A QUALITY AND RISK-ADJUSTED COST FUNCTION FOR BANKS: EVIDENCE ON THE "TOO-BIG-TO-FAIL" DOCTRINE

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Abstract

We estimate a multiproduct cost function model that incorporates measures for the quality of bank output and the probability of failure, which can influence a bank's costs in a variety of ways. We model a bank's price of uninsured deposits as an endogenous variable depending on the bank's output level, output quality, financial capital level, and risk measures. Incorporating these aspects into the cost function has a significant effect on measures of scale and scope economies when compared with results of previous studies that did not take quality and risk into account. We find constant returns to scale at the mean-sized bank and at banks in four different size categories. We also find evidence of diseconomies of scope at the larger banks. Finally, there is evidence that the "too-big-to-fail" doctrine has a significant impact on the price a bank pays for its uninsured deposits. For banks in the largest size category, an increase in size, holding default risk and asset quality constant, significantly lowers the uninsured deposit price.

A Quality and Risk-Adjusted Cost Function for Banks: Evidence on the "Too-Big-To-Fail" Doctrine

1. Introduction

There has been a multitude of studies of bank production costs in recent years. An important innovation in these studies was the introduction of a multiproduct approach, which recognizes that the bank produces a number of different products, and that measuring bank output with a summary statistic such as total assets can bias results concerning economies of scale in the industry. These previous studies have neglected, however, the quality of a bank's assets and the probability of bank failure, which can influence a bank's costs in a variety of ways. For example, a large proportion of nonperforming loans may signal that the bank used fewer than the usual number of resources in the initial credit analysis and continual monitoring of these loans. Thus, lower-quality loans may mean short-run cost savings for the bank. On the other hand, at some point, lower-quality loans will entail extra administrative expenses as the bank tries to resolve these bad loans.

Additionally, since the quality of a bank's assets influences the probability of the bank's failure, the cost of deposits may also be affected. Hannan and Hanweck (1988) report evidence indicating that the interest expense of uninsured deposits contains a risk premium. Thus, lower quality assets can mean increased interest costs for the bank. Another influence on the probability of bank failure, and so interest costs, is a bank's level of capital. The significance of any amount of nonperforming loans depends on the amount of these bad loans relative to the amount of capital available to cover losses. Indeed, a minimum capital-asset ratio is set by the regulators.

Aside from concerns of risk, a bank's capital level directly affects costs by providing an alternative to deposits as a funding source for loans. For some banks, capital notes, as well as other sources of capital, may be cheaper than core deposits.

Incorporating the quality of assets and the probability of failure into a formal model of a bank's production and costs permits an accounting of these effects as well as offering other advantages. In particular, if the cost function is constructed so that the price of uninsured deposits can be influenced by asset quality and the probability of failure, then the effect of their variation on the price of uninsured deposits can be determined. Moreover, while controlling for quality and probability of failure, the effect of bank size on the price of uninsured funds can be calculated for evidence on the existence and magnitude of the "too-big-to-fail" doctrine, which suggests that regulators are more apt to bail out large creditors and equityholders of large failed banks than those of small failed banks, and that bank investors take this into account. Thus, all else equal, the risk premium on deposits at large banks should be smaller than at small banks if uninsured depositors perceive that regulators implement a "too-big-to-fail" doctrine.

There is a more subtle advantage to incorporating financial capital into the cost function. It is possible that the regulations defining capital adequacy may constrain a bank to employ more financial capital than it would in an unregulated environment. Since our formulation *does not* assume that financial capital is optimally employed, it accommodates the case that the minimum required capital-asset ratio is binding. Given the advantages afforded to banks of using deposit and debt financing, this case seems likely and should be considered.

Even if regulations defining capital are not binding, a bank's level of financial capital may not be chosen to minimize cost if that level implies a degree of risk that is unacceptable. Hence, allowing for the possibility of non-risk-neutrality suggests that the level rather than the price of financial capital should be included in the cost function.

In this paper we focus on the cost function as opposed to a profit function, since we want to avoid making the assumption that banks act to maximize profits, which is inherent in the profit function approach used by, for example, Hancock (1991). Since banks are run by managers who may or may not be risk averse, profits may be only one argument in the bank manager's utility function. Although risk-averse managers would not maximize profits, they could still be characterized as minimizing cost, given the level of financial capital. As discussed below, the possibility of risk aversion on the part of the bank is one reason we model cost as a function of the level of financial capital, rather than of its price. Another reason to reject the profit function approach is that, as it is usually implemented, it assumes the bank's output prices are taken as exogenous. This presumes that the bank has no monopoly power. The cost function approach avoids this assumption.

The rest of this paper is organized as follows. Section 2 discusses the bank production and cost structures that explicitly take into account the quality of output and the probability of failure. Section 3 presents the formulas for the cost statistics of interest based on Section 2's model. Section 4 discusses empirical implementation of the theoretical model and includes a direct test of whether deposits should be treated as inputs or outputs in the cost model (the test suggests that they are inputs). Section 5 presents the empirical results and Section 6 concludes.

2. Bank Production and Cost

Summarize the bank's technology by the transformation function $T(y,\mathbf{q},x,u,k) = 0$, where y is a vector of quantities of outputs; $\mathbf{q}$ is a vector of variables characterizing output quality; u is uninsured deposits; k is financial capital; and x is a vector of inputs other than u and k. $T(y,\mathbf{q},x,u,k)$ describes the production possibilities set, and is nondecreasing in x, u, and k, nonincreasing in y and $\mathbf{q}$. Additionally, $T(y,\mathbf{q},x,u,k)$ is strictly quasi-concave in x, u, and k. This means the input requirement sets, $V(y,\mathbf{q}) = \{(x,u,k): T(x,u,k;y,\mathbf{q}) = 0\}$, which describe the set of all inputs needed to produce output quantities y with qualities $\mathbf{q}$, are strictly convex, and the restricted input requirement sets, $\tilde{v}(y,\mathbf{q},k) = \{(x,u): T(x,u;y,\mathbf{q},k) = 0\}$ and $v(y,\mathbf{q},u,k) = \{x: T(x;y,\mathbf{q},u,k) = 0\}$, are strictly convex.

The disaggregation of y and $\mathbf{q}$ in the transformation function recognizes an inherent measurement problem. Ideally, the y vector in the production transformation should be measured as quality-adjusted output. That is, one unit of an output included in y should be one unit of the output of a particular quality. Of course, in cost function estimation, typically the unit of output measurement does not hold quality constant. Disaggregating the bank's outputs into different product lines, e.g., commercial loans, consumer loans, real estate loans, takes a step in the right direction to the extent that loans in different categories have different risk characteristics. But it does not go far enough, since loans within a particular category can have different risks. Thus, adding **q** to the transformation function is a way to control for this.[1]

We assume banks are price-takers in the markets for inputs included in **x** so that the corresponding price vector **w** is competitively determined. We model the price of uninsured deposits, w_u, as a function of a competitively determined risk-free market rate ω and a risk premium. This risk premium is determined by the bank's riskiness as reflected in the quality of its output, **q**, by its capital level k relative to its size,[2] and by a vector θ of variables that do not affect the production transformation. For example, θ might include the variability of net income. Thus, let $w_u = \omega f(y,q,k,\theta)$, where ω is a competitively determined, risk-free interest rate and $f(y,q,k,\theta)$ represents the risk premium. The cost of production is defined by:

$$C(y,q,w,\omega,k,\theta) \equiv \min_{x,u} [w \cdot x + \omega f(y,q,k,\theta)u : (x,u) \in \tilde{v}(y,q,k)] \quad (1)$$

Note that we include the level of financial capital, k, in the cost function. Previous studies have included neither the level of financial capital nor its price in the bank's cost function. Thus they have ignored the fact that financial capital is a substitute for deposits in loan funding. On theoretical grounds, recognizing that financial capital is an input but omitting it in the cost function is equivalent to assuming that the unit price of financial capital

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[1]Note that this approach differs from that of the hedonic cost function used in single product studies. In the typical hedonic approach output *quantity* is considered a function of certain output characteristics, including quality. For example, $y = f(q)$. Here, the output quantities and qualities both are included in the cost function.

[2]A change in k, holding y constant, is equivalent to a change in $k/(\Sigma_i y_i)$.

is perfectly correlated with one of the other input prices (and so its price need not be included separately in the cost function), and that the level of financial capital is determined endogenously as that level which minimizes cost. If we believed that the bank were operating with the cost-minimizing level of financial capital but that the price of financial capital and price of deposits differed, we would include the unit price of financial capital in the cost function. However, there is good reason to suspect that the level of financial capital a bank holds may not be explained entirely by cost minimization. First, regulators set a minimum capital-asset ratio for banks and this may constrain banks from operating at the cost-minimizing financial capital level. Second, if the bank exhibits some risk aversion, then, because lower capital implies higher probability of default risk (capital acts as a cushion for losses), banks may choose a non-cost-minimizing level of financial capital. Thus, we include the *level* of financial capital in the cost function rather than its price.

The formulation in equation (1) exhibits all the standard properties of a cost function. Note, though, that in this reduced-form cost function, the price of uninsured deposits, w_u, does not appear. Thus, we cannot apply the usual version of Shephard's lemma to derive the cost share for uninsured deposits. We use a variant of the lemma: differentiating equation (1) with respect to the risk-free rate of interest ω, using the Envelope Theorem, yields:

$$\frac{\partial C}{\partial \omega} = f(y,q,k,\theta)\ u^*(y,q,w,\omega,k,\theta) \ , \tag{2}$$

where $u^*(y,q,w,\omega,k,\theta)$ is the cost-minimizing level of u.[3]

Hence:

$$u^*(y,q,w,\omega,k,\theta) = \frac{\frac{\partial C}{\partial \omega}}{f(y,q,k,\theta)} = \frac{\omega}{w_u}\frac{\partial C}{\partial \omega} \ , \tag{3}$$

or, in terms of the uninsured deposits cost share equation:

[3]This approach to the specification of an endogenous input price was suggested by Diewert (1982).

$$\frac{w_u u^*}{C} = \frac{\partial \ln C}{\partial \ln \omega} . \tag{4}$$

The expression in equation (4) suggests that the application of this variant of Shephard's lemma to a translog cost function, for example, containing the argument ω, readily yields the share equation of uninsured deposits.

We have been discussing the reduced form model for the cost function defined by the endogeneity of w_u, i.e., cost as a function of (y,q,w,ω,k,θ). However, we are interested in measuring the price of uninsured deposits, w_u, as well as the effect of changes in the riskiness of the bank's assets (changes in θ), in probability of bank failure (changes in k), in the quality of the bank's assets (changes in q), and in the levels of the bank's assets (changes in y) on the marginal cost of uninsured deposits--i.e., $\frac{\partial w_u}{\partial \theta_\ell}\ \forall\ \theta_\ell \in \theta$, $\frac{\partial w_u}{\partial k}$, $\frac{\partial w_u}{\partial q_j}\ \forall\ q_j \in q$, and $\frac{\partial w_u}{\partial y_i}\ \forall\ y_i \in y$. To obtain these derivatives, we will focus on the *structural cost model* consisting of the cost function, where cost is a function of (y,q,w,w_u,k), the cost share equations, and the w_u function. We will use lower case c to denote this cost function. Thus, the structural model is:

$$c(y,q,w,w_u,k) \equiv \min_{x,u} [w \cdot x + w_u \cdot u : (x,u) \in \tilde{v}(y,q,k)] , \tag{5}$$

$$S_j(y,q,w,w_u,k) \equiv \frac{\partial \ln c(y,q,w,w_u,k)}{\partial \ln w_j} , \tag{6}$$

$$w_u \equiv \omega f(y,q,k,\theta) , \tag{7}$$

where S_j is the jth cost share equation. Clearly, $C(y,q,w,\omega,k,\theta) \equiv c(y,q,w,\omega f(\cdot),k)$.

We present estimates of this structural model below, where w_u is treated econometrically as an endogenous variable in the cost function and share equations. This will become clearer in Section 4, where we discuss empirical implementation.

3. Cost Statistics

Once equation (7) is estimated, estimates of the effect of changes in the parameters on the price of uninsured deposits, w_u, can be obtained directly. We are also interested in investigating the magnitude of the "too-big-to-fail" doctrine and its impact on bank costs. Large bank failures are disruptive to the banking and payments system. Participants in the market for uninsured deposits may believe that some institutions are too large for regulators to allow them to fail. If so, then as banks become larger, holding quality and risk constant, the risk premium on uninsured deposits is reduced via the impact of "too big to fail." If size is measured by the level of an individual output, e.g., commercial and industrial loans, then $\partial w_u/\partial y_\ell \leq 0$ might be considered evidence of "too-big-to-fail." This would be true if default risk were held constant as bank size varied. Unfortunately, a variation in any output level, y_i, is also a variation in the i^{th} individual capital-asset ratio (i.e., k/y_i) and in the aggregate capital-assets ratio (i.e., $k/\Sigma_i y_i$). So a variation in y_i is a variation in the bank's default risk. Since the market views some assets as riskier than others, we would expect $\partial w_u/\partial y_i \neq \partial w_u/\partial y_j$ for $i \neq j$. Thus, there is, in general, no unique relationship between the aggregate capital-asset ratio and the price of insured deposits. That is, $\partial w_u/\partial[k/(\Sigma_i y_i)]$ is not generally well defined. Consequently, we must find a means to allow bank size to vary while holding risk constant.

We solve this problem by considering the effect on the price of uninsured deposits of a *proportional variation in the levels of all outputs and financial capital.* In this manner, the effect of a scaled variation in size can be studied while holding the individual and aggregate capital-asset ratios constant. If a quality measure, q_j, is appropriately considered relative to asset size, then it, too, must be included in the scale variation.[4]

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[4]Note that this is the same way Baumol, Panzar, and Willig (1982) solve a similar problem with measuring global economies of scale in a multiproduct firm. They define the degree of multiproduct economies of scale as the percentage change in cost from a proportionate increase in the level of each output.

Consider a composite output quantity, financial capital, and output quality bundle, $\varsigma^0 \equiv (y^0, k^0, q^0)$. Then the change in w_u due to a scaled increase in ς^0 is well defined and the capital-asset ratios (individual and aggregate) remain constant from such a change. Consider $\varsigma = t\varsigma^0$. Then,

$$\begin{aligned}
\frac{dw_u}{dt}(\varsigma) &= \frac{dw_u}{dt}(t\varsigma^0) \\
&= \sum_i \frac{\partial w_u}{\partial y_i}(t\varsigma^0)\frac{dy_i}{dt} + \frac{\partial w_u}{\partial k}(t\varsigma^0)\frac{dk}{dt} + \sum_j \frac{\partial w_u}{\partial q_j}(t\varsigma^0)\frac{dq_j}{dt} \qquad (8) \\
&= \sum_i \frac{\partial w_u}{\partial y_i}(\varsigma)\frac{dty_i^0}{dt} + \frac{\partial w_u}{\partial k}(\varsigma)\frac{dtk^0}{dt} + \sum_j \frac{\partial w_u}{\partial q_j}(\varsigma)\frac{dtq_j^0}{dt} \\
&= \sum_i \frac{\partial w_u}{\partial y_i}(\varsigma)\, y_i^0 + \frac{\partial w_u}{\partial k}(\varsigma)\, k^0 + \sum_j \frac{\partial w_u}{\partial q_j}(\varsigma)\, q_j^0 \\
&= \sum_i \frac{\partial w_u}{\partial y_i}(\varsigma)\frac{y_i}{t} + \frac{\partial w_u}{\partial k}(\varsigma)\frac{k}{t} + \sum_j \frac{\partial w_u}{\partial q_j}(\varsigma)\frac{q_j}{t} \ .
\end{aligned}$$

Therefore,

$$\left[\frac{dw_u}{dt}(\varsigma)\right] t = \sum_i \frac{\partial w_u}{\partial y_i}(\varsigma)\, y_i + \frac{\partial w_u}{\partial k}(\varsigma)\, k + \sum_j \frac{\partial w_u}{\partial q_j}(\varsigma)\, q_j \ . \qquad (9)$$

So,

$$\text{DERW} \equiv \frac{dw_u}{\left(\frac{dt}{t}\right)}(\varsigma) = \sum_i \frac{\partial w_u}{\partial y_i}(\varsigma)\, y_i + \frac{\partial w_u}{\partial k}(\varsigma)\, k + \sum_j \frac{\partial w_u}{\partial q_j}(\varsigma)\, q_j \ , \qquad (10)$$

where we use the acronym DERW to stand for "derivative of w_u."

Since $\frac{dt}{t} = \frac{dy_i}{y_i} = \frac{dk}{k} = \frac{dq_j}{q_j} \ \forall\, i,j$, equation (10) gives the effect on the price of uninsured deposits of a proportionately scaled variation in the levels of all outputs, the quality of output, and financial capital.

When DERW < 0, the risk premium is smaller, the larger the bank's size, holding constant components of default risk such as the individual and aggregate capital-asset ratios and the ratio of nonperforming loans to assets. This would be evidence that large depositors believe that regulators follow the "too-big-to-fail" doctrine.

These components of default risk can also be held constant when economies of scale are measured. The total differential of cost for the scaled variation is:

$$\frac{dC}{\left(\frac{dt}{t}\right)} = \sum_i \frac{\partial C}{\partial y_i} y_i + \frac{\partial C}{\partial k} k + \sum_j \frac{\partial C}{\partial q_j} q_j \,, \tag{11}$$

so that, holding these components of default risk constant, the degree of multiproduct scale economies is given by:

$$\text{SCALE} \equiv \frac{C}{\frac{dC}{\left(\frac{dt}{t}\right)}} = \frac{C}{\sum_i \frac{\partial C}{\partial y_i} y_i + \frac{\partial C}{\partial k} k + \sum_j \frac{\partial C}{\partial q_j} q_j} = \frac{1}{\sum_i \frac{\partial \ln C}{\partial \ln y_i} + \frac{\partial \ln C}{\partial \ln k} + \sum_j \frac{\partial \ln C}{\partial \ln q_j}} \,, \tag{12}$$

where SCALE > 1 implies multiproduct economies of scale.

In addition to economies of scale, we are also interested in measuring economies of scope. Economies of scope exist between outputs when the cost of producing them together in a single firm is less than the cost of producing them separately in different firms. For five outputs (which we will use below), the conventional measure of global economies of scope evaluated at $y=(y_1,y_2,y_3,y_4,y_5)$ is $SC(y) \equiv [C(y_1,0,0,0,0) + C(0,y_2,0,0,0) + C(0,0,y_3,0,0) + C(0,0,0,y_4,0) + C(0,0,0,0,y_5) - C(y_1,y_2,y_3,y_4,y_5)] / C(y_1,y_2,y_3,y_4,y_5)$ (where we have suppressed all parameters except output). This represents the percentage increase in costs of dividing the outputs up into five completely specialized firms. SC > 0 implies economies of scope; SC < 0 implies diseconomies of scope. The conventional measure of scope economies specific to a subset T of N outputs at y is $SC_T(y) \equiv [C(y_T)+C(y_{N-T})-C(y)]/C(y)$, where y_T is the output vector with a zero component in place of y_i for all i not in T, and y_{N-T} is the output vector with a zero component in place of y_i for all i in T. Thus, $SC_T(y)$ measures the percentage increase in costs in dividing the N outputs into two firms, one that completely specializes in the outputs in T and one that completely specializes in the outputs in N–T. $SC_T > 0$ implies product-specific economies of scope; $SC_T < 0$ implies product-specific diseconomies of scope.

There are two problems inherent in estimating these scope measures. The first concerns the particular functional form chosen for the cost function. The second is a more general criticism of measuring economies of scope. We will address both problems by measuring *within-sample* global and product-specific economies of scope rather than the conventional measures.

To estimate the conventional measure of economies of scope, the cost function must be evaluated at zero output levels. A popular functional form often chosen for the cost function is the translog. But the translog function implies that cost is zero if any output level is zero. Thus, economies of scope cannot be measured. To get around this problem, many studies have chosen an arbitrarily small level of output to represent the zero output level in economies of scope measures. Some papers have checked for the robustness of their results by choosing a range of proxies for the zero level of output. A more salient criticism of the conventional measure of scope economies is that it requires the cost function to be evaluated at zero output levels even if all firms in the sample are producing positive levels of each output, as they are here. Thus, the measure involves potentially excessive extrapolation outside the sample. (See Mester (1991) and Mester (1992) for more discussion.)

Within-sample economies of scope remedies both the zero output level problem and the extrapolation problem. In the case of five outputs, the degree of within-sample global economies of scope evaluated at y is defined as $WSCOPE(y) \equiv [C(y_1-4y_1^m, y_2^m, y_3^m, y_4^m, y_5^m) + C(y_1^m, y_2-4y_2^m, y_3^m, y_4^m, y_5^m) + C(y_1^m, y_2^m, y_3-4y_3^m, y_4^m, y_5^m) + C(y_1^m, y_2^m, y_3^m, y_4-4y_4^m, y_5^m) + C(y_1^m, y_2^m, y_3^m, y_4^m, y_5-4y_5^m) - C(y_1, y_2, y_3, y_4, y_5)]/ C(y_1, y_2, y_3, y_4, y_5)$, where y_i^m is the minimum value of y_i in the sample. Note that we replace the zeroes in the conventional measure of scope economies by y_i^m, which is within the sample for each output i and so avoids the extrapolation problem.[5] Similarly, the degree of within-sample economies of scope specific to a subset T of N outputs at y is defined as $WSCOPE_T(y) = [C(\tilde{y}_T)+C(\tilde{y}_{N-T})-C(y)]/C(y)$, where $\tilde{y}_T$ is the output vector whose i^{th} component equals $y_i - y_i^m$ if $i \in T$, and equals y_i^m if $i \notin T$. Similarly, $\tilde{y}_{N-T}$ is the output vector whose i^{th} component equals y_i^m if $i \in T$ and equals $y_i - y_i^m$ if $i \notin T$. Below we will present the within-sample economies of scope measures rather than the conventional measures.[6]

4. Empirical Implementation

4.1. Functional Form. To estimate the structural model--equations (5), (6), and (7)--we must first specify a functional form for the cost function and uninsured deposit price function. We specify a translog cost function and log linear w_u function.[7] We also use Shephard's lemma to derive cost share equations.[8] The structural model is:

[5]We subtract *four* times y_i^m from y_i so that the sum of the output levels across the five relatively specialized firms equals y, the point at which we are evaluating scope economies. For n outputs, we would subtract (n−1) times y_i^m.

[6]One difficulty in interpreting even the within-sample measures of scope economies is that they are evaluated at a fixed level of capital, k. Hence, risk is not held constant across the specialized banks.

[7]Specifying a translog function for w_u involved too much multicollinearity, so we used the log-linear form.

[8]In the estimation, one of the share equations must be dropped, otherwise the error covariance matrix across equations would be singular, since the cost share equations sum to one. Since the maximum likelihood estimates we obtain are invariant to which cost share equation is dropped, we drop the uninsured deposits cost share equation and use the standard version of Shephard's lemma to derive the others.

$$\begin{aligned} ln\,c \; = \; & a_0 + \sum_i a_i ln\,y_i + \sum_j b_j ln\,w_j + \tfrac{1}{2}\sum_i \sum_j s_{ij} ln\,y_i\, ln\,y_j + \tfrac{1}{2}\sum_i \sum_j g_{ij} ln\,w_i\, ln\,w_j \\ & + \sum_i \sum_j d_{ij} \ln y_i\, ln\,w_j + f_k ln\,k + \sum_i f_i ln\,q_i + \tfrac{1}{2} r_{kk} ln\,k\, ln\,k + \sum_j r_{kj} ln\,k\, ln\,q_j \\ & + \tfrac{1}{2}\sum_i \sum_j r_{ij} ln\,q_i\, ln\,q_j + \sum_j h_{kj} ln\,k\, ln\,y_j + \sum_i \sum_j h_{ij} ln\,q_i\, ln\,y_j \\ & + \sum_j t_{kj} ln\,k\, ln\,w_j + \sum_i \sum_j t_{ij} ln\,q_i ln\,w_j + b_u ln\,w_u + \tfrac{1}{2} g_{uu} ln\,w_u\, ln\,w_u \\ & + \sum_j g_{uj} ln\,w_u\, ln\,w_j + \sum_i d_{iu} ln\,y_i ln\,w_u + t_{ku} ln\,k\, ln w_u + \sum_i t_{iu} ln\,q_i ln w_u \end{aligned} \qquad (13)$$

$$ln\,w_u \; = \; \alpha_0 + \sum_i \alpha_i ln\,y_i + \phi_k ln\,k + \sum_i \phi_i ln\,q_i + \sum_j \psi_j ln\,\theta_j \qquad (14)$$

$$S_j \; = \; b_j + \sum_i g_{ij} ln\,w_i + \sum_i d_{ij} ln\,y_i + t_{kj} ln\,k + \sum_i t_{ij} ln\,q_i + g_{uj} ln\,w_u \qquad (15)$$

where: $s_{ij} = s_{ji},\; g_{ij} = g_{ji},\; r_{ij} = r_{ji}$ by symmetry,

$b_u = 1 - \sum_j b_j,\;\; g_{iu} = -\sum_j g_{ij},\; \forall i,\;\; d_{iu} = -\sum_j d_{ij},\; \forall i,\;\; t_{iu} = -\sum_j t_{ij},\; \forall i,$

and $t_{ku} = -\sum_j t_{kj}$ by linear homogeneity,

c = total cost

y_i = quantity of output i

w_j = price of input j (other than uninsured deposits)

k = financial capital

q_i = quality measure i

θ_i = risk measure i

S_j = jth cost share, i.e., expenditures on input j divided by total cost.

All variables (except the shares) are normalized by their means, e.g., y_1 for any bank is that bank's level of output 1 divided by the mean of output 1 across all banks in the sample. (Note that the ω term drops out of equation (14) since w_u is normalized by its mean and ω is the same for all banks.[9]) We estimate the model including the cost shares of each input other than uninsured deposits. We allow the correlation of error terms on the cost function, share equations, and uninsured deposit price equation to be nonzero for any bank, but we assume the correlation is zero across banks. Since w_u is an endogenous variable that appears in the cost and share equations, we use iterative three-stage least squares to estimate the model. All the exogenous variables in the model are used as instruments. The estimates we obtain are asymptotically equivalent to maximum likelihood estimates.

4.2. Data and Variable Measurement. We used 1990 data from the Consolidated Reports of Condition and Income that banks must file each quarter. The 304 banks included in the sample are all the U.S. banks that operated in branch-banking states and that reported over $1 billion in assets as of 1988Q4, excluding the special-purpose Delaware banks chartered under that state's Financial Center Development Act and Consumer Credit Bank Act. We exclude banks in unit-banking states and the Delaware legislated banks to help control for the regulatory environment.

We include five outputs in the cost function: y_1 = commercial real estate loans, y_2 = commercial loans (C&I loans and loans for securities), y_3 = consumer loans, y_4 = other loans, and y_5 = securities, assets in trading accounts, fed funds sold, and total investment securities. Each y_i is measured as the average of its dollar amount at the end of 1990 and its dollar amount at the end of 1989. We include one measure of quality, q, measured as the average volume of

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[9]The $f(y,q,k,\theta)$ function of equation (6) solves $f(\cdot)/\bar{f}(\cdot) = \exp(\alpha_0 + \Sigma_i\alpha_i ln(y_i/\bar{y}_i) + \phi_k ln(k/\bar{k}) + \Sigma_i\phi_i ln(q_i/\bar{q}_i) + \Sigma_j\psi_j ln(\theta_j/\bar{\theta}_j))$, where a bar over a variable represents its mean.

nonperforming loans in 1990 (i.e., loans past due 30 days or more and loans not accruing interest). Note that q is inversely related to quality.[10,11]

Four inputs, in addition to uninsured deposits and financial capital, are considered: (1) labor, (2) physical capital, (3) insured deposits, and (4) other borrowed money. The corresponding input prices are: w_1 = salaries and benefits paid in 1990 ÷ average number of employees in 1990, w_2 = occupancy expense in 1990 ÷ average dollar value of net bank premises in 1990,[12] w_3 = (interest paid on small deposits [i.e., under $100,000] in 1990 – service charges on deposits paid to the bank in 1990) ÷ average volume of interest bearing deposits less CDs over $100,000 in 1990, w_4 = total expense of fed funds, repurchase agreements, obligations to the U.S. Treasury, and other borrowed money in 1990 ÷ average volume of these types of funds in 1990.

Financial capital, k, is measured as the average volume of equity capital, provision for loan losses, and subordinated debt in 1990. We proxy the unit price of uninsured deposits, w_u, as interest paid on CDs over $100,000 ÷ average volume of these deposits in 1990. We include one risk variable θ_1, which is the variability of net income, in the uninsured deposit price function w_u. We measure θ_1 as the standard deviation of yearly net income from 1986 through 1990. Finally, cost, c, is measured as salaries + benefits + occupancy expenses + [(interest paid

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[10]While it might be desirable to have a separate quality measure for each output, such data are unavailable. That nonperforming loans is an ex post measure of quality rather than an ex ante measure is not a problem, since the ex post quality is likely to be a better measure of the resources that went into monitoring the bank's loans. Also note that while the quantity of a bank's nonperforming loans will be influenced by the macroeconomy, its cross-sectional variation measures differences in quality across the banks.

[11]Another potential measure of quality would be provision for loan losses. However, our nonperforming loan measure is superior, since it is not set strategically by banks or at the regulator's directive, as loan loss reserves can be.

[12]This measure of the unit price of physical capital has been used in many other cost studies, including Mester (1991) and Hunter, Timme, and Yang (1990). As an alternative, the rental cost per square foot of office space at the bank headquarter's location could be used. However, it is not clear this would be a better proxy, since many of the banks in the sample have many branches at various locations. While in theory one could use the average rental cost over all markets in which the bank operates, data on branch location were not available.

on deposits (both insured and uninsured) – service charges on deposits paid to the bank + expense of fed funds, repurchase agreements, obligations to the U.S. Treasury, and other borrowed money) × ((total loans, securities, fed funds sold, assets in trading accounts, and total investment securities)/total earning assets)] in 1990.[13]

Table 1 summarizes the data and Table 2 provides the parameter estimates, their standard errors, and goodness-of-fit measures.

4.3. Treating Deposits as Inputs. There has been much debate in the literature about whether deposits should be treated as an input in the bank's production process or as an output. The rationale for treating deposits as an input is that they provide the necessary funding with which banks can make loans or purchase securities--the bank's earning assets (Sealey and Lindley, 1977). This is often called the intermediation approach. However, banks also might provide transactions services for depositors, which might give deposits some characteristics of an output.

Rather than prejudge the role of deposits, we formulated a test to determine how to treat deposits. We estimated a translog variable cost (VC) function in which labor, physical capital, and other borrowed money were treated as inputs, and uninsured deposits (u) and insured deposits (x_3) were entered as levels. Thus, variable cost, which is the cost of labor, physical capital, and other borrowed money, was a function of the unit price of labor, unit price of physical capital, unit price of other borrowed money, outputs, financial capital, quality, the amount of insured deposits, and the amount of uninsured deposits: $VC(y,q,k,w_1,w_2,w_4,x_3,u)$. Then we calculated $\frac{\partial VC}{\partial x_3}$ and $\frac{\partial VC}{\partial u}$. If insured and uninsured deposits are outputs, then these derivatives should be positive: output can be increased only if expenditures on inputs are increased. If insured and uninsured deposits are inputs, then

[13]As in Hunter, Timme, and Yang (1990) and Mester (1992), we weight the interest expense in costs by the ratio of loans-to-earning assets to reflect the interest expense that can be allocated to the bank's loan output.

these derivatives should be negative: increasing the use of some input should decrease the expenditures on other inputs.

Table 3 shows the values of these derivatives evaluated at the overall mean levels of the variables and also at the mean levels for banks in four size categories, which correspond to quartiles determined by total assets in 1990. The four categories are assets ≤ \$1.67 billion; \$1.67 billion < assets ≤ \$2.94 billion; \$2.94 billion < assets ≤ \$6.50 billion; and assets > \$6.50 billion. Since the derivatives are nonlinear functions of the parameters, their standard errors are approximated by expanding each as a Taylor series, dropping terms of order 2 or higher, and using the standard variance formula for linear functions of estimated parameters. As the table shows, there is strong evidence that deposits are *inputs*: all of the derivatives are negative and all but one are strongly significantly negative. Thus, we treat insured and uninsured deposits as inputs.[14]

5. Empirical Results

The statistics of interest include multiproduct economies of scale, within-sample multiproduct economies of scope, the derivative of w_u with respect to output, quality, and capital and the derivative of w_u with respect to a proportional increase in all of these. This latter provides a test of the impact of "too-big-to-fail." Since the cost function is not homothetic, these cost statistics will vary with the levels of outputs, input prices, financial capital, quality, and risk. All of the statistics reported in Tables 4, 5, and 6 are evaluated at the mean levels of the input prices, financial capital, quality, and risk. In the first column, we report the statistics evaluated at the mean levels of the outputs. This can be thought of as the typical bank in the sample. We also calculated the statistics at the mean levels of the outputs for banks in the four size categories that correspond to quartiles determined by total assets in

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[14]We also performed this test on each type of deposit, insured and uninsured, separately. The conclusions were the same.

1990.[15] Again, since these cost statistics are nonlinear functions of the parameters, standard errors are approximated by expanding each statistic as a Taylor series, dropping terms of order 2 or higher, and using the standard variance formula for linear functions of estimated parameters.

5.1. Economies of Scale. The degree of global economies of scale measures the percentage change in costs due to a proportionate increase in all outputs. Since we want to hold the quality and capital/asset ratio constant as we increase output, we calculate SCALE as given in equation (11) above. That is,

$$\begin{aligned} SCALE &= \frac{1}{\sum_i \frac{\partial \ln C}{\partial \ln y_i} + \frac{\partial \ln C}{\partial \ln k} + \sum_j \frac{\partial \ln C}{\partial \ln q_j}} \\ &= \frac{1}{\sum_i \left(\frac{\partial \ln c}{\partial \ln y_i} + \frac{\partial \ln c}{\partial \ln w_u}\frac{\partial \ln w_u}{\partial \ln y_i} \right) + \left(\frac{\partial \ln c}{\partial \ln k} + \frac{\partial \ln c}{\partial \ln w_u}\frac{\partial \ln w_u}{\partial \ln k} \right) + \sum_j \left(\frac{\partial \ln c}{\partial \ln q_j} + \frac{\partial \ln c}{\partial \ln w_u}\frac{\partial \ln w_u}{\partial \ln q_j} \right)} . \end{aligned} \tag{16}$$

It is important to note that when we compute SCALE, we take into account how a change in output level, financial capital, or output quality affects w_u, which in turn affects cost. As indicated in Table 4, there are constant returns to scale at the mean bank in the sample and also across the size categories. While the point estimates of SCALE suggest there are U-shaped average costs (since SCALE is greater than 1 at small firms and less than 1 at large firms), the average cost curve is basically flat, since SCALE is insignificantly different from 1 across size classes.

We wanted to compare these results with those obtained if we neglect to control for quality and financial capital, and/or we neglect to incorporate the effect of a change in y, q, or k on w_u. Thus, we calculated some "partial" scale economies measures:

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[15]Evaluating the cost statistics at the category means rather than at the sample means for variables other than output levels did not qualitatively change the results reported below.

$$\text{PARTSCALE}_1 = \frac{1}{\sum_i \left[\frac{\partial \ln c}{\partial \ln y_i}\right]} , \qquad (17)$$

$$\text{PARTSCALE}_2 = \frac{1}{\sum_i \left[\frac{\partial \ln c}{\partial \ln y_i} + \frac{\partial \ln c}{\partial \ln w_u} \frac{\partial \ln w_u}{\partial \ln y_i}\right]} , \qquad (18)$$

$$\text{PARTSCALE}_3 = \frac{1}{\sum_i \left[\frac{\partial \ln c}{\partial \ln y_i}\right] + \left[\frac{\partial \ln c}{\partial \ln k}\right] + \sum_j \left[\frac{\partial \ln c}{\partial \ln q_j}\right]} . \qquad (18)$$

PARTSCALE_1 is similar to the scale economies measure used in previous studies, in the sense that it does not take into account how the price of uninsured deposits w_u changes when output level, output quality, or financial capital changes, nor does it hold quality or the capital/asset ratio (i.e., default risk) constant when output level changes. (Of course, since we include financial capital and quality measures in our cost function while previous studies did not, our estimate of PARTSCALE_1 need not be the same as estimates of scale economies in previous studies.) PARTSCALE_2 takes into account how w_u changes when output level changes but does not hold quality and default risk constant. PARTSCALE_3 holds quality and default risk constant, but does not take into account changes in w_u.

Interestingly, we find that our results would have implied economies of scale at the mean bank had we used the conventional measure of scale economies--PARTSCALE_1 is significantly greater than 1 at the 5 percent level. This suggests that controlling for capital and quality, and taking into account the endogeneity of the price of uninsured deposits, have a significant effect on the results. In fact, it appears that keeping the capital/asset ratio and quality constant when expanding output has the more significant effect on the scale measures. To see this, notice that the two measures that hold the capital/asset ratio and quality constant when computing economies of scale, i.e., SCALE and PARTSCALE_3, both imply there are constant returns to scale at the mean bank in the sample. While the two measures that do not hold the capital/asset ratio and quality constant when computing economies of scale, i.e., $PARTSCALE_1$ and $PARTSCALE_2$, both imply there are increasing returns to scale at the mean bank.

5.2. "Too-Big-To-Fail." In order to investigate whether "too-big-to-fail" has a significant impact on the price of uninsured deposits, we calculated DERW, the derivative of w_u with respect to a proportionately scaled increase in output. These are given in Table 5 for the mean bank and across the different size categories. We also show in Table 6 the separate derivatives of w_u with respect to output levels, financial capital, and output quality, i.e., $\partial w_u/\partial y_i \ \forall i$, $\partial w_u/\partial k$, and $\partial w_u/\partial q$.

As can be seen in the table, the DERW is insignificantly positive at the banks in the two smallest size categories; DERW is insignificantly negative at the mean and in the third size category; and DERW is significantly negative (at the 10 percent level) at banks in the largest size category. That is, at the largest banks in the sample, an increase in the scale of operations, holding the capital/asset ratio and output quality constant, means a lower price for uninsured deposits. We take this to be evidence of "too-big-to-fail." It is not surprising that we would find DERW to be significantly negative only at the largest sized banks, since it is only for the largest banks where one would expect "too-big-to-fail" to be relevant.

The individual derivatives displayed in Table 5 are also interesting. Not surprisingly, at the mean and for banks in each size category, an increase in the bank's nonperforming loans (q) has a significantly positive impact on the price of uninsured deposits ($\partial w_u/\partial q > 0$). That is, banks with lower quality assets must pay a higher risk premium for uninsured deposits. Also, an increase in the bank's level of financial capital has a negative impact on the bank's price of uninsured deposits, and this is a significant effect for banks in the largest size category. This seems reasonable since higher capital, holding the level and quality of output constant, means lower default risk. Two other results are more difficult to interpret. We find that an increase in commercial real estate loans (y_1) has a significantly negative impact on the price of uninsured deposits ($\partial w_u/\partial y_1 < 0$), and an increase in commercial loans (y_2) has a significantly positive impact on the price of uninsured deposits ($\partial w_u/\partial y_2 > 0$) at the mean bank and across each size category. This suggests that banks that specialize in C&I lending as opposed to commercial real estate lending pay a higher risk premium on their uninsured deposits. Given the recent problems in the commercial real estate market, this seems surprising. It must be kept in mind, however, that these individual derivatives do not hold the capital/asset ratio or quality constant as output changes, so they are difficult to interpret.

5.3. Economies of Scope. Table 6 displays the within-sample measures of global and product-specific economies of scope evaluated at the mean and across the four size categories. The measure of global economies of scope is insignificantly positive for the mean bank and across the size categories.[16] This means that there is relatively little cost savings or dissavings from producing the five outputs in a multiproduct firm compared with producing the outputs in five separate, relatively specialized firms.[17]

The within-sample product-specific economies measures are interesting in that they reveal some evidence of diseconomies of scope at banks in the two largest size categories (and for the mean bank). For the largest banks, $WSCOPE_3$, $WSCOPE_5$, $WSCOPE_{12}$, and $WSCOPE_{35}$ are all significantly less than zero. For the next largest banks (and for the mean bank) $WSCOPE_5$ and $WSCOPE_{35}$ are significantly less than zero. None of the other measures is significantly different from zero; hence there is no evidence of economies of scope. Recall that $WSCOPE_T < 0$ means that there are cost savings from having some firms being relatively more

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[16]At the mean bank and for the four size categories at which we evaluate within-sample economies of scope WSCOPE(y), $y_i - 4y_i^m$ is within the sample and is greater than y_i^m for each output i, so that WSCOPE(y) is well defined. In our sample, the minimum levels of the outputs (in billions of dollars) are $(y_1^m, y_2^m, y_3^m, y_4^m, y_5^m)$ = (0.0002225, 0.020635, 0.001856, 0.000274, 0.0135495).

[17]We say "relatively specialized" rather than "specialized," since in the within-sample scope measures, all firms are producing at least the minimum amount of each output.

specialized in producing the outputs in T and having other firms being relatively more specialized in producing the outputs not in T, compared with having nonspecialized firms that produce all the outputs. One thing the measures indicate is some apparent cost savings of splitting off y_3 (consumer loans) from y_1 (commercial real estate loans) and y_2 (C&I loans). To see this, note that in each of the significant $WSCOPE_T$ measures except $WSCOPE_5$, y_3 is separated from y_1 and y_2. Rather than read too much into this, we believe the focus should be on the general result that there is evidence of significant diseconomies of scope at the larger firms.

That we find diseconomies at larger firms and not at smaller firms may be evidence of hierarchical diseconomies. Larger firms may not be as efficient as smaller firms because their management structure is more complicated--there are more layers of management (hierarchies) and if managers require monitoring to behave efficiently, there may be greater agency costs associated with denser hierarchical structures (see Mester (1991) and Williamson (1967)). The diseconomies of scope result suggests that large firms may not find the strategy of becoming a "financial supermarket" to be the best in terms of cost efficiency. Large banks pursuing such a strategy must derive sufficient revenue benefits for it to pay off. If customers prefer "one-stop shopping," then such revenue benefits may be forthcoming. However, if the revenue benefits are not sufficiently large, we may expect to see large banks become more specialized, e.g., by concentrating on the commercial side of business or the consumer (retail) side.

Previous studies that have measured output by the volume of different types of loans as we do here did not find evidence of economies or diseconomies of scope.[18] We feel our differences derive from our incorporating financial capital and output quality measures into the cost function and treating the price of uninsured deposits as an endogenous variable. Note, for example, that the minimum capital/asset ratio imposed by regulators is likely to be more

[18]While Mester (1992) finds diseconomies of scope between the traditional activities (i.e., loan origination and monitoring) and nontraditional activities (i.e., loan selling and buying) of banks, our results are not comparable, since we use vastly different output measures.

binding on larger firms. Hence these firms are more likely not to be operating with their preferred financial capital level. Since our approach allows for non-optimal capital levels while previous studies did not, it is not too surprising that our results would differ.

6. Conclusion

In this paper we have estimated a cost function model that incorporates measures for the quality of bank output and the probability of failure, which can influence a bank's costs in a variety of ways. We have also modeled a bank's price of uninsured deposits as an endogenous variable depending on the bank's output level, output quality, financial capital level, and risk measures. We found that incorporating these aspects into the cost function has a significant effect on measures of scale and scope economies when compared with results of previous studies that did not take quality and default risk into account. We find constant returns to scale at the mean-sized bank and at banks in four different size categories. We also find evidence of diseconomies of scope at the larger banks. Finally, there is evidence that the "too-big-to-fail" doctrine has a significant impact on the price a bank pays for its uninsured deposits. For banks in the largest size category, an increase in size, holding default risk and asset quality constant, significantly lowers the uninsured deposit price.

In further research we plan to extend the model to incorporate objectives other than cost minimization on the part of the bank. Utility maximization may be important, particularly at larger banks, given their more complicated management structure.

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Table 1 Means of the Variables

	All Banks (304 banks)	Banks with Assets under $1.67 Billion (76 banks)	Banks with Assets Between $1.67 and $2.94 Billion (76 banks)	Banks with Assets Between $2.94 and $6.50 Billion (76 banks)	Banks with Assets over $6.50 Billion (76 banks)
$y_1^{\dagger}$ commercial real estate loans	0.8064	0.2014	0.3345	0.7053	1.9845
$y_2^{\dagger}$ commercial loans	1.2341	0.2369	0.4132	0.8197	3.4665
$y_3^{\dagger}$ consumer loans	1.3279	0.3502	0.6205	1.1049	3.2362
$y_4^{\dagger}$ other loans	0.2816	0.0361	0.0615	0.1539	0.8749
$y_5^{\dagger}$ securities	1.1103	0.3035	0.5227	0.8744	2.7406
$w_1^{\dagger\dagger\dagger}$ labor	33.0731	29.5048	30.5613	32.7577	39.4684
$w_2^{\dagger}$ physical capital	0.4048	0.4090	0.3745	0.4084	0.4274
$w_3^{\dagger\dagger}$ insured deposits	0.0601	0.0604	0.0599	0.0596	0.0603
$w_4^{\dagger\dagger}$ other borrowed money	0.0895	0.0836	0.0807	0.0862	0.1073
$w_{\blacksquare}^{\dagger\dagger}$ uninsured deposits	0.0813	0.0803	0.0813	0.0836	0.0801
$k^{\dagger}$ financial capital	0.5816	0.1072	0.1789	0.3370	1.7033
$q^{\dagger}$ nonperforming loans	0.2676	0.0374	0.0762	0.1413	0.8155
$\theta_1^{\dagger}$ std. dev. of net income	0.04360	0.0054	0.0115	0.0200	0.1375
$c^{\dagger}$ cost	0.4495	0.0914	0.1565	0.3014	1.2486

†in billions of dollars ††in dollars per dollar †††in thousands of dollars per employee

Table 2 **Parameter Estimates and Goodness of Fit Measures**

Parameter	Estimate (Approx. Std. Error)	Parameter	Estimate (Approx. Std. Error)	Parameter	Estimate (Approx. Std. Error)
a_0	−0.03688 (0.4982)	g_{25}	0.01078 (0.007340)	r_{kk}	−0.09961* (0.01510)
a_1	−0.2285 (1.250)	g_{33}	0.3171* (0.02588)	r_{k1}	0.02950* (0.005291)
a_2	0.2906 (0.9467)	g_{34}	−0.01843 (0.01445)	r_{11}	0.006153** (0.003669)
a_3	0.3068 (0.6880)	g_{35}	−0.1381* (0.02376)	h_{k1}	−0.02637* (0.001984)
a_4	−0.04166 (0.4579)	g_{44}	0.05518* (0.01693)	h_{k2}	0.01483* (0.005255)
a_5	0.2294 (0.2023)	g_{45}	−0.02656** (0.01364)	h_{k3}	0.01975* (0.003264)
b_1	0.2285* (0.004162)	g_{55}	0.1460* (0.03576)	h_{k4}	0.01433* (0.001913)
b_2	0.08105* (0.001910)	d_{11}	0.0006982 (0.003912)	h_{k5}	−0.001410 (0.003077)
b_3	0.3771* (0.006540)	d_{12}	0.002695 (0.001828)	h_{11}	−0.0009988 (0.001442)
b_4	0.1815* (0.006903)	d_{13}	0.01047** (0.006287)	h_{12}	−0.01535* (0.002031)
b_5	0.1319* (0.005975)	d_{14}	−0.03692* (0.006712)	h_{13}	−0.007419* (0.001486)
s_{11}	−0.06705 (0.5107)	d_{15}	0.02305* (0.005643)	h_{14}	−0.001265 (0.0008578)
s_{12}	−0.4425 (1.051)	d_{21}	−0.02437* (0.006197)	h_{15}	−0.007517* (0.001081)
s_{13}	−0.02036 (0.3545)	d_{22}	−0.01508* (0.002883)	t_{k1}	0.02590* (0.01027)
s_{14}	−0.1636 (0.5686)	d_{23}	0.001699 (1.0000)	t_{k2}	0.01277* (0.004705)
s_{15}	0.1933 (0.6593)	d_{24}	0.02071 (0.01040)	t_{k3}	−0.1137* (0.01610)
s_{22}	0.5781 (1.548)	d_{25}	0.01704** (0.009148)	t_{k4}	0.08706* (0.01699)
s_{23}	0.2478 (0.6393)	d_{31}	0.01301* (0.004720)	t_{k5}	−0.01205 (0.01489)

Table 2 continued

Parameter	Estimate (Approx. Std. Error)	Parameter	Estimate (Approx. Std. Error)	Parameter	Estimate (Approx. Std. Error)
s_{24}	−0.008424* (0.001391)	d_{32}	0.0009159 (0.002110)	t_{11}	−0.01364* (0.005475)
s_{25}	−0.03437* (0.003107)	d_{33}	0.05315* (0.006963)	t_{12}	0.001281 (0.002554)
s_{33}	−0.00007874 (0.002882)	d_{34}	−0.03657* (0.007124)	t_{13}	0.01317 (0.008730)
s_{34}	0.01111* (0.0009535)	d_{35}	−0.03051* (0.006790)	t_{14}	−0.009022 (0.009253)
s_{35}	0.01654* (0.001527)	d_{41}	0.003512 (0.002730)	t_{15}	0.008205 (0.007857)
s_{44}	0.002865* (0.0006625)	d_{42}	0.0004708 (0.001274)	α_0	−0.01545 (0.01546)
s_{45}	0.02094* (0.001293)	d_{43}	−0.007592** (0.004423)	α_1	−0.04605* (0.01424)
s_{55}	−0.01644* (0.002348)	d_{44}	0.005844 (0.004668)	α_2	0.04464* (0.02232)
g_{11}	0.1075* (0.01436)	d_{45}	−0.002235 (0.003935)	α_3	0.008471 (0.01528)
g_{12}	0.01254* (0.004894)	d_{51}	0.001581 (0.004910)	α_4	−0.01318 (0.01001)
g_{13}	−0.1187* (0.01292)	d_{52}	0.001298 (0.002299)	α_5	0.004301 (0.01829)
g_{14}	−0.009244 (0.009199)	d_{53}	0.01183 (0.007919)	ϕ_k	−0.04985 (0.03612)
g_{15}	0.007890 (0.01814)	d_{54}	−0.004907 (0.008414)	ϕ_1	0.04057** (0.02374)
g_{22}	0.01950* (0.002666)	d_{55}	−0.009803 (0.007035)	ψ_1	0.04762 (0.01486)
g_{23}	−0.04187* (0.005805)	f_k	0.4694* (0.01447)		
g_{24}	−0.0009431 (0.004208)	f_1	−0.08331* (0.006889)		

*significant at 5% level **significant at 10% level

$\bar{R}^2$ on cost equation = 0.8315, $\bar{R}^2$ on labor share equation = 0.2902,
$\bar{R}^2$ on physical capital share equation = 0.1872, $\bar{R}^2$ on insured deposit share equation = 0.6577,
$\bar{R}^2$ on borrowed funds share equation = 0.4319, $\bar{R}^2$ on uninsured deposit price equation = 0.0538

Table 3 **Derivative of Variable Cost with Respect to Level of Insured Deposits (x_3) and with Respect to Level of Uninsured Deposits (u)†**

	All Banks (304 banks)	Banks with Assets under $1.67 Billion (76 banks)	Banks with Assets Between $1.67 and $2.94 Billion (76 banks)	Banks with Assets Between $2.94 and $6.50 Billion (76 banks)	Banks with Assets over $6.50 Billion (76 banks)
$\frac{\partial VC}{\partial x_3}$	−0.04000* (0.008709)	−0.04709* (0.006660)	−0.03906* (0.005519)	−0.03897* (0.006153)	−0.03412* (0.01424)
$\frac{\partial VC}{\partial u}$	−0.03388* (0.01462)	−0.06321* (0.01117)	−0.05989* (0.009724)	−0.05707* (0.01002)	−0.009108 (0.02420)

†Evaluated at mean output levels, input prices, financial capital level, and quality measure in each asset size category. Approximate standard errors in parentheses.

*significantly different from 0 at 5% level
**significantly different from 0 at 10% level

VC = variable costs with labor, physical capital, and other borrowed money as inputs
x_3 = level of insured deposits
u = level of uninsured deposits

$$\frac{\partial VC}{\partial x_3} = \frac{\partial ln\,VC}{\partial ln\,x_3}\frac{VC}{x_3} \qquad \frac{\partial VC}{\partial u} = \frac{\partial ln\,VC}{\partial ln\,u}\frac{VC}{u}$$

Table 4 Economies of Scale†

	All Banks (304 banks)	Banks with Assets under \$1.67 Billion (76 banks)	Banks with Assets Between \$1.67 and \$2.94 Billion (76 banks)	Banks with Assets Between \$2.94 and \$6.50 Billion (76 banks)	Banks with Assets over \$6.50 Billion (76 banks)
SCALE	1.0622* (0.1257)	1.2503 (1.9328)	1.1159 (0.6946)	1.1635* (0.3089)	0.9413 (0.9777)
PARTSCALE$_1$	1.7964*,# (0.3614)	2.4510 (7.4294)	1.9634 (2.1521)	2.0881* (0.9983)	1.4599 (2.3509)
PARTSCALE$_2$	1.7971*,# (0.3613)	2.4525 (7.4383)	1.9644 (2.1540)	2.0892* (0.9991)	1.4603 (2.3524)
PARTSCALE$_3$	1.0606* (0.1253)	1.2480 (1.9256)	1.1141 (0.6924)	1.1615* (0.3079)	0.9401 (0.9750)

†Cost statistics evaluated at mean input prices, financial capital level, quality measure, risk measure, and mean output levels in each category. Approximate standard errors in parentheses.

*significantly different from 0 at 5% level #significantly different from 1 at 5% level
**significantly different from 0 at 10% level ##significantly different from 1 at 10% level

$$\text{SCALE} = \frac{1}{\sum_i \left(\frac{\partial \ln c}{\partial \ln y_i} + \frac{\partial \ln c}{\partial \ln w_u} \frac{\partial \ln w_u}{\partial \ln y_i} \right) + \left(\frac{\partial \ln c}{\partial \ln k} + \frac{\partial \ln c}{\partial \ln w_u} \frac{\partial \ln w_u}{\partial \ln k} \right) + \sum_j \left(\frac{\partial \ln c}{\partial \ln q_j} + \frac{\partial \ln c}{\partial \ln w_u} \frac{\partial \ln w_u}{\partial \ln q_j} \right)}$$

$$\text{PARTSCALE}_1 = \frac{1}{\sum_i \left(\frac{\partial \ln c}{\partial \ln y_i} \right)}$$

$$\text{PARTSCALE}_2 = \frac{1}{\sum_i \left(\frac{\partial \ln c}{\partial \ln y_i} + \frac{\partial \ln c}{\partial \ln w_u} \frac{\partial \ln w_u}{\partial \ln y_i} \right)}$$

$$\text{PARTSCALE}_3 = \frac{1}{\sum_i \left(\frac{\partial \ln c}{\partial \ln y_i} \right) + \left(\frac{\partial \ln c}{\partial \ln k} \right) + \sum_j \left(\frac{\partial \ln c}{\partial \ln q_j} \right)}$$

Table 5 Derivatives of w_u†

	All Banks (304 banks)	Banks with Assets under $1.67 Billion (76 banks)	Banks with Assets Between $1.67 and $2.94 Billion (76 banks)	Banks with Assets Between $2.94 and $6.50 Billion (76 banks)	Banks with Assets over $6.50 Billion (76 banks)
DERW	-0.8885×10^{-3} (0.1633×10^{-2})	0.2152×10^{-2} (0.1645×10^{-2})	0.1041×10^{-2} (0.1642×10^{-2})	-0.5909×10^{-3} (0.1623×10^{-2})	$-0.2865\times10^{-2**}$ (0.1634×10^{-2})
$\frac{\partial w_u}{\partial y_1}$	$-0.4571\times10^{-8*}$ (0.1414×10^{-8})	$-0.1831\times10^{-7*}$ (0.5761×10^{-8})	$-0.1104\times10^{-7*}$ (0.3448×10^{-8})	$-0.5192\times10^{-8*}$ (0.1598×10^{-8})	$-0.1860\times10^{-8*}$ (0.5771×10^{-9})
$\frac{\partial w_u}{\partial y_2}$	$0.2896\times10^{-8*}$ (0.1442×10^{-8})	$0.1509\times10^{-7*}$ (0.7046×10^{-8})	$0.8667\times10^{-8*}$ (0.4141×10^{-8})	$0.4331\times10^{-8*}$ (0.2122×10^{-8})	$0.1032\times10^{-8*}$ (0.5361×10^{-9})
$\frac{\partial w_u}{\partial y_3}$	0.5107×10^{-9} (0.9220×10^{-9})	0.1937×10^{-8} (0.3448×10^{-8})	0.1095×10^{-8} (0.1960×10^{-8})	0.6097×10^{-9} (0.1098×10^{-8})	0.2098×10^{-9} (0.3824×10^{-9})
$\frac{\partial w_u}{\partial y_4}$	-0.3748×10^{-8} (0.2829×10^{-8})	-0.2925×10^{-7} (0.2251×10^{-7})	-0.1719×10^{-7} (0.1316×10^{-7})	-0.6814×10^{-8} (0.5170×10^{-8})	-0.1208×10^{-8} (0.9042×10^{-9})
$\frac{\partial w_u}{\partial y_5}$	0.3101×10^{-9} (0.1319×10^{-8})	0.1135×10^{-8} (0.4806×10^{-8})	0.6601×10^{-9} (0.2801×10^{-8})	0.3911×10^{-9} (0.1662×10^{-8})	0.1258×10^{-9} (0.5364×10^{-9})
$\frac{\partial w_u}{\partial k}$	-0.6862×10^{-8} (0.4980×10^{-8})	-0.1827×10^{-8} (0.4874×10^{-8})	-0.3676×10^{-8} (0.4876×10^{-8})	-0.6333×10^{-8} (0.4890×10^{-8})	$-0.1014\times10^{-7**}$ (0.5267×10^{-8})
$\frac{\partial w_u}{\partial q}$	$0.1214\times10^{-7**}$ (0.7122×10^{-8})	$0.1256\times10^{-7**}$ (0.7197×10^{-8})	$0.1243\times10^{-7**}$ (0.7167×10^{-8})	$0.1210\times10^{-7**}$ (0.7076×10^{-8})	$0.1188\times10^{-7**}$ (0.7148×10^{-8})
$\frac{\partial w_u}{\partial \theta_1}$	0.8744×10^{-8} (0.2732×10^{-7})	0.8748×10^{-8} (0.2733×10^{-7})	0.8762×10^{-8} (0.2737×10^{-7})	0.8686×10^{-8} (0.2714×10^{-7})	0.8754×10^{-8} (0.2735×10^{-7})

†Cost statistics evaluated at mean input prices, financial capital level, quality measure, risk measure, and mean output levels in each category. Approximate standard errors in parentheses.

*significantly different from 0 at 5% level
**significantly different from 0 at 10% level

y_1 = commercial real estate loans
y_2 = C&I loans
y_3 = consumer loans
y_4 = other loans
y_5 = securities
k = financial capital
q = nonperforming loans
θ_1 = standard deviation of net income 1986-1990

$$\text{DERW} = \frac{dw_u}{\left(\frac{dt}{t}\right)}(\zeta) = \sum_i \frac{\partial w_u}{\partial y_i}(\zeta)\, y_i + \frac{\partial w_u}{\partial k}(\zeta)\, k + \frac{\partial w_u}{\partial q}(\zeta)\, q$$

Table 6 Within-Sample Global and Product-Specific Economies of Scope†

	All Banks (304 banks)	Banks with Assets under $1.67 Billion (76 banks)	Banks with Assets Between $1.67 and $2.94 Billion (76 banks)	Banks with Assets Between $2.94 and $6.50 Billion (76 banks)	Banks with Assets over $6.50 Billion (76 banks)
WSCOPE	3609.5 (86928.5)	423.2 (8559.7)	971.6 (21350.3)	3183.7 (75895.3)	11499.3 (287950.3)
$WSCOPE_1$	3615.9 (87070.8)	426.1 (8622.4)	975.5 (21441.7)	3189.7 (76042.5)	11575.5 (288303.4)
$WSCOPE_2$	37.01 (351.2)	11.04 (86.29)	17.02 (143.8)	35.90 (346.2)	62.67 (610.7)
$WSCOPE_3$	−0.8671 (0.5942)	1.126 (10.15)	−0.07703 (1.922)	−0.7130 (0.7057)	−0.9863* (0.1671)
$WSCOPE_4$	0.5346 (6.627)	−0.4679 (0.5702)	−0.2994 (0.3022)	0.3042 (4.055)	3.419 (38.07)
$WSCOPE_5$	−0.6933* (0.2771)	0.01981 (2.413)	−0.2954 (1.035)	−0.6357* (0.1885)	−0.9019* (0.4111)
$WSCOPE_{12}$	−0.6940 (0.7518)	1.503 (13.40)	0.3333 (4.253)	−0.4366 (0.6752)	−0.9461* (0.4789)
$WSCOPE_{13}$	12.58 (155.4)	4.732 (44.54)	6.716 (70.48)	13.22 (160.3)	17.04 (232.5)
$WSCOPE_{14}$	997.7 (21067.5)	514.8 (11234.1)	769.91 (17126.1)	1125.4 (24292.5)	793.1 (14115.2)
$WSCOPE_{15}$	7366.5 (180996.6)	310.7 (5615.0)	944.7 (19431.4)	5522.8 (133355.1)	142279.9 (4136398.0)

Table 6 continued

	All Banks (304 banks)	Banks with Assets under $1.67 Billion (76 banks)	Banks with Assets Between $1.67 and $2.94 Billion (76 banks)	Banks with Assets Between $2.94 and $6.50 Billion (76 banks)	Banks with Assets over $6.50 Billion (76 banks)
$WSCOPE_{23}$	3750.5 (81941.4)	514.2 (10101.6)	1126.4 (23471.4)	3376.3 (74048.3)	10811.7 (233029.7)
$WSCOPE_{24}$	58.65 (1024.1)	4.541 (31.73)	9.957 (88.85)	40.46 (532.3)	763.8 (26604.0)
$WSCOPE_{25}$	5.314 (53.46)	8.273 (86.91)	7.735 (82.08)	6.982 (71.88)	1.448 (14.19)
$WSCOPE_{34}$	−0.6731 (0.5985)	0.4232 (4.554)	−0.1088 (1.638)	−0.4253 (0.6230)	−0.8816 (0.6151)
$WSCOPE_{35}$	−0.9342* (0.3473)	1.732 (19.01)	−0.08565 (3.144)	−0.8379** (0.4635)	−0.9974* (0.04205)
$WSCOPE_{45}$	−0.1547 (2.031)	−0.3024 (0.5476)	−0.2835 (0.8824)	−0.2038 (1.631)	0.02642 (4.000)

†Cost statistics evaluated at mean input prices, financial capital level, quality measure, risk measure, and mean output levels in each category. Approximate standard errors in parentheses.

*significantly different from 0 at 5% level
**significantly different from 0 at 10% level

y_1 = commercial real estate loans
y_2 = C&I loans
y_3 = consumer loans
y_4 = other loans
y_5 = securities

$$WSCOPE = [C(y_1-4y_1^m,y_2^m,y_3^m,y_4^m,y_5^m) + C(y_1^m,y_2-4y_2^m,y_3^m,y_4^m,y_5^m) + C(y_1^m,y_2^m,y_3-4y_3^m,y_4^m,y_5^m) + C(y_1^m,y_2^m,y_3^m,y_4-4y_4^m,y_5^m) + C(y_1^m,y_2^m,y_3^m,y_4^m,y_5-4y_5^m) - C(y_1,y_2,y_3,y_4,y_5)] \;/\; C(y_1,y_2,y_3,y_4,y_5)$$

where y_i^m is the minimum value of y_i in the sample.

$$WSCOPE_T = [C(\tilde{y}_T) + C(\tilde{y}_{N-T}) - C(y)] \;/\; C(y)$$

where $\tilde{y}_T$ = output vector with i^{th} component $y_i - y_i^m$ if $i \in T$, and y_i^m if $i \notin T$, and $\tilde{y}_{N-T}$ is the output vector with i^{th} component y_i^m if $i \in T$ and $y_i - y_i^m$ if $i \notin T$