two. The construction boom has ended in the Eleventh District, and there are concerns that an oversupply of commercial space will result in financial pressure on the real estate industry and loan losses at the banks. This change in the business environment does not necessarily mean that banks following this strategy will suffer losses. If, as the loan loss ratios suggest, management at these banks has carefully judged credit risks or has structured loans in an effort to lower risks, then earnings may not be reduced. Since provisions for losses from real estate loans are only beginning to be made, it is too early to tell if these top performers will be adversely affected. The change in the business environment does suggest that such banks should consider a change in financial strategy.

Finally, it is unwise for a bank to mimic the successful financial strategy of one of its competitors. Financial strategies are based on a specific forecast of the business environment. It takes time for a financial strategy to generate the high returns that identify it as successful. By the time a strategy has been identified and a mimicking bank implements a similar strategy, the business environment may have changed so dramatically that the strategy in question is no longer appropriate. The commercial real estate strategy is a perfect example. It would be unwise for a bank to mimic this successful strategy of the past because it will not be a successful strategy in the near future.

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1. The first four categories of management decisions are the standard decision variables in models of bank behavior. For a review of this literature, see Ernst Baltensperger, "Alternative Approaches to the Theory of the Banking Firm," *Journal of Monetary Economics* 6 (January 1980): 1-37.

2. The five-year time period was chosen arbitrarily. The length of the time period can have an important effect on the performance measure.

3. It can easily be shown that if a bank has a source of funds that is completely interest-elastic, then profit-maximizing behavior will not maximize return on assets. For a full description of the differences between profits and profit margins under liability management, see John M. Mason, *Financial Management of Commercial Banks* (Boston and New York: Warren, Gorham & Lamont, 1979), 62-64. Another important characteristic that has not been addressed here is the trade-off of risk for return. The measure of performance used in this article is the rate of return on assets. Based on this measure, both the conservative and commercial real estate top-performance banks had roughly similar performances. The conservative banks, however, were able to generate a high rate of return and, at the same time, take on much less credit and liquidity risk. If a risk-adjusted measure of performance were to be used, a much different sample of top-performance banks might be selected.

4. Bank holding company affiliation and market concentration, two important nonfinancial factors that might affect performance, were also examined. Bank holding company affiliation did not appear to have any impact on the composition of the top-performance banks. The effect of being affiliated with a bank holding company has been examined extensively in the literature. For one of the more extensive studies, see Duane B. Graddy and Reuben Kyle, III, "Affiliated Bank Performance and the Simultaneity of Financial Decision-Making," *Journal of Finance* 35 (September 1980): 951-57.

   A multitude of studies have shown a small but significant relationship between market concentration and bank profitability. For a summary of the structure-conduct-performance literature regarding banking, see Stephen A. Rhoades, *Structure-Performance Studies in Banking: An Updated Summary and Evaluation*, Staff Studies, no. 119 (Washington, D.C.: Board of Governors of the Federal Reserve System, 1982). An alternative hypothesis is that the line of causation is reversed. The essential component of this hypothesis is that performance will affect structure. Based on this alternative hypothesis, it has been shown that the concentration of bank markets has little explanatory power over bank profitability after market share has been taken into account. For empirical evidence of this alternative hypothesis, see Michael Smirlock, "Evidence on the (Non) Relationship Between Concentration and Profitability in Banking," *Journal of Money, Credit, and Banking* 17 (February 1985): 69-83. In this sample, there is no evidence of any relationship between concentration of the market and designation as a top-performance bank.

5. The exact number of clusters within a given group of data is an imprecise issue. The number of clusters here reflects the requirement that clusters have more than three observations; otherwise, there might have been several one- or two-member clusters representing outlying

observations. The midsize banks had the most definitive separation into three clusters. When the number of clusters was reduced from four to three, the cubic clustering criterion increased 57 percent; when the number of clusters was reduced from three to two, the cubic clustering criterion declined 267 percent. For small banks the decision about the number of clusters was much less definitive. Reducing the number of clusters from three to two decreased the cubic clustering criterion only 1.4 percent. Since the decline in the cubic clustering criterion was relatively small, it was decided to use only two clusters for the small banks. This decision increased the number of degrees of freedom in the analysis of the financial ratios. The clustering analysis was unable to determine more than one cluster among the large banks. See Brian Everitt, *Cluster Analysis*, 2d ed. (London: Heinemann Educational Books on behalf of Social Science Research Council; New York: Halsted Press, Division of John Wiley & Sons, 1980), 66.

6. Since each observation includes 22 variables, it is impossible to graph the clusters directly. Consequently, a canonical discriminant analysis was conducted to determine summary measures for each observation. The canonical function produces one fewer summary measures than there are clusters. As a result, there is one canonical variable for the two small-bank clusters and two canonical variables for the three midsize-bank clusters.

7. The results of this analysis are not diminished by the fact that the differences between the top-performance and low-performance banks may be maximized by the method of selecting the comparison sample. First, the definition of "top-performance banks" is entirely arbitrary. It would be just as feasible to increase the differences by redefining top banks as those in the 95th percentile instead of the 90th percentile. Second, the goal of this work is to contrast successful strategies with unsuccessful strategies. If the comparison group included all banks not classified as top-performing, then a "low-performance bank" in the 89th percentile would be compared with a top-performance bank in the 90th percentile. Close comparisons would only cloud the differences between successful and unsuccessful strategies.

8. There have been some changes in tax law that reduce the ability of banks to deduct interest expense for funds used to finance the banks' holdings of tax-exempt bonds. These securities still retain some tax advantages.

9. The relatively greater use of capital to fund the asset portfolio was common to all top-performance banks. Since the dividends paid to capital are not written off as expenses, it is likely that the increased use of equity would bias upward the return on assets.

10. See Larry Wall, "Why Are Some Banks More Profitable Than Others?" *Journal of Bank Research* 15 (Winter 1985): 240-56.

11. See William R. Klecka, *Discriminant Analysis*, Sage University Paper Series on Quantitative Applications in the Social Sciences, no. 07-019 (Beverly Hills and London: Sage Publications, 1980), 38.

Appendix

CLUSTER MEANS FOR TOP-PERFORMANCE BANKS

	Financial strategies and bank sizes					
	Commercial real estate			Conservative		Not distinct
	Small	Midsize	Large	Small	Midsize	Midsize
	As percent of total income					
Sources of income						
Loan income	57.2	66.6	66.9	52.6	61.8	64.2
Security income	22.2	18.9	18.8	29.6	23.9	23.7
Other interest income	9.9	6.0	7.5	5.6	4.8	4.9
Noninterest income	9.5	8.2	6.1	8.8	7.8	6.6
	As percent of total assets					
Asset composition						
Loans						
Commercial and industrial	14.5	14.8	17.9	14.0	18.8	23.2
Commercial real estate	14.3	21.2	22.4	8.4	15.8	14.6
Residential real estate	6.7	5.2	3.8	5.9	6.6	5.6
Foreign real estate	.0	.0	.0	.0	.0	.0
Consumer	15.5	14.2	10.9	12.8	10.7	10.8
Agricultural	1.1	3.1	1.0	5.0	1.5	2.0
Depository institutions	.1	2.1	3.8	.8	1.5	.1
Lease financing	.2	.0	.6	.1	.0	.1
Securities						
U.S. Government	11.0	11.4	11.0	18.7	10.5	16.1
All other	13.7	9.3	10.0	14.7	17.9	10.2
Liability composition						
Deposits						
Transaction	30.7	25.8	23.8	28.3	28.7	27.0
Savings and small time	40.3	40.6	38.6	41.2	38.6	37.6
Large time	17.5	23.1	27.3	17.1	20.7	24.5
Foreign	.0	.0	.0	.0	.0	.0
Borrowed funds	1.1	1.6	.9	.6	1.6	.7
Off-balance-sheet activity						
Commitments on loans, leases	3.7	6.2	8.3	2.6	7.1	7.1
Commitments on forwards, futures, options	.0	.0	.0	.0	.0	.0
Asset growth						
Percent change in total assets from 1981 to 1985	96.3	113.8	50.8	42.4	22.4	60.7

Structure and Technology of Manufacturing in Texas and Louisiana

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Manufacturing is a significant source of employment in Texas and Louisiana, but it is also a troubled sector of the economy. Since 1981, manufacturing in these two states has lost over 200,000 jobs. Although manufacturing employment is also shrinking in the remainder of the nation, the rate of decline in Texas and Louisiana has been much steeper as a result of the heavy concentration of energy-related industries in these two states and the sharp drop in oil prices since 1982.

This sharper decline in manufacturing performance in Texas and Louisiana is attributable to energy ties and underscores the dramatic differences in their industry composition in comparison with that of the remainder of the United States. No other region of the country exhibits such a high concentration of petroleum refining, petrochemicals, or oil field machinery production.[1] This concentration of energy-related manufacturing in Texas and Louisiana has resulted from the greater concentration of oil and gas exploration and production in these two states. These dissimilarities add to the variation that normally would occur among regions of the country because of differences in input prices and the age of their respective capital stocks.

Other studies have examined input substitution in manufacturing, on both the national and the regional level, but these studies have not looked specifically at manufacturing in Texas and Louisiana. By obtaining estimates unique to this region, the present study has described how manufacturing firms in these two states respond to input price changes. These estimates indicate that in these two states in comparison with the remainder of the nation, inputs are more easily substituted for one another and that inputs are generally more responsive to changes in their prices. In addition, input substitution as a result of changing energy prices is responsible for a significant portion of the employment changes that have occurred in these two states, both while energy prices were rising and since they have been falling.

To describe the differences in manufacturing between Texas and Louisiana as a unit (Texas/Louisiana) and the remainder of the United States as a group, this study has analyzed both the industry composition of value added and the input cost shares. To provide a measure of how manufacturers adjust input use as input prices change, the substitution elasticities and the price elasticities of input demand were calculated for manufacturing in Texas and Louisiana. These estimates allow the determination of the direct impacts on factor use stemming from changes in relative input prices. Because a change in the relative price of

Table 1
INDUSTRY DISTRIBUTION OF VALUE ADDED IN MANUFACTURING, 1982

	Percentage shares of value added			
Industry	Texas	Louisiana	Combined	Remainder of United States
Food and kindred	10.0	9.4	9.9	10.8
Tobacco	0.0	0.0	0.0	1.2
Textile	n.r.	n.r.	n.r.	2.4
Apparel	2.7	1.3	2.4	3.2
Paper and allied	1.9	6.0	2.6	4.2
Printing	4.6	3.0	4.3	6.8
Chemical and allied	15.8	26.4	17.7	8.7
Petroleum refining	9.0	21.1	11.1	2.0
Rubber	2.4	0.7	2.1	3.4
Leather	0.3	0.0	0.3	0.6
Nondurable	46.6	67.8	50.5	43.3
Lumber and wood	1.7	2.3	1.8	1.9
Furniture	0.8	n.r.	0.7	1.6
Stone, clay, and glass	3.5	2.6	3.4	2.7
Primary metal	3.5	5.2	3.8	4.1
Fabricated metal	7.8	5.4	7.4	7.1
Machinery, except electrical	17.7	5.0	15.4	12.2
Electrical and electronic machinery	8.5	4.0	7.7	10.5
Transportation equipment	6.5	8.1	6.8	10.6
Instruments	1.7	0.6	1.5	4.3
Miscellaneous	1.3	0.3	1.1	1.8
Durable	53.1	33.4	49.5	56.7
Total value added (millions of dollars)	53,361.4	11,751.6	65,113.0	759,004.7
Share of United States (percent)	6.5	1.4	7.9	92.1

NOTE: n.r. signifies not reported.
SOURCE OF PRIMARY DATA: U.S. Bureau of the Census, *1982 Census of Manufactures*.

one input may affect a firm's demand for all other inputs it uses, each of the substitution relationships among inputs needed to be examined. For example, because labor and energy are substitutes, a fall in energy prices is likely to cause labor employment to decline as the relatively cheaper energy is substituted for labor.

It should be noted here that the present study does not directly address the effects on input demand resulting from changes in the demand for manufactured goods. Although such effects are important, only the shifts in input demand resulting from the substitution effects of price changes are covered in this study.

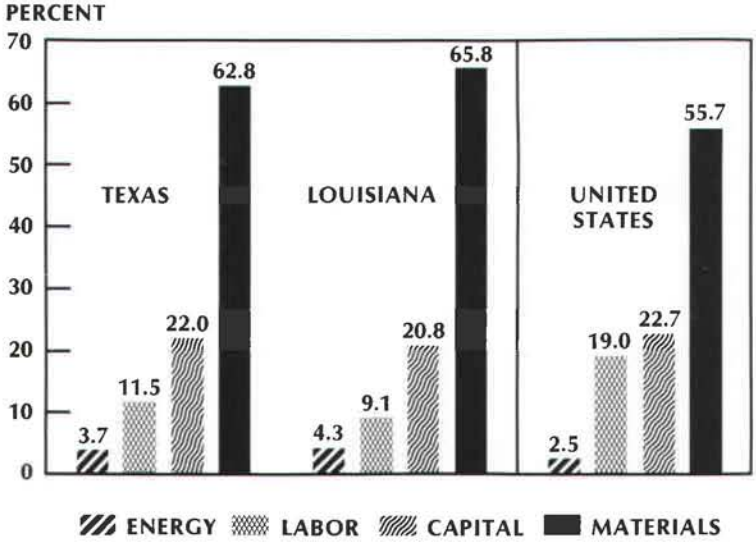
Composition of manufacturing in Texas and Louisiana

The most obvious difference in manufacturing in Texas/Louisiana in comparison with the remainder of the United States lies in the large concentration of petroleum refining and chemical manufacturing in these two states. Petrochemicals, the production of petroleum- and natural-gas-based compounds, represents the majority of the chemical and allied industry. Refineries and chemical plants have located operations in these two states because of the proximity to abundant crude oil and natural gas production and to seaports, which allow for transporting products to other markets and permit easy delivery of raw materials. The concentration of these two industries makes nondurable goods manufacturing more important in these two states than in the rest of the nation. Evidence of this structure can be seen by examining Table 1, which compares the proportion of value added that was contributed by each industry (as identified by a two-digit Standard Industrial Classification [SIC] Code) in Texas/Louisiana and the remainder of the United States.

An examination of the individual states reveals some other significant differences. Reflecting the abundance of forest resources in Louisiana, the paper and allied products and lumber and wood products industries in this state constitute a higher proportion of value added than they do in Texas and the remainder of the nation. In contrast, Texas has a particularly high proportion of value added from nonelectrical machinery. This reflects the status of Texas as a major international site for manufacturing oil field machinery. That status—plus a construction industry that until recently was more vigorous in Texas than in the remainder of the nation—probably accounts for the higher proportion of value added in fabricated metals and stone, clay, and glass production.

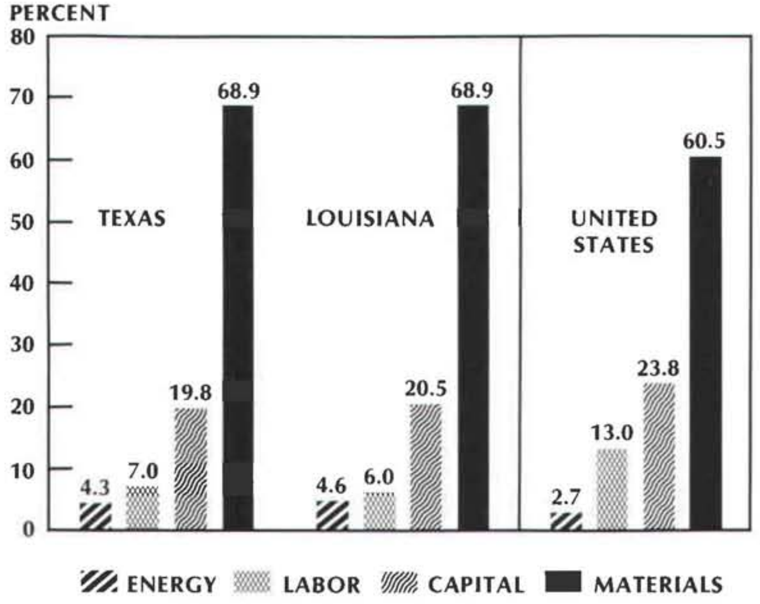
The compositional differences between Texas/Louisiana and the remainder of the nation are actually greater than Table 1 implies. Even in industries where the proportions of value added are similar to those nationally, the actual markets served will vary. In these two states, a greater part of the demand for manufacturing output—especially in durable goods—comes from the energy industry. Transporta-

Chart 1
Factor Cost Shares for Aggregate Manufacturing, 1978



SOURCE OF PRIMARY DATA: U.S. Bureau of the Census, *1978 Annual Survey of Manufactures.*

Chart 2
Factor Cost Shares for Nondurable Goods Manfacturing, 1978



SOURCE OF PRIMARY DATA: U.S. Bureau of the Census, *1978 Annual Survey of Manufactures.*

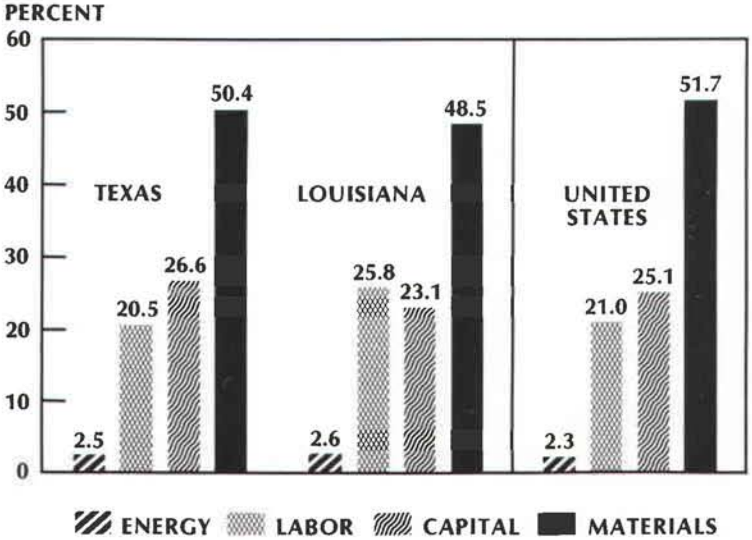
tion equipment manufacturing is an example. In Texas and Louisiana, this sector includes a relatively larger share of shipbuilding and repairing, which in this region is related to offshore oil and gas drilling. On the other hand, automobile manufacturing in the nation is a much larger share of value added in transportation equipment.

The differences in manufacturing are not limited to the industry composition of value added but also include overall factor use. (See Chart 1 for a comparison of the share of factor costs in manufacturing in Texas/Louisiana and the remainder of the United States.) In Texas and Louisiana, manufacturing is generally more energy-intensive, while labor is used less intensively, although raw materials represent the largest share of total cost. Given the composition of industry in these two states, this differential utilization of energy, labor, and raw materials is predictable. Chemicals and refining, for instance, use large amounts of raw materials, relatively less labor, and relatively more energy. (In this context, materials include crude petroleum and natural gas that are processed into different products. Only if used directly as a fuel are they included in the energy total.) Charts 2 and 3, respectively, show the factor cost shares for nondurable and durable manufacturing. In nondurable manufacturing, which includes refining and chemical production, the proportion of total costs accounted for by energy and materials is much greater for the two-state area than it is for the nation. Conversely, labor and capital in the nondurable industries constitute a smaller share of total costs. For durable manufacturing, however, the relative factor costs for Texas and Louisiana are roughly similar to those for the nation.

Calculating the effects of input price changes

Firms alter their input usage by substituting away from inputs that have become more expensive towards relatively cheaper ones. This substitution effect examined in the present study (and in most other studies of input demand) is measured holding the firms' output constant. Input price

Chart 3
Factor Cost Shares for Durable Goods Manufacturing, 1978



SOURCE OF PRIMARY DATA: U.S. Bureau of the Census, *1978 Annual Survey of Manufactures.*

changes, however, can also affect input demand by altering the firms' production costs. This occurs when a firm is led to produce a different profit-maximizing level of output and is induced to use different quantities of its inputs. Because of the difficulty in obtaining suitable data, this output or scale effect—which shifts the firm's demand for its inputs—is not explicitly examined in this study.

How responsive the employment of a particular input is to changes in its own or another input's price is typically measured by the own-price and cross-price elasticities of demand. These elasticities depend on two key influences.

The first influence is the input's share of total production costs.[2] In general, the larger the share of total costs an input comprises, the more elastic its own demand—and the demand for other inputs—for a given change in the particular input's price. Therefore, inputs with large cost shares will exert a greater influence over a firm's input demand than will those constituting a smaller share of the total cost. Given the large proportion of energy used by manufacturing in Texas and Louisiana, the response to increases in energy prices likely will be greater in these two states than in the remainder of the nation.

The second influence determining the response to an input price change is the elasticity of substitution. This measures the degree to which a given technology permits inputs to be substituted for one another when factor prices change by a given percentage. The substitution elasticities therefore describe the technology an industry uses. These elasticities are distinct from the intensities—as measured by their shares of total cost—with which factors are used. That the substitution elasticities are distinct from the cost shares permits comparison across regions for which cost shares are different, as in the case of Texas/Louisiana and the remainder of the United States.

Past research on input substitution has focused on the elasticity of substitution because it describes the technology and tells how input demand curves shift in response to other input price changes. Much of the recent research has focused on the relationship between energy and other inputs. The origin of much of this debate was whether rising energy prices would stimulate or inhibit investment and capital formation. The magnitude and sign of the elasticity of substitution between these two inputs determined which effect would take place. As Berndt and Wood note,

> If energy and capital are substitutable, ceteris paribus, then higher priced energy will increase the demand for new capital goods. If energy and capital are complementary, however, then ceteris paribus, higher priced energy will dampen the demand for energy and the demand for new plant and equipment.[3]

The same statement applies to the relationship between energy and labor. Price changes in energy can be expected to lead to changes in the demand for labor.

The price elasticities of input demand permit the calculation of the overall change in input usage resulting from changes in factor prices. These elasticities are more appropriate for this computation than the substitution elasticities because the former reflect the influence of both the technology and the factor cost shares. Given this study's finding that labor and energy are substitutes, the estimated elasticity of demand between labor and energy is used to calculate the employment gains (losses) from increases (decreases) in energy prices.

Deriving the demand for inputs

The firms' response to input price changes must be modeled in order to estimate the elasticities of substitution and the price elasticities of input demand. (See Appendix A for a full description of the model and the estimation method.) In the model, the firms first are assumed to be competitors in the input markets in which they operate. Therefore, firms take factor prices as given and minimize the cost of producing an exogenously determined level of output. This output is produced according to a neoclassical production function[4] of the form

$$(1) \qquad Y = g[f(L,K,E), M],$$

where
Y = the firm's output,
L = labor,
K = capital,
E = energy, and
M = materials.[5]

The production function is specified in this way because of the assumption that materials are weakly separable from the rest of the inputs. The separability assumption implies that the elasticities of substitution between labor, capital, and energy are independent of the quantity of materials.[6] This, in turn, allows the derivation of the elasticities of substitution between the nonmaterial inputs from the following restricted cost-minimizing problem:[7]

(2) Minimize $(P_L \cdot L + P_K \cdot K + P_E \cdot E)$
subject to the constraint that
$f(L,K,E) = Y^*$

where
P_i = the price of input i,
$i = L,K,E,$
Y^* = the given level of output, and
f has the properties described above.

A further assumption is that the firm's average costs correspond to a translog cost function. Use of a translog cost function has advantages over other functional forms in production theory (such as the Cobb-Douglas or constant elasticity of substitution) because the translog avoids restrictions on the elasticities of substitution. Using the translog cost function allows the elasticities of substitution and price elasticities of input demand to be calculated from regressions where each factor's cost share is a dependent variable and the logarithms of the input prices are the independent variables. The data used are on the three-digit SIC manufacturing industries for the period 1976-78.[8]

Estimation results

The most important finding of this study—as contrasted with various studies of the nation—is that a greater substitutability generally occurs between inputs for manufacturing in Texas and Louisiana. Evidence to support this comes from both the elasticities of substitution and the price elasticities of input demand.

For Texas and Louisiana, the results indicate that labor and capital are substitutes, with an elasticity of substitution close to unity for total manufacturing and for the durable and nondurable components. (See Table 2 for complete results and Appendix A for a description of how these elasticities were calculated from the regression coefficients.) As expected, significant differences exist between the results for Texas/Louisiana and those for the remainder of the country (see Table 3).[9]

Similarly, for labor and energy the elasticity for aggregate manufacturing in these two states ($\sigma_{LE} = 4.26$) suggests strong substitutability between these two inputs. As with labor and capital, the elasticity of substitution between labor and energy was greater in Texas/Louisiana than in the remainder of the nation. Though small and lacking statistical significance in the durable sector, the elasticity of substitution between labor and energy in nondurable manufacturing was large and statistically significant.

Table 2
ELASTICITIES OF SUBSTITUTION

Elasticity of substitution	Manufacturing: Durable goods	Nondurable goods	Aggregate
σ_{LK}	1.09*	1.05*	1.18*
	(21.80)	(15.00)	(23.60)
σ_{LE}	−0.07	6.12*	4.26*
	(−0.04)	(2.34)	(2.39)
σ_{KE}	1.39*	0.74+	0.95*
	(3.48)	(1.68)	(3.06)

NOTES: The t-statistics are in parentheses; * denotes estimates significant at the .01 level; and + denotes estimates significant at the .10 level.

The results of this study reveal that energy and capital in the manufacturing industries in Texas and Louisiana are also substitutes. The estimated elasticities between capital and energy are statistically significant in aggregate manufacturing, as well as in the durable and nondurable components.[10] This result is in contrast with those of some other studies of manufacturing in the United States that have found the two inputs to be complements. As indicated by the larger elasticity for durable manufacturing compared to nondurable, energy and capital are more easily substituted in the durable sector. This may reflect the specialized use that energy has in nondurable manufacturing, especially chemicals and refining, where large amounts of energy are necessary for the industrial processes.

Additional comparisons can be made by looking at the price elasticities of input demand (see Table 4). As noted earlier, the price elasticities of input demand take into account the effects of technology (as described by the elasticity of substitution) and the importance of the factor cost share.

The demands for labor and energy are both more sensitive to each input's own price in Texas/Louisiana than they are for the nation as a whole. The own-price elasticity of labor demand thus is notably larger for the two states than are the estimates for the entire nation.[11] Therefore, the own-price elasticity of demand for energy exceeded unity for aggregate manufacturing and for the durable and nondurable sectors.[12]

The larger energy elasticity, compared with other studies, can be explained in two ways. First, the greater elasticity in these two states is probably a function of the larger proportion of total cost that energy expenditures account for. As noted earlier, the larger a factor's cost share, generally the more elastic is its demand. In addition, the rapid increases in energy prices in the early 1970s initiated techno-

Table 3
SUMMARY OF RESULTS FROM OTHER STUDIES[1]

Elasticity of substitution	United States: Berndt/ Wood (1971)	Garofalo/ Malhotra (1974-77)	Hudson/ Jorgenson (1947-71)	Texas/ Louisiana: Dunstan/ Long (1976-78)
σ_{LK}	1.01	.84	1.09	1.18
σ_{LE}	.68	3.35	2.16	4.26
σ_{KE}	−3.53	−.35	−1.39	.95
E_{LL}	−.45	−.74	−.45	−1.14
E_{KK}	−.44	−.24	−.42	−.15
E_{EE}	−.49	−.81	.07	−1.35

SOURCES: Ernst R. Berndt and David O. Wood, "Technology, Prices, and the Derived Demand for Energy," *Review of Economics and Statistics* 57 (August 1975): 259-68.

Gasper A. Garofalo and Devinder M. Malhotra, "Input Substitution in the Manufacturing Sector during the 1970's: A Regional Analysis," *Journal of Regional Science* 24 (February 1984): 51-63.

Edward A. Hudson and Dale W. Jorgenson, "U.S. energy policy and economic growth, 1975-2000," *The Bell Journal of Economics and Management Science* 5 (Autumn 1974): 461-514; estimates from the latter study are calculated in Griffin and Gregory, see footnote 6.

Table 4
PRICE ELASTICITIES

Price elasticity	Manufacturing Durable goods	Nondurable goods	Aggregate
E_{LL} . . .	−0.91*	−1.51*	−1.14*
	(−15.67)	(−34.04)	(−56.84)
E_{LK} . . .	0.90*	0.90*	0.98*
	(22.50)	(15.00)	(24.50)
E_{LE} . . .	−0.01	0.28*	0.16
	(−0.17)	(2.33)	(0.24)
E_{KK} . . .	−0.13*	−0.14*	−0.15*
	(−13.00)	(−14.00)	(−15.00)
E_{KL} . . .	0.17*	0.11*	0.16*
	(17.00)	(11.00)	(16.00)
E_{KE} . . .	0.04*	0.03	0.04*
	(4.00)	(1.50)	(4.00)
E_{EL} . . .	−0.01	0.66*	0.56*
	(−0.03)	(2.36)	(2.33)
E_{EK} . . .	1.14*	0.63^{+}	0.79*
	(3.56)	(1.70)	(3.03)
E_{EE} . . .	−1.13*	−1.28*	−1.35*
	(−6.28)	(−7.53)	(−45.00)

NOTES: The t-statistics are in parentheses; * denotes estimates significant at the .01 level; and $^{+}$ denotes estimates significant at the .10 level.

logical and structural changes that may have significantly altered the demand functions of most energy users. During this period, energy users faced natural gas supply curtailments and petroleum product shortages, and the price of energy generally became more volatile over the period. The increased uncertainty about energy prices and energy supply, as well as the radical changes in energy prices, would be expected to generate significant changes in the energy demand functions of industrial users. As a result, energy demand functions are likely to be more responsive now to changes in fuel prices, relative both to each other and to other inputs. Such differences also are likely to be more apparent in this study because the period examined includes more recent data than has previous research.[13]

Implications

The results of the present study suggest that the rapid movements of energy prices since 1973 have significantly affected employment because labor and energy are substitutes. Because of the enhanced substitutability between inputs in general—and labor and energy in particular—the relative impact can be expected to be greater in Texas/Louisiana than in the remainder of the nation. The greater substitutability also implies that the region will maintain full employment more easily in the wake of an economic shock, although the adjustment to a large shock such as a major oil price decline will not be immediate.

In quantifying the impact of changing energy prices on labor employment, the study used a set of basic calculations to examine the substitution effect for the periods 1972-82 and 1982-86. Based on annual data, the percentage changes in inflation-adjusted energy prices were calculated for these periods. Then, from the relationship

$$E_{LE} = \frac{\%\Delta L}{\%\Delta P_E}, \qquad (3)$$

the estimated percentage change in employment (ΔL) was calculated from the elasticity (E_{LE}) and the actual percentage change in energy prices (ΔP_E). This estimated percentage response was then applied to the number of workers in the base year to obtain an estimate of how much employment changed as a result of energy-labor substitution.[14]

Based on the results of this study, the substitution of labor for energy during 1972-82 would have increased manufacturing employment in Texas and Louisiana by about 240,000 jobs, or about 22,000 jobs per year. This contrasts with an actual employment change of about 326,000 workers, or 29,000 jobs per year. Thus, although the substitution effect is not strictly comparable to the actual employment change, the results suggest that a substantial fraction of the job gains during this period resulted from input substitution.

Conversely, the fall in energy prices from 1982 to 1986 would be expected to reduce labor employment as a result of the substitution of energy for labor. Based on the results of this study, this effect would be responsible over this period for an estimated loss of about 75,000 jobs in manufacturing in Texas and Louisiana. To date, the actual employment decline has been about 100,000 workers. Again, input substitution is an important factor influencing job growth in this region.

The validity of these particular calculations rests on several important assumptions. First, the relative prices of all inputs except energy are assumed to have remained constant during the periods under examination. Second, because the elasticity estimates came from data on manhours of labor input, it is necessary to assume that total employment responds in the same way as manhours. In addition, the response to increases or decreases in energy prices obtained from these estimates implies that the full adjustment takes place within the time period under consideration. Such an adjustment, however, may require a longer period for full completion. Nevertheless, these calculations provide a rough measure of the magnitude and direction of the substitution effect on employment.

These calculations also ignored the effect on employment of increased demand for manufacturing output, but the output effect is likely to have been different in Texas/Louisiana than in the nation as a whole. In the United States, the aggregate effect of higher energy prices was probably to depress the demand for manufactured goods. Because of the importance of energy industry demand in Texas and Louisiana, however, the effect was to increase the demand for many manufactured goods in these two states.

Because of data limitations, it was not possible to quantify any effects regarding capital substitution. Nevertheless, such changes can be analyzed qualitatively. One expected effect is a reduced demand for new capital goods in these two states because of the energy price decline. Again, in the short run, the effect of declining output demand is likely to be greater, but the substitution effect will offer no support. Durable manufacturing is likely to experience the greatest effects. The substitution of energy for capital also is likely to entail lowered utilization of existing capital. The fact that the price elasticities are higher in Texas and Louisiana suggests that any such demand declines will be greater there than in other portions of the country.[15]

Even though a quantitative estimate of changes in the use of capital cannot be made, the results of this study do have an interesting policy implication. One indirect effect of the decline in oil and gas prices and the subsequent weakening of the economies of Texas and Louisiana is the effort to attract other types of industries to these two states. Currently, both Texas and Louisiana have active economic development programs. Frequently, such programs affect input costs by lowering the effective price of an input. The use of governmentally issued bonds to finance industrial facilities is an example.

Provided that the objective of a state economic development program is to increase the employment of state residents—and given this study's result that labor and capital are substitutes—then subsidizing a nonlabor input may undermine the subsidy's objective. For example, it is possible that industrial development bonds (which subsidize capital by permitting private companies to take advantage of the lower borrowing costs of state and local governments) would not increase employment in the region in the long run.[16] This occurs because lower capital costs result in the substitution of capital for labor, other things equal, making labor demand lower than it might otherwise have been. As was noted earlier, because of the larger value of the elasticity of substitution of labor for capital, the negative effect on labor demand may be greater in Texas/Louisiana than it is nationally.

Summary

This study has identified the major differences in the technology and structure of manufacturing in Texas/Louisiana compared with the remainder of the nation. Significant differences were noted between manufacturing in these two states and in the United States as a whole, particularly a more elastic demand for energy and an enhanced substitutability between labor and energy and between labor and capital. Regarding the relationship between inputs for Texas/Louisiana in comparison with national estimates, the main points in the present study show that (1) labor and energy are more responsive to changes in their own and other input prices; (2) capital and energy are substitutes in this region; and (3) significant differences exist between durable and nondurable manufacturing in the two states.

The most obvious explanation for the differences between Texas/Louisiana and the nation overall is the unique industrial structure of these two states. Not only do manufacturers in Texas and Louisiana use a larger share of energy and materials, but the energy industry also is a more important source of demand for manufactured goods in these two states than elsewhere in the nation.

The compositional difference does raise a potential problem for the future of these industries in Texas and Louisiana. As oil and natural gas resources in this region diminish, some of the energy-related industries are likely to move to new sites of oil and natural gas production. Some exodus of activity has already occurred in petrochemicals and refining. The declining importance of energy-related manufacturing means that other industries will have to assume a more dominant role if manufacturing is to remain healthy in these two states. The relative ease of substituting factors as shown in this study may help manufacturing in this region compete and grow.

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1. Some other areas of the country also contain energy-related manufacturing. For example, the Northeast has heavy concentrations of refining and chemicals but little other energy-related manufacturing. The West Coast also has refining and some manufacturing associated with energy extraction, but manufacturing there is not as heavily dependent on the energy industry.

2. As shown in equation A-10 in Appendix A, both the own-price and cross-price elasticities are explicitly dependent on the factor cost shares.

3. See Ernst R. Berndt and David O. Wood, "Technology Prices, and the Derived Demand for Energy," *The Review of Economics and Statistics* 57 (August 1975): 259-68; the quotation appears on p. 259.

4. The production function is assumed to be homothetic, strictly positive, and concave; any technical change is assumed to be Hicksian neutral.

5. The flow of capital services is assumed to be proportional to the stock of capital. To the extent that the operating rate of equipment can vary, this assumption may not be entirely accurate. The only feasible method for measuring the intensity of capital utilization, however, is through energy use. For energy to be a proxy for capital, the assumption must be made that capital and energy are used in fixed proportions. Given this article's finding that capital and energy are relatively strong substitutes, the assumption that capital and energy are used in fixed proportions is unnecessarily restrictive and limiting.

   As used in the model, energy is an aggregate of purchased fossil fuels and electricity usage. Because electricity and fossil fuels can be extremely close substitutes, the study examines the response of an aggregate energy measure to changes in energy prices. In addition, estimates of fossil fuels and electricity were calculated separately. Because of the proximity of Texas and Louisiana to abundant sources of fossil fuels, this factor may be important for these two states' manufacturing.

   One complicating factor concerning energy use is cogeneration—the generation of electricity from heat from industrial processes. Frequently, the surplus electricity resulting from this process is sold to electric utilities. A substantial number of firms in these two states generate electricity in this fashion. For these firms—principally paper, refining, and chemicals—the cost function would need to take account of this joint production of multiple goods. See Randall S. Brown, Douglas W. Caves, and Laurits R. Christensen, "Modelling the Structure of Cost and Production for Multiproduct Firms," *Southern Economic Journal* 46 (July 1979): 256-73.

   Another complicating factor is that a considerable amount of the energy used in refining and petrochemicals is produced onsite instead of being purchased. Because no suitable data on this usage were available, this portion of energy was omitted from the study.

6. In the study, it was necessary to assume that the raw materials input was separable because data on the quantity of raw materials utilized were not available. Under this assumption, the substitution possibilities between the other inputs does not depend on the quantity of raw materials used by the firms, thus enabling the study to omit the consideration of the materials input. If the assumption of separability does not hold, the results are gross elasticities, which are generally different from the net elasticities obtained when all inputs are included in the model. Despite the bias in the estimates under the assumption of separability, there is evidence that the sign of elasticity will be unaffected by this assumption. This is a common—although somewhat controversial—assumption in other studies. See for example, James M. Griffin and Paul R. Gregory, "An Intercountry Translog Model of Energy Substitution Responses," *The American Economic Review* 66 (December 1976): 845-57; Robert S. Pindyck, "Interfuel Substitution and the Industrial Demand for Energy: An International Comparison," *The Review of Economics and Statistics* 61 (May 1979): 169-79; or Gasper A. Garofalo and Devinder M. Malhotra, "Input Substitution in the Manufacturing Sector during the 1970's: A Regional Analysis," *Journal of Regional Science* 24 (February 1984): 51-63.

   Separability has been tested and found to hold in most industries. For example, see David Burras Humphrey and J. R. Moroney, "Substitution among Capital, Labor, and Natural Resource Products in American Manufacturing," *Journal of Political Economy* 83 (February 1975): 57-82.

   Conversely, the hypothesis of weak separability was rejected in other studies. For example, see Berndt and Wood, "Technology, Prices, and the Derived Demand for Energy," and Edward A. Hudson and Dale W. Jorgenson, "U.S. energy policy and economic growth, 1975-2000," *The Bell Journal of Economics and Management Science* 5 (Autumn 1974): 461-514.

7. In the two-input case, the elasticity measures the percentage change in the ratio of the two inputs for a given percentage change in the ratio of their prices. This interpretation does not strictly hold when more than two inputs are used, such as in the present study. Under these conditions, the elasticity of substitution is a *partial* elasticity of substitution, meaning that it measures this responsiveness, allowing all other input quantities to adjust optimally but holding other factor prices constant.

8. Data for three-digit manufacturing industries came from the U.S. Bureau of the Census, *1977 Census of Manufactures* and the *1976* and *1978 Annual Survey of Manufactures*. These sources provided information on the expenditures and quantities (and therefore the prices) of labor and energy, the capital expenditures, as well as data on value added by manufacture. The prices of the labor and energy inputs were calculated from these data as the total expenditure on these inputs divided by the quantity utilized. In order to compute the price of capital, however, it was necessary to construct a series on the capital stock for each firm. For information on the construction of a capital stock series for an individual state, see Appendix B.

9. Studies that calculated elasticities of substitution using international data were omitted (including Griffin and Gregory and Pindyck). Although these articles estimate separate elasticities for the United States, the results may not be strictly comparable because of the use of cross-country data.

10. The straightforward substitution relationship between energy and capital changed when the energy input was disaggregated into its fossil fuel and electricity components. Some of the elasticities were negative (indicating complementarity), and some remained positive. Further, most of the elasticity estimates comparing capital and energy lost their statistical significance when energy was disaggregated.

    These results point out the inherent difficulties in determining whether energy and capital are substitutes. Capital and different forms of energy may be either substitutes or complements, depending on the type of production process used. Aggregating dissimilar production processes also may mask important differences in the production relationship. Other empirical work using more disaggregated data supports this view that energy and capital could be either substitutes or complements (see Humphrey and Moroney, "Substitution among Capital, Labor, and Natural Resource Products in American Manufacturing").

11. Disaggregating the energy sources shows that the own-price elasticities for electricity and fossil fuels are somewhat larger than the estimates derived in A. L. Walton, "Variations in the Substitutability of Energy and Nonenergy Inputs: The Case of the Middle Atlantic Region," *Journal of Regional Science* 21 (August 1981): 411-20.

12. In contrast, most estimates at the national level are typically less than one.

13. See, for example, the studies cited in footnote 6, *supra*.

14. The elasticity used for these calculations was for total manufacturing, and it was not statistically significant at the 90-percent confidence level. Based on the present results, however, the vast majority of the adjust-

ment in manufacturing employment is likely to occur in nondurable manufacturing, and this elasticity is strongly significant.

15. A point worth noting is that falling oil and gas prices do not necessarily mean a commensurate decline in overall energy costs. Electricity prices, for example, may not fall proportionately, depending on the regulatory factors affecting rates. Durable manufacturing in these two states has an advantage should electricity prices *not* decline relative to fossil fuels. A very large substitutability exists between fossil fuels and electricity in durable manufacturing, making it easier for these firms to take advantage of falling natural gas and crude oil prices by substituting away from electricity.

16. For a discussion on the use of these bonds, see Gerald Carlino and Edwin S. Mills, "Do Public Policies Affect County Growth?" *Business Review*, Federal Reserve Bank of Philadelphia, July/August 1985, 3-16.

Appendix A

Theoretical Model

The firms in the sample are assumed to be competitors in the input markets in which they operate. Therefore, firms take factor prices as given and minimize the cost of producing an exogenously determined level of output. This output is produced according to a standard neoclassical production function of the form:

$$(A.1) \qquad Y = g(f(Q), X),$$

where
Y = output,
Q and X = input vectors, and
g and f = functions of the inputs.

The production function is specified in this way because it is assumed that a subset (X) of the inputs are weakly separable from the rest. Specifically, the separability assumption implies that the elasticities of substitution between labor, capital, and energy are independent of the quantity of materials. Thus, the problem facing these firms can be stated in the following way:

(A.2) Minimize $P \cdot Q$,
subject to the constraint that
$f(Q) = Y^*$

where
P = the vector of input prices,
Q = the vector of input quantities,
Y^* = the given level of output, and
f has the properties described above.

Solving this problem gives the firm's restricted cost function

$$(A.3) \qquad C = h(P, X, Y)$$

in terms of input prices (P) and output (Y) holding the quantities of the separable inputs (X) fixed.

It is further assumed that the *average* costs of the firms in these industries can be described by a transcendental logarithmic (translog) cost function of the form:

$$(A.4) \qquad \ln C = \alpha_0 + \sum_i \alpha_i \ln P_i + \tfrac{1}{2}\sum_i \sum_j \beta_{ij} \ln P_i \ln P_j, \quad i,j = K,L,E$$

where
C = average cost,
K = capital,
L = labor, and
E = energy.[1]

This well-known functional form provides several convenient features for empirical analysis. First, it is a second-order approximation to any differentiable cost function, eliminating the need to make arbitrary assumptions about the elasticities of substitution one is trying to estimate. In addition, based on Shephard's Lemma, this cost function can be differentiated with respect to the price of factor i to get

$$(A.5) \qquad \frac{d\ln C}{d\ln P_i} = S_i = \alpha_i + \sum_j \beta_{ij} \ln P_j, \quad i,j = K,L,E$$

These factor cost share equations are variants of the factor demand functions and express the cost of each of the inputs as a fraction (S_i) of the total cost of production.[2] As is evident from equation A-5, these factor cost shares are linear in the parameters.

The cost share equations take the following form:

(A.6)
$$S_L = \alpha_L + \beta_{LL}\ln P_L + \beta_{LK}\ln P_K + \beta_{LE}\ln P_E$$
$$S_K = \alpha_K + \beta_{LK}\ln P_L + \beta_{KK}\ln P_K + \beta_{KE}\ln P_E$$
$$S_E = \alpha_E + \beta_{LE}\ln P_L + \beta_{KE}\ln P_K + \beta_{EE}\ln P_E$$

The cost shares in equation system A-6 are likely to deviate from those given by cost-minimizing behavior because of random errors. Therefore, an error term is added to each equation for econometric estimation.

Because the errors in one equation are likely to be related to errors in the others, these equations are estimated as a seemingly unrelated system to account for these error correlations across equations. Because the sum of the cost shares must equal unity, estimating all three equations as a system leads to a variance-covariance matrix that is singular. To resolve this problem, a standard solution of dropping an equation—the energy equation—was used, and the remaining equations were estimated as a system. Using Zellner's seemingly unrelated regression approach and iterating the estimation until the parameter estimates converged ensured that the estimates were invariant with respect to the excluded equation.[3] Iterative Zellner estimation is equivalent to full-information maximum-likelihood estimation provided the assumptions of homoscedasticity or autocorrelation are valid.

Implicit in this specification are the following parameter restrictions imposed by the study's assumptions and the model's underlying theory:

(A.7)
$$\sum_i \alpha_1 = 1,$$
$$\beta_{ij} = \beta_{ji},$$
$$\sum_i \beta_{ij} = 0, \text{ and}$$
$$i,j = K,L,E$$

The estimated values of the coefficients can then be used to calculate the elasticities of substitution and the demand elasticities. Based on standard results about the relationship between the cost function and the elasticities of substitution and between the elasticities of substitution and the demand elasticities, these parameters can be computed in the following way:[4]

(A.8)
$$\sigma_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i S_j}, i \neq j$$

(A.9)
$$\sigma_{ii} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i^2}$$

(A.10)
$$E_{ij} = S_j \sigma_{ij}$$

From these equations, the standard errors of the input demand and substitution elasticities can be calculated. They are evaluated at the mean factor share for the relevant samples. The variances needed are given by the following:

(A.11)
$$\text{Var}(\sigma_{ij}) = \frac{\text{Var}(\beta_{ij})}{S_i^2 S_j^2}$$

(A.12)
$$\text{Var}(E_{ij}) = \frac{\text{Var}(\beta_{ij})}{S_i^2 S_j}$$

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1. The properties of this functional form are well known. The seminal article describing this class of functional forms is Laurits R. Christensen, Dale W. Jorgenson, and Lawrence J. Lau, "Transcendental Logarithmic Production Frontiers," *The Review of Economics and Statistics* 55 (February 1973): 28-45.

2. See Ronald W. Shephard, *Theory of Cost and Production Functions* (Princeton, N.J.: Princeton University Press, 1970).

3. See Arnold Zellner, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," *Journal of the American Statistical Association* 57 (June 1962): 348-68.

4. See Hirofumi Uzawa, "Production Functions with Constant Elasticities of Substitution," *The Review of Economic Studies* 29 (October 1962): 291-99, and R. G. D. Allen, *Mathematical Analysis for Economists* (London: Macmillan and Co., Ltd., 1938).

Appendix B

Deriving Capital Stock Data

From data in the U.S. Bureau of the Census, *Census of Manufactures* and the *Annual Survey of Manufactures*, the prices of the labor and energy inputs were calculated as the total expenditure on these inputs divided by the quantity utilized. In order to compute the price of capital, however, a series on the capital stock for each firm was constructed. Such a capital stock series can be constructed from the investment numbers by means of the following equation:

$$K_{it} = K_{it-1}(1 - d_i) + I_{it} \quad \text{(B.1)}$$

where
K = the capital stock in industry i at time t,
d = the depreciation rate for industry i, and
I = industry i's investment in time t.

Obviously, an initial capital stock (K_0) is required for this calculation. The only data reported in the *Census of Manufactures* and the *Annual Survey of Manufactures* at the state level for three-digit Standard Industrial Classification (SIC) industries are capital expenditures (i.e., investment) but not the total of book value of the capital stock in each industry. This initial capital stock was obtained by assuming that the capital-to-output ratio for the firms in each industry in Texas and in Louisiana equaled that ratio for firms in the United States as follows:

$$\frac{K_{iUS}}{VA_{iUS}} = \frac{K_{im}}{VA_{im}}, \quad \text{(B.2)}$$

where
i = industry,
m = state, and
VA is value added by manufacture.

Thus, the capital stock for Texas and Louisiana for the base year were obtained by multiplying the national capital stock by the ratio of value added in each state to national value added. The depreciation rate for each industry also was calculated from national data. The relationship that

$$VA = (P_K \cdot K + P_L \cdot L) \quad \text{(B.3)}$$

then was used to compute the total expenditure on capital by each industry. Dividing by the capital stock yielded the study's measure of the price of capital. The measure of the total cost of these inputs was the sum of value added and the expenditures on energy.