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Deregulation, Cost Economies and Allocative Efficiency of Large Commercial Banks

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The production process is one of the most extensively researched topics in banking. Recent additions to the literature evaluate cost economies, competitive viability, and the costs of geographic restrictions to expansion. However, until recently, most of these studies have ignored the potential for inefficiency in the production process creating a corresponding potential methodological error. Specifically, most cost studies utilize duality theory to generate a neoclassical cost function based on the maintained assumption of cost minimization with respect to market input prices in competitive markets. However, extensive evidence exists suggesting that this is not the behavior practiced by regulated firms. Banking firms are subject to extensive regulation in nearly all facets of operations, raising the possibility that this assumption may be inappropriate.

The purpose of this study is to expand on previous research evaluating the multiproduct production process of large commercial banks and to generate cost estimates utilizing a generalized cost function that subsumes the standard neoclassical cost function as a special case. The generalized model allows for cost minimization with respect to *shadow* input prices which may deviate from market prices because of regulatory-induced distortions in the production process. From a theoretical or economic viewpoint the generalized model is superior to the neoclassical model. We test to see if there is also a statistical difference. Behavior based on shadow input prices could result in significantly different estimates of various cost function characteristics, e.g., economies of scale, scope, the role of technological change, factor shares, etc. We evaluate these characteristics and, realizing regulatory stringency was not constant over the period analyzed, account for changing industry regulation.

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1 Background

Many of the early studies of bank costs utilized the Cobb-Douglas cost function and generally found scale economies over a rather substantial range of output [(Bell and Murphy 1968), (Benston 1965, 1972)]. Using flexible functional forms, a number of recent studies have reevaluated bank costs taking into account directly the potential for U-shaped average cost curves, multi-product production, and economies of scope as well as scale effects. These studies generally have found that benefits from scale economies are fully exhausted at relatively low levels of output [Berger, Hanweck, and Humphrey (1987), Gilligan and Smirlock (1984), and Gilligan et al. (1984)]. In fact, significant diseconomies have been found for single office unit banks (Berger, Hanweck, and Humphrey). In most cases, cost advantages from multiproduct production have also not been found [Clark (1988)]. The policy implications are that cost advantages do not drive industry structure.

There are a number of potential problems with much of the bank cost literature. First, most of the studies analyze relatively small banks utilizing data from the Federal Reserve System's Functional Cost Analysis (FCA) Program. While rich in cost allocation detail, FCA samples exclude the very banks (those over $1 billion in assets) which are most likely to be involved in market expansion. Until recently, analysis of costs for large commercial banks were not nearly as prevalent. Studies by Shaffer (1985), Hunter and Timme (1986), and Evanoff, Israilevich and Merris (1989) consider large banks and find significant scale economies over a broad range of outputs. However, each study utilized an aggregate output measure which may bias scale elasticity estimates toward greater economies. Noulas et al., using a multiple output specification, analyzed large banks and found scale advantages to be exhausted for most banks in their sample.

Another potential problem with previous bank cost studies involves the implicit assumptions concerning firm behavior. Most of the studies in the 1980s utilized developments in duality theory [(Shephard 1970) and (Diewert 1974)]. While duality theory and the adoption of flexible functional forms have produced advances in modeling bank costs, there is evidence that the functional forms used may still be too restrictive. Duality implies that under certain conditions the cost function provides a description of the production process that is equivalent to that provided by the production function. Additionally, given that the conditions hold, the factor shares can be derived directly via differentiation from the cost function. The conditions required to generate the dual cost function are firm cost minimization in competitive markets constrained *only* by the predetermined output level, and certain regularity conditions (Diewert). It is seriously doubtful that these conditions hold in banking. Despite the recent trend toward deregulation, the banking industry still is heavily supervised and behavior is obviously restrained. Restrictions include entry barriers, geographic and product limitations, loan size limitations, reserve and capital requirements, allowable interest on certain deposit accounts, etc. These constraints are likely to alter the optimum choice of inputs from the firm's perspective at the margin. Therefore, the assumption that firms operate efficiently in competitive markets may simply be incorrect.

Recent studies have considered the possibility that banks do not operate efficiently.[1] However the methodologies employed to detect this inefficiency– data envelopment analysis (e.g., Aly, et al. 1990), the stochastic frontier approach (e.g., Ferrier and Lovell 1990), and the thick frontier approach (Berger and Humphrey 1990)– assume that the behavior of the best practiced firm is not distorted by regulation. This would appear to be a strong assumption since one would expect that the behavior of even the best managed banks would be altered by regulation. It is this regulatory induced effect which we attempt to capture.

Our priors are that bank regulations are physical capital-using as a result of restrictions on industry behavior. For example, banking firms have frequently been forced to compete on a nonprice basis and this generally results in the employment of additional capital. Thus, competition is manifested via capital-using "service" offerings, e.g., Lloyd Davies (1977).

Another frequently overlooked aspect of bank costs concerns the effect of technology. Although it is generally thought to be significant (electronic and computer advances have allowed banks to streamline production and incorporate more efficient processes), the literature findings are somewhat mixed. Using a nonparametric approach Elyasiani and Mehdian (1990b) found that, on average, technology played a significant positive role over the 1980-85 period. Using a parametric approach and accounting for technology with a time trend, Hunter and Timme (1986) and Evanoff, Israilevich, and Merris (1989) each found significant technical advancement occurred during the 1970s and 1980s. However, both findings were based on the use of an aggregate output measure and production expenses only, excluding interest expenses involved in generating funds. When these expenses were included, Hunter and Timme found no significant role for technology. Using a number of alternative means to account for technology over the 1977-88 period, Humphrey (1990) found that cost had actually increased over the period and attributed the "technical regression" to industry deregulation. Thus, the changing influence of regulatory forces should be considered in evaluating technological change.

The basic objective of this study is to evaluate whether industry regulation distorts firm behavior and, as a result, generates production inefficiency–i.e., allocative inefficiency. We evaluate the resulting impact on various cost characteristics, e.g., scale and scope estimates. However, there are additional contributions from the analysis. First, we evaluate the production process of a class of banks (large banks) which has frequently been ignored.[2] Second, by utilizing a panel data set we are able to analyze the role of technological change on cost factors. Finally, we analyze the effect of relaxing regulatory constraints.

[1]Humphrey (1987) was the first to address the issue of potential bank inefficiency when he analyzed the wide dispersion of costs across banks.

[2]Exceptions include Hunter, Timme and Yang (1990), Noulas, et al. (1990), and Shaffer and David (1986).

2 The Theoretical Model, Empirical Specification, and Data Sources

To generate our cost estimates we use a methodology developed by Lau and Yotopoulos (1971) and Atkinson and Halvorsen (1980). This *shadow price model* has been employed in previous studies to account for regulatory induced market distortions, e.g., Atkinson and Halvorsen (1984), and Evanoff, Israilevich, and Merris. We apply the shadow price (SP) model augmented to include variables pertinent to banking. The reader is referred to these studies for a detailed discussion of the methodology.

From the first-order conditions for cost minimization in the neoclassical model, the marginal rate of technical substitution between inputs is equal to the ratio of the prices of the inputs. Given input prices and the predetermined level of output as the only constraint, the optimal combination of inputs can be derived to minimize costs. The resulting cost function is the dual to the production process in that it provides an equivalent description of that process.

However, if additional (regulatory) constraints exist they need to be accounted for in the optimization process. From the first-order conditions for cost minimization, the rate of technical substitution between the inputs should be equal to the ratio of the *effective* prices of the inputs. It is these effective or shadow prices which are influenced by regulation and which determine behavior. In the absence of binding regulatory constraints, shadow and actual prices are equal and the first-order condition reduces to the standard neoclassical condition. This special case is nested in the more general SP model. If market and shadow prices are not equal, then the regulatory constraints should be accounted for and a modified version of Shephard's Lemma should be utilized to derive factor shares.

Since the shadow prices of the inputs are not directly observable, following Lau and Yotopolous and Atkinson and Halvorsen the shadow prices are approximated by

$$P_i^* = k_i P_i \text{ for } i = 1, \ldots, m \qquad (1)$$

where k_i is an input-specific factor of proportionality. As noted by AH, the shadow-price approximations can be interpreted as first-order Taylor's series expansions of arbitrary shadow-price functions. When regulation is nonbinding, all shadow prices equal the respective market prices, $k_i = 1$ for all i, and the shadow cost function reduces to the more restricted function.

Applying Shephard's Lemma to the more general Shadow Cost function the input demand functions can be obtained, from which the the actual or observed cost and factor share equations can be derived,[3]

$$\ln C^A = \ln C^S + \ln \sum_{i=1}^{k} \frac{M_i^S}{k_i}. \quad (2)$$

and

$$M_i^A = \frac{P_i X_i}{C^A} = \frac{M_i^S k_i^{-1}}{\sum_{i=1}^{m} M_i^S k_i^{-1}}. \text{ for } i = 1, \ldots, m. \quad (3)$$

where C^A and C^S are actual and shadow cost, respectively; and M^A and M^S are actual and shadow factor-cost shares, respectively. Equations (2) and (3) comprise our model.

As explained above, the shadow cost function is a more comprehensive representation of costs to be minimized and is the appropriate dual to the production process. As with the standard cost model we can evaluate various characteristics of the cost representation. These can be contrasted to characteristics of the less general market price (MP) model. Additionally, the SP model also allows one to calculate the optimal (unobserved) input combination given observed prices, P. This combination is relevant for measuring the cost differences resulting from production under competitive conditions and those under binding regulatory constraints. Correspondingly, differences in C^A computed with P and P^* measure the cost of the binding constraints, or, stated differently, the extent of production inefficiency produced by regulation. We employ this procedure in our analysis of cost distortions induced by regulation.

2.1 Empirical Specification

In applying the Shadow-Price Model to large U.S. banks, we make certain assumptions concerning the production/cost relationship. Variables pertinent to the banking industry include the number of bank offices, B; holding company structure, H; and technological change, T. Employing the intermediation approach, it is assumed that banks produce four outputs measured as the dollar value of commercial and industrial loans, installment loans, real estate loans, and investment securities, utilizing labor, L; physical capital, K; and funds, F.[4] The shadow cost function is specified in translog form, a second-order approximation to an arbitrary continuous twice-differentiable function. Total shadow cost is specified as linearly homogenous in shadow prices. The shadow price factors, i.e., k_i, are specifed as

[3] Again, the reader is referred to the previous cited sources.

[4] We are utilizing an "intermediation approach" in defining bank outputs, i.e., we measure output as the dollar value of produced assets and include the interest expense of funds in our measure of costs. This is in line with much of the recent bank cost literature although an alternative "production approach" has been utilized by others when evaluating small commercial banks. For a discussion of the alternative approaches and their differences see Berger, Hanweck, and Humphrey (1987).

input specific but identical across banking firms. The level of k_i cannot be estimated, given that the equations for total actual cost and factor cost shares are homogeneous of degree zero in the k_is. The shadow price factor for labor, k_L, is set equal to unity and the shadow price factors for the remaining inputs are estimated. Therefore, we test for relative price efficiency only, not absolute efficiency.

The total shadow cost function measure in translog form is

$$\begin{aligned}
\ln C^S \;=\;& \alpha_0 + \sum_i \beta_{Q_i} \ln Q_i \\
&+0.5 \sum_i \sum_j \beta_{Q_i Q_j} (\ln Q_i \ln Q_j) + \sum_i \gamma_{iQ_j} \ln Q_j \ln(k_i P_i) \\
&+ \sum_i \beta_i \ln(k_i P_i) + 0.5 \sum_i \sum_j \gamma_{ij} \ln(k_i P_i) \ln(k_j P_j) \\
&+ \phi_T \ln T + 0.5 \phi_{TT} (\ln T)^2 + \sum_i \theta_{Q_i T} \ln Q_i \ln T + \sum_i \gamma_{iT} \ln(k_i P_i) \ln T \\
&+ \beta_B \ln B + 0.5 \beta_{BB} (\ln B)^2 + \sum_i \theta_{Q_i B} \ln Q_i \ln B + \theta_{TB} \ln T \ln B \\
&+ \sum_i \gamma_{iB} \ln(k_i P_i) \ln B + \beta_H H + \sum_i \theta_{HQ_i} H \ln Q_i + \theta_{HT} H \ln T \\
&+ \theta_{HB} H \ln B + \sum_i \gamma_{iH} \ln(k_i P_i) H; \\
&\forall\, i,j = K, L, F \text{ and } Q_i, Q_j = \text{ the four outputs.} \qquad (4)
\end{aligned}$$

where $\gamma_{ij} = \gamma_{ji}$. Linear homogeneity in shadow prices implies the following adding-up restrictions on parameters:

$$\begin{aligned}
\sum_i \beta_i &= 1 \text{ and } \sum_i \gamma_{iQ_j} = \sum_i \gamma_{iB} = \sum_i \gamma_{iT} = \sum_i \gamma_{iH} = 0 \\
\sum_i \gamma_{ij} &= 0;\;\; \forall\, i,j \text{ and } Q_j. \qquad (5)
\end{aligned}$$

Shadow cost shares for the translog specification are derived by logarithmic differentiation of C^S in equation (4):

$$\begin{aligned}
M_i^S &= \frac{\partial \ln C^S}{\partial \ln(k_i P_i)} \\
&= \beta_i + \sum_j \gamma_{iQ_j} \ln Q_j + \sum_j \gamma_{ij} ln(k_j P_j) + \gamma_{iT} \ln T + \gamma_{iB} \ln B + \gamma_{ih} H \\
&\quad \forall\, i,j \text{ and } Q_j. \qquad (6)
\end{aligned}$$

From equations (2), (4), and (6), total actual (observed) costs are

$$\begin{aligned}
\ln C^A &= \ln C^S + \ln(\sum_i [\beta_i + \sum_j \gamma_{ij} \ln(k_j P_j) + \sum_j \gamma_{iQ_j} \ln Q_j \\
&\quad \sum_i \gamma_{iT} \ln T + \sum_i \gamma_{iB} \ln B + \sum_i \gamma_{iH} H] k_i^{-1}) \\
&\quad \forall\ i, j \text{ and } Q_j. \qquad (7)
\end{aligned}$$

Using equations (3), and (6), the actual (observed) cost shares are given by

$$\begin{aligned}
M_i^A &= [\beta_i + \sum_j \gamma_{ij} \ln(k_j Pj) + \sum_j \gamma_{iQ_j} \ln Q_j + \gamma_{iT} \ln T + \gamma_{iB} \ln B \\
&\quad + \gamma_{iH} H] k_i^{-1} / \\
&\quad \sum_i [\beta_i + \sum_j \gamma_{ij} \ln(k_j P_j) + \sum_j \gamma_{iQ_j} \ln Q_j + \gamma_{iT} \ln T + \gamma_{iB} \ln B \\
&\quad + \gamma_{iH} H] k_i^{-1} \\
&\quad \forall\ i, j \text{ and } Q_j. \qquad (8)
\end{aligned}$$

Equation (7) and two of the share equations (8), appended with classical additive disturbance terms, constitute the set of equations to be jointly estimated. One share equation is dropped because of the singularity of the variance-covariance matrix of the error terms for the three-equation system resulting from the adding-up conditions on the share equations. We arbitrarily drop the capital-share equation. The empirical results are invariant to the choice of share equation deleted and to the shadow price chosen for normalization.

2.2 Data

The model was estimated for a panel data set for the years 1972-87 for the largest banks in the U.S. which were members of a holding company over the entire period. The final data set consisted of 164 banks and 2,624 observations. Our priors were that these institutions were probably in the best position to avoid adverse effects from regulation, thus making our findings conservative. Inefficiency could be less for these institutions than for smaller ones because they may have more astute management, be more cost conscious, and be more involved in wholesale banking whereas most regulations concentrate on the retail side of banking.[5]

[5]Rangan, et al. (1988), Berger and Humphrey (1990), and Elyasiani and Mehdian (1990a) found large banks to be more efficient. Elyasiani and Mehdian attribute most of the differential to scale advantages, and Rangan, et al. attributed it to pure technical efficiency differences. Neither study, however, tested for allocative efficiency. Using a nonparametric approach Aly, et al. (1990) did not find allocative efficiency to be related to bank size.

The Federal Reserve Call Report was the major data source. Costs, defined as the sum of expenditures on labor, funds, and physical capital, were obtained from this source, as was the number of banking offices and the type of bank holding company organization — i.e., single or multibank. Technical progress was accounted for with a time trend. The input price for labor, P_L, was obtained from the Bureau of Labor Statistics. State level wage trends were collected for each year and assigned to each bank according to the location of its home office. The price of physical capital, P_K, was approximated from Call Report data as the ratio of physical capital expenditures measured as additions to plant and equipment, furniture, and physical premises, to the book value of net bank premises, furniture and physical equipment. The price of funds was also calculated from Call Report data as an average cost of funds.

3 Empirical Results

Cost estimates were derived using the iterated seemingly unrelated regression technique and are presented in table 1.[6] While a cursory review suggests that the results from the MP and SP model are similar, additional analysis indicate they are different. In evaluating the SP model we find, as expected, that the price of physical capital is distorted downward relative to that of labor and funds suggesting that the regulatory-induced production constraints are binding. We also find the price of funds to be biased downward slightly relative to that of labor.[7] The significant coefficients on the measures of factor price distortion, k_K and k_F, suggests the MP model should be rejected. More formally, results from a likelihood ratio test also lead us to reject the more restrictive model (see table 2).

A number of production characteristics and additional comparisons between the MP and SP models can be analyzed. For example, we can utilize likelihood ratio tests to test for homogeneity and homotheticity of the production process, and to determine whether the process everywhere displays constant returns to scale (CRS). We can also evaluate the characteristics of the cost function at various data points. Results from a number of tests are presented in table 2. Summarizing, concerning the SP Model, the restrictive cost

[6] Our sample includes both unit and branch banks. This was done to preserve the attributes of the panel sample over the period studied during which some states changed their restrictions on geographic expansion. Analysis of a sample of branch banks only produced similar results for all the analysis, albeit distortions of a smaller magnitude, including the findings presented in Section 4.2. Therefore, our results should be interpreted as also detecting distortions from geographic expansion regulations.

[7] Given that there were rate restrictions in place over much of the time period analyzed one would expect the true price of funds, if anything, to be above the stated market price. Therefore, the distortion may be coming from the price of labor. Alternatively, the finding may support those who argue that the interaction effects of different regulations is too complex to attempt to isolate individual effects. Similar results were found using an alternative average wage measure derived from the Call Report Data.

relationships (homothetic and homogeneous in output, and global CRS) are rejected.[8] At the mean of the sample the calculated scale elasticity suggests the existence of economies of scale which are significant in a statistical sense. From a more micro perspective, our "U" shaped average cost curve results in 1518 observations in the range of the cost relationship in which statistically significant scale economies exists, and 909 observations in the range of significant diseconomies. Significant scope economies are also found for the two broad catagories of outputs analyzed; loans and investment securities. The significant savings from joint production no doubt result from the substantial sunk costs imposed on the "average" firm in spite of the lack of production of one of the outputs.

The role of technological change is also found to be significant in the analysis suggesting that technical advancements have significantly aided the production process.[9] The advances were found to be funds using, labor saving, and capital using relative to labor. Additionally, technical advancement tended to flatten the average cost curve, i.e., decreased scale advantages.[10]

Although the more restrictive MP Model is rejected relative to the SP model, the findings presented in Table 3 suggest that the resulting biases induced by the misspecification are relatively minor for most cost characteristics. The exception to this is the measure of technical progression which is understated downward by approximately 10 percent in the MP model.

3.1 Bank Efficiency

We evaluate the extent of allocative inefficiency resulting from regulatory restrictions by deriving the difference between shadow costs evaluated at the sample mean assuming relative price efficiency and assuming the estimated factor price distortions, i.e.,

$$Ineff_A = \ln C^S(\hat{k}_i) - \ln C^S(k_i = 1) \quad \forall\, i. \tag{9}$$

Although our estimates suggest the perceived price of capital is distorted downward, the resulting measured inefficiency from regulatory distortions is relatively small, i.e., less than

[8]The rejection of homotheticity brings into question the use of aggregate output measures in bank cost studies.

[9]Using similar data, an aggregate output measure, and production expenses only (excluding funding cost) an earlier study found more significant influence from technology (Evanoff, Israilevich, and Merris). This suggests, as expected, that technical advances have aided the physical production process significantly more than the funds gathering process.

[10]These results can be derived directly from the coefficient estimates presented in table 1. Technology was only slightly funds-using relative to capital.

one percent of total costs.[11] The finding of limited allocative inefficiency is somewhat similar to findings of previous studies. Berger and Humphrey (1990) found a "virtual absence" of allocative inefficiency when they decomposed the inefficiency found using their thick frontier approach.[12] Using a nonparametric linear programing approach Aly, et al. found slightly larger allocative inefficiency, but found it to be dominated by technical inefficiencies. Only Ferrier and Lovell using a parametric one-sided error approach found significant allocative effects. Their analysis, however, combines different types of financial institutions (credit unions, savings and loans, and commercial banks) and may be influenced by data measurement problems. They also find labor to be overused relative to capital; precisely the opposite of what we have argued should occur as a result of regulation.

We also check to see if measures of technical efficiency found using our sample of banks are similar to those found in previous studies. In addressing technical efficiency we are evaluating whether banks over-utilize all inputs once the optimal combination of inputs is determined. For this analysis we utilize the "thick frontier" approach developed by Berger and Humphrey (1990) modified to account for allocative inefficiency using the approach taken in this paper. Berger and Humphrey estimate a thick frontier from the data instead of a precise frontier edge by separately estimating and contrasting cost functions for sample quartiles. The approach essentially compares the efficiency level of high and low cost banking firms.

We arrange our data in quartiles according to total cost per dollar of output and separately estimate SP models for the high and low cost banks. We then compare the costs of the average bank in the two groups holding factor prices and market characteristics constant.[13] Summarily, we find technical inefficiency of approximately 21 percent. This is slightly less than that found in previous studies, but may be attributable to the sample being made up exclusively of large banks which have been shown elsewhere to operate more efficiently.

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[11] Again, contrasting these findings to those using an aggregate output measure and production costs only suggests, as expected, that regulatory-induced inefficiencies affect the production process more than the funds collection process.

[12] The authors use a somewhat ad hoc approach to generate an estimated frontier function instead of a production frontier edge. We discuss this approach in more detail below.

[13] The reader is referred to Berger and Humphrey (1990) for a complete description of the procedure. Our methodology differs slightly because we do not have to assume that the low cost quartile firms are both technical and allocative efficient. We can account for allocative inefficiencies by utilizing the SP model. In theory we believe this is preferred since even well managed (technically) efficient institutions can be adversely affected by regulation. However, quantitatively the difference may be small given our finding of limited allocative inefficiency. Also, by utilizing a panel data set we do not encounter the problem of limited observations for our subsample of large banks. Detailed results from the estimates summarized here are available from the authors on request.

3.2 Comparison of Regulatory Periods

Given the relatively low level of allocative inefficiency, one is tempted to say that regulatory distortions were minor over the period studied. Thus, arguments for industry deregulation are less persuasive given that the constraints are not shown to appreciably distort behavior. Additionally, inspite of the statistical significance of the differences found using the two models, one may question the net benefits of the shadow price specification since biases resulting from use of the MP model appear relatively minor. We expect, however, that although our results can be interpreted as representing the average distortion over the seventeen year period, regulatory stringency was not constant over this period. For example, the 1980 Depository Institution Deregulation and Monetary Control Act and the 1982 Garn-St. Germain Act relaxed constraints on industry prices, products, and geographic expansion; each considered a significant industry restriction. Other studies have found that deregulation in the early 1980s did impact firm behavior; e.g., LeCompe and Smith (1990). We next account for the changing regulatory environment and evaluate whether industry productive behavior varied over the period.

To account for the influence of industry deregulation we subdivide the seventeen year period into three subperiods. The 1972-79 period is characterized by "significant regulation," the 1984-87 period is considered the deregulated environment, and the 1980-83 period is thought to be one of adjustment in response to the newly relaxed restrictions. During this adjustment period it is assumed banks adjusted their input mix– i.e., closed a number of offices previously opened as a substitute for explicit interest payments, altered their use of funds relative to the earlier period, etc.– and, essentially, moved from one equilibrium to another. We compare the early and latter periods to contrast the productive behavior of large commercial banks under "restrictive" and "less restrictive" regulatory environments.

To contrast the two regulatory regimes we separately estimate our SP model for the two subperiods. Estimates are presented in Table 4. More interesting, however, is a comparison of the resulting cost function characteristics presented in Table 5. The differences found for the two periods are substantial. As expected, in the earlier time period in which price competition was more restricted, the price distortions and resulting production inefficiency are significantly greater. The regulatory induced inefficiencies would not be captured by the MP model. Thus, this indicates the SP model is preferred in both a statistical *and* economic sense. Results from a likelihood ratio test indicated the two periods should be viewed separately.

In comparing the two regulatory regimes we find that for the average bank in the sample, scale economies existed in the early period, but were fully exhausted after deregulation. One interpretation of this would be that the banks, faced with fewer production constraints and increased competition in the deregulated period, were able to alter their operations to capture the benefits from scale.

The findings concerning the role of technology are particularly interesting. Although technical progression over the *entire* period was estimated to be approximately seven percent (table 3), it appears that most of the cost savings were realized after deregulation. More precisely, during the eight year regulated period technology decreased costs by only five percent, while over the significantly shorter deregulated period it lowered costs by nearly 26 percent.[14] What caused the change? Again, there is reason to believe it was a result of the deregulation. With deregulation the incentives and ability to take advantage of more efficient production techniques were greater. We know that the technology was different in the two time periods based on our finding that each period has a unique cost relationship. To evaluate how banks would have behaved in the latter period had the old technology still been in place, we imposed the old technology on the data for the latter time period and recalculated technological change. That is, given the current factor prices and market characteristics, how would banks have behaved had the regulatory framework and resulting technology of the earlier period still been in place. Analyzing this situation we find that the role of technology would have been to decrease cost over the period by approximately nine percent; significantly less than that actually realized.[15] Inefficiency would have also been significantly greater than that realized in the latter period, i.e., greater than two percent compared to 0.1 percent. It appears, therefore, that banks responded to deregulation by

[14] We also find that the role of technology on factor shares was significantly different between the two time periods. While technology was funds-using in both periods, the effect was much larger in the deregulated period. Similarly, technology was significantly more capital-saving in the deregulated period–i.e., when firms could compete directly via prices instead of employing alternative (capital intensive) means to compete.

[15] As in Hunter and Timme (1986), Elyasiani and Mehdian (1990b), Lawrence and Shay (1986), and Evanoff and Israilevich our analysis uses current levels of the variables, i.e., nondeflated values. As a result, our estimates may overstate the role of technology and should, therefore, be considered a rough approximation. Choosing proper deflators and accounting for quality or price changes is difficult in any industry study. However, it is even more problematic in banking. In addition to the selection of an appropriate deflator for factor prices *and* outputs, the maturity structure of the loan portfolio should be considered. For example, expressing the current time period as t, output for a firm having placed all the loans on its books in year t-5 should be deflated differently than one having generated all of them in the current time period. The deflators could differ significantly. However, data on loan maturity structure for the banks analyzed are not available. Simply ignoring the maturity structure and deflating outputs using a single deflator could, alternatively, significantly understate the role of technology. To address this issue in a somewhat cursory manner we reestimated our cost system assuming all outputs were placed on the books in the current year, i.e., by using a single deflator and deflating output values for each year to constant dollars. We also assume that a single deflator is appropriate for all factor prices, and realize that costs are linearly homogeneous in factor prices. The results, which are available from the authors on request, were nearly identical to those produced in the tables *except* for the role of technology which actually showed technical regression in each time period. This is somewhat similar to the findings of Humphrey (1990) who used a similar deflating procedure. However the differences between the two periods was in line with the results presented here. That is, the influence of technology was greater in the latter time period than in the regulated environment. Thus, again, although the role of technology is consistently shown to be much more important after deregulation, its absolute estimated influence on costs should be interpreted cautiously.

altering their production techniques to reap significant benefits from technology which could not be realized in the regulated environment.

4 Summary and Conclusions

Analyzing costs for a sample of banks which may be more resilient than most to regulation we find statistically significant factor price distortions. We reject the standard Neoclassical Market Price model in favor of a more general one which allows for cost minimization subject to *shadow* factor prices which can differ from market prices as a result of regulation. Our analysis incorporates the multiproduct production process and employs the intermediation approach to measuring bank output and costs–that is banks serve as an intermediator of financial services. Findings from our analysis of the 1972-87 period suggests that for the sample of banks analyzed scope economies and minor scale economies exists, technology has played a significant role in reducing costs, and the standard market cost model should be rejected relative to the more general shadow price model. However, viewing this time period, the distortions created by using the less general model appear to be relatively minor.

However, the advantages of the shadow price model relative to the market price model are highlighted in a comparison of the pre- and post-deregulated periods in banking. Our findings suggests that the banking environment changed significantly. Allocative inefficiency was a factor in the early time period, but was nearly nonexistent after deregulation. Banks apparantly responded to the deregulated environment by altering their production process to fully exploit scale economies, and reaped significant returns from technological change. Scope advantages existed in each period.

This study has viewed the effect of regulation on large commercial banks. The effect may be significantly different for alternative samples. Future studies of bank costs should consider the role of inefficiencies induced by regulation and determine whether the production process has changed over time. Our analysis suggests the change has been significant.

Table 1: Estimation Results For the Shadow and Market Price Models.

Coefficients	*Model Estimates*	
	MP	SP
α_0	1.19 (6.34)	1.1903 (6.35)
β_L	-0.251 (-14.24)	-0.2516 (-13.18)
γ_{LL}	0.109 (52.87)	0.1210 (39.92)
γ_{LQ1}	-0.016 (-10.20)	-0.0185 (-10.55)
γ_{LQ2}	0.022 (14.68)	0.0253 (15.00)
γ_{LQ3}	0.017 (10.32)	0.0178 (9.87)
γ_{LQ4}	-0.020 (-11.43)	-0.0233 (-11.95)
γ_{LB}	0.00518 (6.34)	0.005890 (6.69)
γ_{LH}	-0.00331 (-1.63)	-0.005080 (-2.34)
γ_{LT}	-0.038 (-27.33)	-0.0423 (-26.22)
β_F	1.270 (59.39)	1.2587 (58.60)
γ_{LF}	-0.129 (-70.61)	-0.1346 (-55.40)
γ_{FF}	0.177 (90.92)	0.1637 (66.19)
γ_{FQ1}	0.017 (8.56)	0.0199 (9.66)
γ_{FQ2}	-0.028 (-14.25)	-0.0294 (-15.27)
γ_{FQ3}	-0.023 (-10.84)	-0.0219 (-10.13)
γ_{FQ4}	0.033 (14.09)	0.0318 (13.74)
γ_{FB}	-0.00561 (-5.31)	-0.006270 (-6.03)
γ_{FH}	0.00383 (1.46)	0.005829 (2.26)
γ_{FT}	0.04350 (24.07)	0.0464 (25.76)
β_{Q1}	0.276 (10.92)	0.2934 (11.64)
β_{Q11}	0.089 (33.40)	0.0906 (34.11)
β_{Q12}	-0.027 (-10.78)	-0.0269 (-10.82)
β_{Q13}	-0.032 (-14.39)	-0.0322 (-14.27)
β_{Q14}	-0.032 (-9.18)	-0.0347 (-9.86)
θ_{Q1B}	0.00563 (3.90)	0.004968 (3.48)
θ_{Q1T}	0.00532 (2.16)	0.005474 (2.24)
θ_{Q1H}	0.012 (3.46)	0.0113 (3.08)
β_{Q2}	0.183 (6.61)	0.1704 (6.19)
β_{Q22}	0.159 (51.00)	0.1602 (51.72)
β_{Q23}	-0.039 (-14.10)	-0.0401 (-14.63)
β_{Q24}	-0.090 (-34.72)	-0.0897 (-34.91)

t-values are in parenthesis. The t value for the k_i coefficient was calculated under the hypothesis of $k_i = 1$.

Coefficients	*Model Estimates (Continued)*	
	MP	SP
θ_{Q2B}	-0.00374 (-2.50)	-0.003403 (-2.29)
θ_{Q2T}	-0.014 (-6.28)	-0.0140 (-6.18)
θ_{Q2H}	0.00537 (1.48)	0.004867 (1.35)
β_{Q3}	0.340 (11.83)	0.3398 (11.93)
β_{Q33}	0.100 (28.73)	0.1001 (28.81)
β_{Q34}	-0.041 (-12.27)	-0.0405 (-12.05)
θ_{Q3B}	0.00222 (1.52)	0.002497 (1.73)
θ_{Q3T}	0.00081 (0.31)	0.0000913 (0.03)
θ_{Q3H}	-0.00979 (-2.51)	-0.0100 (-2.59)
β_{Q4}	0.276 (8.21)	0.2772 (8.28)
β_{Q44}	0.169 (45.04)	0.1697 (45.46)
θ_{Q4B}	-0.00324 (-1.84)	-0.002127 (-1.22)
θ_{Q4T}	0.00380 (1.31)	0.005295 (1.84)
θ_{Q4H}	-0.017 (-4.07)	-0.0162 (-3.76)
β_b	-0.045 (-3.07)	-0.0590 (-4.02)
β_{BB}	0.00818 (5.51)	0.007262 (4.93)
θ_{TB}	-0.00114 (-0.94)	-0.001684 (-1.40)
θ_{BH}	0.00613 (3.25)	0.007578 (4.04)
ϕ_T	0.194 (8.08)	0.1967 (8.24)
ϕ_{TT}	-0.010 (-3.12)	-0.0145 (-4.25)
θ_{TH}	0.00666 (2.37)	0.007002 (2.52)
β_H	0.095 (2.88)	0.1028 (3.13)
k_K	NA	0.5887 (8.60)
k_F	NA	0.9765 (5.67)

t-values are in parenthesis. The t value for the k_i coefficient was calculated under the hypothesis of $k_i = 1$.

Table 2: Results of Hypothesis Tests Concerning the Shadow Price Model.

Null-Hypothesis	*(J)*	*Restrictions*	*LR*	$\chi^2(J)$
$\widehat{SP} = \widehat{MP}$	2	$k_i = 1 \; \forall \, i$	56.9	5.99
Homotheticity	20	$\theta_{QiT} = \theta_{QiB} = \theta_{QiH} = \gamma_{iQj} = 0$	644.5	31.4
Homogeneity	30	$\theta_{QiT} = \theta_{QiB} = \theta_{QiH} = \gamma_{iQj} = \beta_{QiQj} = 0$	6216	43.7
Constant Returns to Scale	34	$\theta_{QiT} = \theta_{QiB} = \theta_{QiH} = \gamma_{iQj} = \beta_{QiQj} = 0$ and $\beta_{Qi} = 1$	6980	43.7

Note: J is the number of restrictions, LR denotes the likelihood-ratio test statistic $(-2\ln\lambda)$, χ^2 denotes the chi-square value for J–degrees of freedom at the five percent significance level.

Table 3: Shadow and Market Price Models Statistical Results.

Variables	*SP Model*	*MP Model*
Ray Scale Economies $\sum_i \frac{\partial \ln C}{\partial \ln Q_i}$	0.981 (.0033)	.983 (.0033)
Product Specific Ray Scale Economies $\frac{\partial \ln C}{\partial \ln Q_i}$		
Real Estate Loans	0.180	.184
C&I Loans	0.340	.338
Installment Loans	0.224	.229
Investment Securities	0.236	.233
Scope Economies: $\frac{\sum_i C(Q_i)-C(Q)}{C(Q)}$	.280	.282
Technical Change $\frac{\partial \ln C}{\partial \ln T}$	-0.076 (.0033)	-0.069 (.0034)

Note: Standard errors are in parentheses. In calculating scope economies, two outputs were considered; loans and investment securities. The zero output values under log were replaced with small values to avoid arithmetic errors.

Table 4: Estimation Results For Two SP Models: Pre- and Post-industry Deregulation.

Coefficients	*Model Estimates*	
	1972-79	1984-87
α_0	2.1093 (8.07)	3.4131 (1.33)
β_L	-0.3801 (-13.29)	-0.1589 (-1.97)
γ_{LL}	0.1644 (36.77)	0.1075 (16.15)
γ_{LQ1}	-0.0178 (-7.09)	-0.0275 (-6.93)
γ_{LQ2}	0.0326 (13.25)	0.0286 (7.61)
γ_{LQ3}	0.0242 (8.43)	0.0141 (3.93)
γ_{LQ4}	-0.0434 (-14.17)	0.001644 (0.46)
γ_{LB}	0.008387 (6.85)	-0.001069 (-0.52)
γ_{LH}	0.001045 (0.35)	-0.0210 (-3.53)
γ_{LT}	-0.0288 (-12.39)	-0.1226 (-3.99)
β_F	1.3685 (44.82)	1.1820 (11.99)
γ_{LF}	-0.1741 (-50.36)	-0.1213 (-20.61)
γ_{FF}	0.1940 (61.93)	0.1528 (24.23)
γ_{FQ1}	0.0178 (6.45)	0.0304 (6.31)
γ_{FQ2}	-0.0363 (-13.85)	-0.0329 (-7.33)
γ_{FQ3}	-0.0269 (-8.42)	-0.0171 (-3.86)
γ_{FQ4}	0.0519 (15.50)	0.000512 (0.12)
γ_{FB}	-0.008430 (-6.29)	0.001687 (0.66)
γ_{FH}	-0.001295 (-0.39)	0.0272 (3.76)
γ_{FT}	0.0295 (11.61)	0.1404 (3.70)
β_{Q1}	0.3542 (9.95)	0.1779 (1.56)
β_{Q11}	0.0742 (23.37)	0.1193 (16.90)
β_{Q12}	-0.0328 (-9.61)	-0.0398 (-7.12)
β_{Q13}	-0.0375 (-9.95)	-0.0284 (-6.48)
β_{Q14}	-0.0149 (-3.06)	-0.0497 (-8.55)
θ_{Q1B}	0.009655 (4.95)	0.004583 (1.73)
θ_{Q1T}	0.009098 (3.14)	0.0484 (1.10)
θ_{Q1H}	0.007154 (1.68)	0.008375 (0.86)
β_{Q2}	0.1637 (3.83)	0.1962 (1.88)
β_{Q22}	0.1732 (33.49)	0.1564 (28.95)
β_{Q23}	-0.0384 (-7.95)	-0.0496 (-9.19)
β_{Q24}	-0.1005 (-27.29)	-0.0603 (-12.44)

t-values are in parenthesis. The pre- and post-deregulation periods are 1972-79 and 1983-87, respectively. The t value for the k_i coefficients were calculated under the hypothesis of $k_i = 1$.

Coefficients	*Model Estimates (Continued)*	
	1972-79	1984-87
θ_{Q2B}	-0.0022 (-1.11)	-0.00286 (-1.08)
θ_{Q2T}	-0.0069 (-2.30)	-0.055 (-1.38)
θ_{Q2H}	0.0058 (1.29)	0.018 (2.25)
β_{Q3}	0.17 (3.83)	0.531 (4.71)
β_{Q33}	0.11 (18.25)	0.109 (19.08)
β_{Q34}	-0.03 (-6.49)	-0.052 (-8.94)
θ_{Q3B}	0.0013 (0.70)	0.00020 (0.07)
θ_{Q3T}	0.0068 (1.97)	-0.023 (-0.61)
θ_{Q3H}	-0.01 (-2.21)	-0.00541 (-0.65)
β_{Q4}	0.28 (5.25)	0.237 (2.17)
β_{Q44}	0.16 (31.38)	0.156 (23.88)
θ_{Q4B}	-0.0079 (-3.09)	0.00549 (1.78)
θ_{Q4T}	-0.01 (-3.01)	0.034 (0.82)
θ_{Q4H}	-0.0010 (-0.17)	-0.040 (-4.41)
β_B	-0.03 (-2.03)	-0.111 (-1.87)
β_{BB}	0.0025 (1.46)	0.00248 (0.86)
θ_{TB}	-0.0025 (-1.82)	0.00678 (0.31)
θ_{BH}	0.0047 (2.25)	-0.00043 (-0.08)
ϕ_T	0.15 (5.07)	-1.742 (-0.93)
ϕ_{TT}	-0.02 (-4.59)	0.710 (0.98)
θ_{TH}	0.0047 (1.39)	0.169 (2.45)
β_H	-0.04 (-0.94)	-0.140 (-0.81)
k_K	0.35 (10.59)	0.714 (1.98)
k_F	1.00 (0.35)	0.964 (4.70)

t-values are in parenthesis. The t value for the k_i coefficients were calculated under the hypothesis of $k_i = 1$.

Table 5: Two Subperiods Shadow Price Models – Statistical Results.

Variables	*1972-79*	*1984-87*
Allocative Inefficiency	0.021	0.001
Ray Scale Economies $\sum_i \frac{\partial \ln C}{\partial \ln Q_i}$	0.981 (0.0045)	1.01 (0.0067)
Product Specific Ray Scale Economies $\frac{\partial \ln C}{\partial \ln Q_i}$		
Real Estate Loans	0.163	0.209
C&I Loans	0.352	0.350
Installment Loans	0.242	0.212
Investment Securities	0.223	0.240
Scope Economies: $\frac{\sum_i C(Q_i)-C(Q)}{C(Q)}$	.885	.891
Technical Change $\frac{\partial \ln C}{\partial \ln T}$	-0.050 (0.0045)	-0.258 (0.056)
Observations	1312	656

Note: Standard errors are in parentheses. In calculating scope economies, two outputs were considered; loans and investment securities. The zero output values under log were replaced with small values to avoid arithmetic errors.

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