WORKING PAPER NO. 96-9/R

EFFICIENT BANKING UNDER INTERSTATE BRANCHING

Joseph P. Hughes
Rutgers University

William Lang
Office of the Comptroller of the Currency

Loretta J. Mester
Federal Reserve Bank of Philadelphia
and
The Wharton School, University of Pennsylvania

Choon-Geol Moon
Hanyang University

Revised May 1996
Original Draft November 1995

We thank our discussant Curt Hunter, the editors, and other participants at the Conference on Payment Systems Research and Public Policy: Risk, Efficiency, and Innovation, Board of Governors of the Federal Reserve System and *Journal of Money, Credit, and Banking*, December 1995.

EFFICIENT BANKING UNDER INTERSTATE BRANCHING

Abstract

Nationally chartered banks will be allowed to branch across state lines beginning June 1, 1997. Whether they will depends on their assessment of the profitability of such a delivery system for their services and on their preferences regarding risk and return. We investigate the probable effect of interstate branching on banks' risk-return tradeoff, accounting for the endogeneity of deposit volatility. If interstate branching improves the risk-return tradeoff banks face, then banks that branch across state lines may choose a higher level of risk in return for higher profits. We find efficiency gains due to geographic diversity.

EFFICIENT BANKING UNDER INTERSTATE BRANCHING

The Interstate Banking Efficiency Act of 1994 allows nationally chartered banks to branch across state lines beginning June 1, 1997. Whether banks take advantage of this new ability to branch will depend on their assessment of the profitability of such a delivery system for their services. It will also depend on their preferences regarding risk and return. Interstate branching can lead to a reduction in the price of controlling liquidity risk because it allows the bank to more fully geographically diversify its deposit gathering. Similarly, geographical diversity may also lower the volatility of returns on a bank's loan portfolio. If these diversification effects exist, then geographic diversification improves the bank's risk-return opportunity set. This effectively lowers the cost, in terms of risk, of engaging in activities that generate higher profits. These profitable activities are likely to include the substitution of loans for securities in the bank's portfolio.

Hence, on balance, it is not clear what the impact of geographic diversification will be on the riskiness (i.e., volatility of returns) of the bank. Interestingly, previous studies that have looked at bank risk have not found that it is lower for banks that are more fully geographically diversified. This seems perplexing until one accounts for the fact that risk is endogenous—the bank chooses its level of risk. Depending on the bank's risk preferences, interstate branching might lead to a higher level of risk-taking by banks, since it improves the risk-return tradeoff (i.e., lowers the price of risk), but also to a higher level of profitability.

1. GEOGRAPHIC DIVERSIFICATION AND BANK EFFICIENCY

A. Geographic Diversification and the Price of Risk

Deposit volatility contributes to liquidity risk and increases the cost of risk management. Liquid assets are the first line of defense against liquidity risk. Hence, a higher degree of liquidity risk requires that a higher proportion of assets be held in securities. The cost of managing this risk includes the interest differential between loans and securities that is sacrificed when the loan-to-asset ratio must be reduced to accommodate a higher degree of liquidity risk. In principle, liquidity risk can be reduced when the deposit base is diversified. Greater diversification can be achieved by increasing the number of deposit accounts, given the branching network, and by increasing the number of branches, given the number of deposit accounts, or by distributing operations across geographically diverse markets.

Unit banks can be especially vulnerable to liquidity risk, since both their deposit and lending bases likely depend on the local economy. Branching reduces this dependency and diversifies these various risks. If intrastate branching is good, then interstate branching should be better. The more extensive the branching network, the lower the relative deposit volatility and, hence, the lower the liquidity risk. In turn, the reduced liquidity risk permits a higher loan-to-asset ratio and, hence, higher profit and greater efficiency (measured in terms of return per unit of risk). Similarly, an increase in the number and geographic diversity of loans can be expected to reduce the loan portfolio's credit risk.

So does geographic diversification imply an increase in profit and a reduction in liquidity risk (as measured by deposit volatility) and credit risk (as measured by return volatility)? Not necessarily. Geographic diversification may lead to an increased proportion of loans to assets, which will tend to increase credit risk, since credit-risky loans are being substituted for risk-free securities. This increased credit risk raises the interesting possibility that risk, measured by the relative volatility of earnings, might increase with geographic diversification. Geographic diversification, in effect, increases the gain in return that is expected when additional risk is assumed, i.e., it increases the marginal compensation for risk or, equivalently, it reduces the price of risk. So if banks that are more geographically diversified are riskier, one cannot conclude that there is no diversification effect. Instead, these banks may be responding to the reduced price of risk by assuming more risk in exchange for a higher return.

B. Endogenous Deposit Volatility

There is an important connection between the loan portfolio and transactions deposits. Transactions deposits give banks an informational advantage over other types of lenders because they provide information that is useful in credit analysis and in loan monitoring. The composition and quality of the loan portfolio can be expected to be related to the composition of the transactions deposits and to their relative volatility. Hence, just as the credit risk of the loan portfolio may respond to the reduced price of risk, the volatility of transactions deposits may also be endogenous. Therefore, geographic diversification may increase not only risk, but also the volatility of deposits. Holding these endogenous factors constant, geographic diversification can be expected to reduce deposit volatility and the price of risk; however, when banks respond to the more favorable tradeoff, they may increase not only return, but also risk and deposit volatility.

C. Interstate Banking Efficiency

If, a priori, the effect of geographic diversification on risk and deposit volatility cannot be predicted, then at least it should be true that geographic diversification unambiguously improves banking return and efficiency. This assertion has taken on added significance since the passage of the Interstate Banking Efficiency Act of 1994. Industry participants argue that the ability to branch across state lines promises important gains in banking efficiency. The already existing interstate banking structure provides casual evidence that this is true. While the new law makes it permissible to branch across state boundaries, for a long time banking organizations have been able to cross state lines via a bank holding company (BHC) structure in which banks in different states operate as separate subsidiaries of the parent BHC. The holding company structure is a costly means of crossing state boundaries. Its popularity suggests that it may be worth the cost.

A number of studies have examined these BHCs and have found little evidence to date that interstate expansion improves profitability or reduces risk (see Rose (1995)). In fact, risk is often found to increase with geographic diversity. Using stock market returns and the event study methodology, Chong (1991) found evidence that interstate expansion increases bank profitability and risk. He concludes that, although geographic diversification reduces the risk of a given set of activities, it also gives banks greater opportunities to take risk. Demsetz and Strahan (1995) also examine stock market data and find that better diversification does not necessarily lead to reductions in overall risk. However, when they control for portfolio composition and bank activities, risk is reduced by size-related diversification. Controlling for portfolio composition, McAllister and McManus (1993) find that risk declines as asset size increases. Preliminary findings of Akhavein, Berger, and Humphrey (forthcoming) show that mergers of large banks lead to significant increases in profit efficiency that appear to result in part from increases in the loan-to-asset ratio and increases in leverage. The authors note that the larger asset size and greater geographic coverage generated by these mergers improve diversification and permit the merged banks to increase their loan-to-asset ratios and leverage without adding to total risk.

The expectation that greater size and geographic dispersion necessarily leads to reduced risk implicitly relies on the assumption that risk is exogenous, i.e., that there is no endogenous response of risk to the diversification effect. Hence, when risk is found to increase with geographic diversity, it is tempting to conclude that there is no diversification effect. However, as Chong and Akhavein, Berger, and Humphrey suggest, there may indeed be benefits to diversification that are simply masked by not accounting for the potential endogeneity of risk. The benefits of geographic expansion are better measured by its effect on efficiency.

D. Measuring Bank Efficiency When Managers Trade Return for Risk

Efficiency is commonly measured by each bank's deviation from a best-practice frontier defined in terms of a profit function or cost function. The difficulty with this approach is that it assumes managers are risk neutral. They maximize profit or, equivalently, minimize cost without regard to risk. If, for example, risk-averse bank managers devote extra labor to credit analysis and loan monitoring to reduce credit risk, they will be trading profit for reduced risk. This tradeoff, however efficiently done, will be counted as inefficiency in the usual approach.

If risk can be defined, then one might model managers who maximize profit given the level of risk. However, this is an unsatisfactory solution to the problem of incorporating risk preferences when measuring efficiency, since the approach is not fully consistent with the theory of the non-risk-neutral firm, whose comparative statics differ from those of the profit-maximizing firm. For example, a fully consistent approach should allow for profit tax rates to impact the production decisions of the non-risk-neutral firm. Hughes, Lang, Mester, and Moon (1995) develop a structural model of production that allows managers to trade profit for other managerial objectives, in particular, reduced risk. Hughes and Moon (1995) use this model to solve the problem of how to account for the risk-return tradeoff in efficiency measurement. Using the estimated model parameters, they derive a predicted rate of return on equity (ROE) and a measure of risk, the standard error of the prediction, and estimate a stochastic, best-practice, risk-return frontier for a sample of banks. They measure efficiency relative to this frontier. Hence, their framework can distinguish additional expenditures that efficiently reduce risk from those that simply reduce profit with no apparent benefit. There are several important features of this approach. It links a structural model of production to an efficient risk-return frontier. The measured return is expected return, not realized return, and risk is measured relative to expected, not realized, return. The model is sufficiently general to subsume nonneutrality toward risk as well as risk-neutrality. Finally, because the structural model does not sacrifice duality to accommodate nonneutrality, it can also be used to measure important relationships in production, such as economies of scale and input demand elasticities.

E. Investigating the Efficiency of Interstate Banking

Using the models of Hughes, Lang, Mester, and Moon (1995) and Hughes and Moon (1995), this paper looks for evidence of efficiency gains in interstate banking from a sample of 443 U.S. BHCs operating in 1994. We compute the expected ROE and risk for each of these banks from the structural model of production and estimate a stochastic risk-return frontier. Each BHC's efficiency is measured relative to this frontier. We focus on the role of geographic expansion in diversifying the transactions deposit base and look for evidence of an improved price of risk and gain in return and efficiency. We also examine the structural model for evidence of scale economies that would motivate geographic expansion. We find relatively large economies of scale that increase with size and with geographic expansion. These scale effects have eluded the standard models based on risk neutrality, but are consistent with studies of commercial banks that allow for nonneutrality (e.g., Hughes and Mester (1995) and Hughes, Lang, Mester, and Moon (1995)). In addition, we find evidence that more geographically diversified efficient BHCs have lower deposit volatility, higher return, and higher risk, and BHCs with more extensive branch networks have higher efficiency.

2. A BANKING ORGANIZATION PRODUCTION MODEL THAT INCORPORATES MANAGERIAL PREFERENCES[1]

If bank managers trade profit for other objectives, then their utility function will include arguments in addition to profit. If they seek to reduce risk, these arguments will constitute aspects of this risk. It is tempting to add measures of risk to the utility function; however, it is difficult to find good measures of many types of risk, and it is also difficult to decide which of the many types of risk should be included. Instead, we include the production plan and contractual asset returns so that managers will simply rank production plans and profit according to their risk preferences and their expectations about the probability distribution of profit, conditional on the production plan. Hughes and Moon (1995) show that this specification of the utility function is consistent with expected utility and, under certain conditions, utility defined over expected profit and risk.

Following the model of Hughes, Lang, Mester, and Moon (1995), the utility function is represented by $U(\pi,\mathbf{s})$, where π is real, after-tax accounting profit; $\mathbf{s}=(\mathbf{y},\mathbf{x},\mathbf{p},r,n,k)$ where $\mathbf{y}$ is the vector of outputs; $\mathbf{x}$, the vector of inputs; $\mathbf{p}$, the vector of output prices; r, the risk-free rate of return; n, the level of nonperforming loans; and k, the level of financial capital. Let $\mathbf{w}$ be the input price vector; w_k, the price of financial capital (rate of return on equity); and m, income from sources other than those accounted for by output. Letting t be the tax rate on profit and $\tilde{p}_\pi$ (=1) be the nominal "price" of a real dollar, the price of a dollar of real after-tax profit in terms of nominal, before-tax dollars is $p_\pi = \frac{\tilde{p}_\pi}{(1-t)}$.[2] Nominal before-tax accounting profit is, thus, defined as

$$p_\pi \pi = \boldsymbol{p} \cdot \boldsymbol{y} + m - \boldsymbol{w} \cdot \boldsymbol{x}. \tag{1}$$

Nominal accounting profit is composed of before-tax economic profit, $p_\pi\hat{\pi}$, and the required payment to equity, $w_k k$, which will depend on the riskiness of the BHC. Hence, let $w_k = r\cdot g(\mathbf{s})$, where, as noted above, r is the risk-free rate of return and $g(\mathbf{s}) \geq 1$ is a risk premium, assumed to be homogeneous of degree zero in $(\mathbf{p},r)$. Thus, a proportional variation in the risk-free rate r and the asset returns $\mathbf{p}$ results in an equiproportional variation in w_k. The other arguments that affect the premium are discussed below. Thus,

$$p_\pi \pi = p_\pi \left[\frac{w_k k}{\tilde{p}_\pi} + \hat{\pi} \right]$$

$$= p_\pi \left[\frac{r \cdot g(\boldsymbol{s}) \cdot k}{\tilde{p}_\pi} + \hat{\pi} \right]. \tag{2}$$

The nominal, before-tax return on equity is then $\frac{p_\pi \pi}{k} = \frac{p_\pi r \cdot g(\boldsymbol{s})}{\tilde{p}_\pi} + \frac{p_\pi \hat{\pi}}{k}$, which consists of the required return and the economic rent.

The bank's technology is characterized by the transformation function T(**y**,**x**,n,k) = 0. Financial capital is included, since it is a source of loanable funds.[3] The level of nonperforming loans, n, influences the mix of inputs through, for example, the labor required to respond to nonperformance. It may also indicate the labor intensity of credit analysis and loan monitoring.

Managers may decide to produce the output vector, **y**, with the least costly input vector or with a more costly but less risky input vector. Their *most preferred (MP) production plan* is derived from the solution to the managers' problem

$$\max_{\pi,\boldsymbol{x}} \quad U(\pi,\boldsymbol{x};\boldsymbol{y},\boldsymbol{p},r,n,k) \tag{3}$$

$$s.t. \quad \boldsymbol{p} \cdot \boldsymbol{y} + m - \boldsymbol{w} \cdot \boldsymbol{x} - p_\pi \pi = 0 \tag{4}$$

$$T(\boldsymbol{x};\boldsymbol{y},n,k) = 0 . \tag{5}$$

Note that the MP production plan will differ from the standard minimum cost plan if bank managers have objectives other than profit maximization.

Letting the price vector be represented by **v**=(**w**,**p**,r,p_π), the optimal production plan is defined by the solution **x**(**y**,n,**v**,m,k) and π(**y**,n,**v**,m,k).[4] The profit equation reflects the optimal tradeoff of profit for other objectives and will yield the MP cost function and its characterization in terms of scale economies.

The expansion path defining the solution to (3), which deviates from the standard one, is given by

$$\frac{\frac{\partial T}{\partial x_i}}{\frac{\partial T}{\partial x_j}} = \frac{\lambda w_i - \frac{\partial U}{\partial x_i}}{\lambda w_j - \frac{\partial U}{\partial x_j}} , \tag{6}$$

i.e., the marginal rate of technical substitution equals the ratio of shadow prices. The shadow price is the market price adjusted by the marginal utility of the input (λ is the Lagrangian multiplier associated with the constraint (4)). Hence, in the case of a risk-averse manager, if the marginal utility of a risky input is negative, its shadow price will be increased by the element of risk.

The *most preferred (MP) cost function* is defined by

$$\hat{C}(\boldsymbol{y},n,\boldsymbol{v},m,k) \;\equiv\; \boldsymbol{w}\cdot\boldsymbol{x}(\boldsymbol{y},n,\boldsymbol{v},m,k) \;\equiv\; \boldsymbol{p}\cdot\boldsymbol{y} \;+\; m \;-\; p_{\pi}\pi(\boldsymbol{y},n,\boldsymbol{v},m,k)\,. \tag{7}$$

Notice that this cost function is embedded in the utility-maximizing demand for profit and will be used to derive our measures of scale economies. Also notice that when the manager has objectives that are more general than profit maximization, revenue influences cost. Not only will output-based revenue, **p·y**, affect the optimum, so will fixed revenue, m (and fixed cost). Additionally, the tax rate the bank pays on its profit will, in general, influence the optimum. Of course, in the special case of a risk-neutral manager, where only profit has marginal significance in the utility function, revenue and tax rates will not influence cost. Finally, notice that input mixes on the interior of the input requirement sets (isoquants) can be utility-maximizing.[5]

3. THE EMPIRICAL MODEL BASED ON THE ALMOST IDEAL DEMAND SYSTEM

Since a large part of the literature on bank production is based on the standard translog cost function, we wanted to base our model on a functional form that would yield the standard translog model in the special case of risk neutral (i.e., profit-maximizing) bank managers. Therefore, we derive the functional forms for the utility-maximizing input demands and profit revenue share equation from the Almost Ideal (AI) Demand System.

The expenditure function describes the amount of expenditure required to achieve a given level of utility U^0. The managerial expenditure function is defined by the following problem:

$$\min_{\pi,\boldsymbol{x}} \quad \boldsymbol{w}\cdot\boldsymbol{x} \;+\; p_{\pi}\pi \tag{8}$$

$$s.t. \quad U^0 \;-\; U(\pi,\boldsymbol{y},\boldsymbol{x},\boldsymbol{p},r,n,k) \;=\; 0 \tag{9}$$

$$T(\boldsymbol{x};\boldsymbol{y},n,k) \;=\; 0\,. \tag{10}$$

whose solution yields the constant-utility demand functions $\mathbf{x}^u(\mathbf{y},n,\mathbf{v},k,U^0)$ and $\pi^u(\mathbf{y},n,\mathbf{v},k,U^0)$. Substituting these demand functions into (8), the expenditure function $E(\mathbf{y},n,\mathbf{v},k,U^0)$ is obtained. The expenditure-minimization problem (8) is dual to the utility-maximization problem (3) so that $E(\mathbf{y},n,\mathbf{v},k,U^0) = \mathbf{p}\cdot\mathbf{y} + m$. Additionally, the demand functions obtained from (3) and (8) are identically equal when the indirect utility function, $V(\mathbf{y},n,\mathbf{v},m,k)$, derived by inverting the expenditure function, is substituted for the utility index in the expenditure-minimizing demands:

$$x^{u}(\boldsymbol{y},n,\boldsymbol{v},k,V(\boldsymbol{y},n,\boldsymbol{v},m,k)) \ \equiv \ \boldsymbol{x}(\boldsymbol{y},n,\boldsymbol{v},m,k), \tag{11}$$

$$\pi^{u}(\boldsymbol{y},n,\boldsymbol{v},k,V(\boldsymbol{y},n,\boldsymbol{v},m,k)) \ \equiv \ \boldsymbol{\pi}(\boldsymbol{y},n,\boldsymbol{v},m,k). \tag{12}$$

A. The Input and Profit Revenue-Share Equations

In the estimation presented below, to save on degrees of freedom, instead of including the prices of each output as separate variables, we will use the weighted-average price of the outputs, $\tilde{p} = \sum_i p_i \left[\frac{y_i}{\sum_j y_j}\right]$. So from here on we will use p̃ in the equations where appropriate. It should also be noted that since the risk-free rate, r, is the same for all BHCs, it is not included when estimating the equations. However, when we impose the homogeneity conditions on the model, they allow us to recover the parameter estimates on variables involving r; therefore, we will present the estimating equations including r variables. Thus, the expenditure function of the AI Demand System is given by,

$$\ln E(\cdot) \ = \ \ln P \ + \ U\cdot\beta_0\left(\prod_i y_i^{\beta_i}\right)\left(\prod_j w_j^{\nu_j}\right) p_\pi^{\mu} k^{\kappa}, \tag{13}$$

where

$$\begin{aligned}
\ln P \ = \ & \alpha_0 \ + \ \alpha_p \ln\tilde{p} \ + \ \sum_i \delta_i \ln y_i \ + \ \sum_i \omega_j \ln w_j \\
& + \ \eta_\pi \ln p_\pi \ + \ \tau \ln r \ + \ \vartheta \ln n \ + \ \rho \ln k \ + \ \tfrac{1}{2}\alpha_{pp}(\ln\tilde{p})^2 \ + \ \tfrac{1}{2}\sum_i\sum_j \delta_{ij}\ln y_i \ln y_j \\
& + \ \tfrac{1}{2}\sum_s\sum_t \omega_{ij}^{*}\ln w_s \ln w_t \ + \ \tfrac{1}{2}\eta_{\pi\pi}(\ln p_\pi)^2 \\
& + \ \tfrac{1}{2}\tau_{rr}(\ln r)^2 \ + \ \tfrac{1}{2}\vartheta_{nn}(\ln n)^2 \ + \ \tfrac{1}{2}\rho_{kk}(\ln k)^2 \\
& + \ \sum_j \theta_{pj}\ln\tilde{p}\ln y_j \ + \ \sum_s \varphi_{ps}\ln\tilde{p}\ln w_s \ + \ \psi_{p\pi}\ln\tilde{p}\ln p_\pi \\
& + \ \psi_{pr}\ln\tilde{p}\ln r \ + \ \psi_{pn}\ln\tilde{p}\ln n \ + \ \psi_{pk}\ln\tilde{p}\ln k
\end{aligned}$$

$$
\begin{aligned}
&+ \sum_j \sum_s \gamma_{js} \ln y_j \ln w_s + \sum_j \gamma_{j\pi} \ln y_j \ln p_\pi + \sum_j \gamma_{jr} \ln y_j \ln r \\
&+ \sum_j \gamma_{jn} \ln y_j \ln n + \sum_j \gamma_{jk} \ln y_j \ln k \\
&+ \tfrac{1}{2} \sum_s \omega^*_{s\pi} \ln w_s \ln p_\pi + \tfrac{1}{2} \sum_s \omega^*_{\pi s} \ln p_\pi \ln w_s \\
&+ \sum_s \omega_{sr} \ln w_s \ln r + \sum_s \omega_{sn} \ln w_s \ln n + \sum_s \omega_{sk} \ln w_s \ln k \\
&+ \eta_{\pi r} \ln p_\pi \ln r + \eta_{\pi n} \ln p_\pi \ln n + \eta_{\pi k} \ln p_\pi \ln k \\
&+ \tau_{rn} \ln r \ln n + \tau_{rk} \ln r \ln k + \vartheta_{nk} \ln n \ln k .
\end{aligned}
\tag{14}
$$

Hence, from (13) the indirect utility function is

$$
V(\cdot) = \frac{\ln(\boldsymbol{p} \cdot \boldsymbol{y} + m) - \ln P}{\beta_0 \left(\prod_i y_i^{\beta_i} \right) \left(\prod_j w_i^{\nu_j} \right) p_\pi^{\mu} k^{\kappa}} . \tag{15}
$$

Applying Shephard's lemma to (13) to obtain the constant-utility input demand equations and profit share equation and then substituting the indirect utility function (15) into these equations yields the utility-maximizing choice functions:

$$
\begin{aligned}
\frac{\partial \ln E}{\partial \ln w_i} &= \frac{w_i x_i}{\boldsymbol{p} \cdot \boldsymbol{y} + m} = \frac{\partial \ln P}{\partial \ln w_i} + \nu_i [\ln(\boldsymbol{p} \cdot \boldsymbol{y} + m) - \ln P] \\
&= \omega_i + \sum_s \omega_{si} \ln w_s + \varphi_{pi} \ln \tilde{p} + \sum_j \gamma_{ji} \ln y_j + \omega_{\pi i} \ln p_\pi \\
&\quad + \omega_{ir} \ln r + \omega_{in} \ln n + \omega_{ik} \ln k \\
&\quad + \nu_i [\ln(\boldsymbol{p} \cdot \boldsymbol{y} + m) - \ln P]
\end{aligned}
\tag{16}
$$

$$
\begin{aligned}
\frac{\partial \ln E}{\partial \ln p_\pi} &= \frac{p_\pi \pi}{\boldsymbol{p} \cdot \boldsymbol{y} + m} = \frac{\partial \ln P}{\partial \ln p_\pi} + \mu [\ln(\boldsymbol{p} \cdot \boldsymbol{y} + m) - \ln P] \\
&= \eta_\pi + \eta_{\pi\pi} \ln p_\pi + \psi_{p\pi} \ln \tilde{p} + \sum_j \gamma_{j\pi} \ln y_j + \sum_s \omega_{s\pi} \ln w_s \\
&\quad + \eta_{\pi r} \ln r + \eta_{\pi n} \ln n + \eta_{\pi k} \ln k \\
&\quad + \mu [\ln(\boldsymbol{p} \cdot \boldsymbol{y} + m) - \ln P]
\end{aligned}
\tag{17}
$$

where $\omega_{si} = \tfrac{1}{2}(\omega^*_{si} + \omega^*_{is}) = \omega_{is}$ and $\omega_{s\pi} = \tfrac{1}{2}(\omega^*_{s\pi} + \omega^*_{\pi s}) = \omega_{\pi s}$.

B. The Demand for Financial Capital

In addition to the input share equations (16) and the profit share equation (17), the model we estimate also includes the demand for financial capital. The utility-maximizing demands for inputs and profit derived from (3) are conditioned on the level of financial capital, k. It is straightforward to add a second stage to the maximization problem to determine the bank's choice of capital. Writing the Lagrangian function for (3) and evaluating it at the first-stage optimum, conditional on k, yields the conditional indirect utility function

$$\begin{aligned} V(\boldsymbol{y},n,\boldsymbol{v},m,k) \;\equiv\; & U(\pi(\cdot),\boldsymbol{x}(\cdot);\boldsymbol{y},\boldsymbol{p},r,n,k) \\ & + \lambda(\cdot)[\boldsymbol{p}\cdot\boldsymbol{y} + m - \boldsymbol{w}\cdot\boldsymbol{x}(\cdot) - p_\pi\pi(\cdot)] \\ & + \gamma(\cdot)[T(\cdot);\boldsymbol{y},n,k] \,. \end{aligned} \tag{18}$$

The demand for financial capital follows from maximizing (18) with respect to k. Using the definition from (2) that $p_\pi\pi = p_\pi\left[\frac{r\cdot g(s)\cdot k}{\tilde{p}_\pi} + \hat{\pi}\right]$ and differentiating (18) with respect to k yields the first-order condition

$$\frac{\partial V(\cdot)}{\partial k} = \frac{\partial U(\cdot)}{\partial k} - \lambda(\cdot)\,\frac{p_\pi\left[r\cdot g(\boldsymbol{s}) + rk\frac{\partial g(\boldsymbol{s})}{\partial k}\right]}{\tilde{p}_\pi} + \gamma(\cdot)\frac{\partial T(\cdot)}{\partial k} = 0\,, \tag{19}$$

whose solution is the demand for financial capital, k(**y**, n, **v**, m).

For the AI system's conditional indirect utility function (15), this first-order condition is

$$\frac{\partial V(\cdot)}{\partial k} = \frac{\partial V(\cdot)}{\partial \ln k}\,\frac{\partial \ln k}{\partial k}$$

$$= -\frac{1}{k\left[\beta_0\left(\prod_i y_i^{\beta_i}\right)\left(\prod_j \omega_j^{\nu_j}\right)p_\pi^{\mu}k^{\kappa}\right]}\left[\frac{\partial \ln P}{\partial \ln k} + \kappa[\ln(\boldsymbol{p}\cdot\boldsymbol{y} + m) - \ln P]\right] = 0$$

$$\begin{aligned} \Rightarrow\; & \rho + \rho_{kk}\ln k + \psi_{pk}\ln\tilde{p} + \sum_j \gamma_{jk}\ln y_j + \sum_s \omega_{sk}\ln w_s + \eta_{\pi k}\ln p_\pi + \tau_{rk}\ln r \\ & + \vartheta_{nk}\ln n + \kappa[\ln(\boldsymbol{p}\cdot\boldsymbol{y} + m) - \ln P] = 0\,. \end{aligned} \tag{20}$$

C. The Empirical Model

Thus, the empirical model we estimate consists of the input share equations (16), the profit share equation (17), and the demand for financial capital equation (20). We estimate the model using nonlinear two-stage least squares, subject to several conditions on the parameters of the model. Symmetry requires that

(S1) $\delta_{ij} = \delta_{ji}\ \forall$ i,j, (S2) $\omega_{s\pi} = \omega_{\pi s}\ \forall$ s, and (S3) $\omega_{si} = \omega_{is}\ \forall$ s,i.

(S1) must be imposed in the estimation of the share equations, since the constituent coefficients cannot be separately identified. However, (S2) and (S3) involve coefficients of prices that are used by Shephard's lemma to obtain the share equations. Consequently, they appear in separate share equations and are, thus, identifiable. In the estimation we do not impose (S2) and (S3), as the conditions are violated.[6]

The input and profit share equations are homogeneous of degree zero in (w, $\tilde{p}$, r, p_π), which implies the following conditions:

(H1) $\Sigma\nu_j + \mu = 0$,

(H2) $\alpha_p + \Sigma\omega_j + \eta_\pi + \tau = 1$,

(H3) $\alpha_{pp} + \Sigma_t\, \varphi_{jt} + \psi_{jr} + \psi_{j\pi} = 0\ \forall$ j,

(H4) $\varphi_{pt} + \Sigma_s\, \omega_{st} + \omega_{tr} + \omega_{t\pi} = 0\ \forall$ t,

(H5) $\tau_{rr} + \psi_{pr} + \Sigma_s\, \omega_{sr} + \eta_{\pi r} = 0\ \forall$ j,

(H6) $\theta_{pj} + \Sigma_t\, \gamma_{jt} + \gamma_{j\pi} + \gamma_{jr} = 0\ \forall$ j,

(H7) $\eta_{\pi\pi} + \psi_{p\pi} + \Sigma_s\, \omega_{s\pi} + \eta_{\pi r} = 0$

(H8) $\psi_{pn} + \Sigma_s\, \omega_{sn} + \tau_{rn} + \eta_{\pi n} = 0$,

(H9) $\psi_{pk} + \Sigma_s\, \omega_{sk} + \tau_{rk} + \eta_{\pi k} = 0$, and

(H10) $\frac{1}{2}\alpha_{pp} + \frac{1}{2}\Sigma_s\, \Sigma_t\, \omega_{st} + \Sigma_t\, \varphi_{pt} + \frac{1}{2}\tau_{rr} + \frac{1}{2}\eta_{\pi\pi} + \psi_{p\pi} + \psi_{pr} + \Sigma_s\, \omega_{sr} + \Sigma_s\, \omega_{s\pi} + \eta_{\pi r} = 0$.

The input and profit revenue share equations sum to one, which implies the following adding up conditions:

(A1) $\Sigma_i\, \omega_i + \eta_\pi = 1$,

(A2) $\Sigma_i\, \omega_{si} + \omega_{s\pi} = 0,\ \forall$ s,

(A3) $\Sigma_i\, \varphi_{pi} + \psi_{p\pi} = 0$,

(A4) $\Sigma_i\, \gamma_{ji} + \gamma_{j\pi} = 0\ \forall$ j,

(A5) $\Sigma_i\, \omega_{\pi i} + \eta_{\pi\pi} = 0$,

(A6) $\Sigma_i\, \omega_{ir} + \eta_{\pi r} = 0$,

(A7) $\Sigma_i\, \omega_{ik} + \eta_{\pi k} = 0$,

(A8) $\Sigma_i\, \omega_{in} + \eta_{\pi n} = 0$, and

(A9) $\Sigma\nu_j + \mu = 0$.

Notice that condition (A6) is redundant given the homogeneity conditions. Thus, in estimating the model, we imposed (S1), (A1)-(A5), and (A7)-(A9). The homogeneity conditions (H1)-(H10), then, are used to recover the parameters on variables involving the risk-free rate, r, which does not vary over the cross-section of banks.

4. EMPIRICAL INVESTIGATION

A. Managerial Objectives

The first question we ask is whether banks are acting to maximize profits or whether they are pursuing additional objectives as well. If banks maximize profits (which is equivalent to maximizing return on equity here, since financial capital is treated as exogenous in the share equations), then (1) a variation in the tax rate and, equivalently, in $p_\pi \left(= \frac{1}{1-t}\right)$, will not affect the bank's choice of before-tax profit, so that $\eta_\pi = \eta_{\pi\pi} = \psi_{p\pi} = \gamma_{j\pi} = \omega_{s\pi} = \eta_{\pi r} = \eta_{\pi n} = \eta_{\pi k} = 0 \ \forall$ j,s; (2) the revenue and risk characteristics of production represented by the output price vector will not influence the bank's cost-minimizing production plan, so that $\alpha_p = \alpha_{pp} = \theta_{pj} = \varphi_{ps} = \psi_{p\pi} = \psi_{pn} = \psi_{pk} = 0 \ \forall$ j,s; and (3) a variation in m will have no marginal significance for the optimal input demands **x** and k, so that $\nu_i = -\frac{w_i x_i}{\boldsymbol{p}\cdot\boldsymbol{y} + m} \ \forall j$, $\mu = 1 - \frac{p_\pi \pi}{\boldsymbol{p}\cdot\boldsymbol{y} + m}$, and $\kappa = 0$.[7]

It is worth noting that if banks maximize profit alone, so that all these restrictions can be imposed, then the input revenue-share equations, (16), that we derived from the AI system are cost share equations identical to those derived from the translog cost function, and the profit-share equation becomes equivalent to the translog cost function.

B. Scale Economies and Cost Elasticities

Scale economies are defined by the inverse of the elasticity of cost with respect to output. Using the definition of the MP cost function (7) and substituting the utility-maximizing demand for financial capital into (7), the degree of scale economies is given by

$$SCALE = \frac{\hat{C}}{\sum_i y_i \left(\frac{\partial \hat{C}}{\partial y_i} + \frac{\partial \hat{C}}{\partial k} \frac{\partial k}{\partial y_i} \right)} \tag{21}$$

$$= \frac{\boldsymbol{p}\cdot\boldsymbol{y} + m - p_\pi \pi}{\sum_i y_i \left(p_i - \frac{\partial p_\pi \pi}{\partial y_i} - \frac{\partial p_\pi \pi}{\partial k} \frac{\partial k}{\partial y_i} \right)}$$

$$= \frac{\boldsymbol{p}\cdot\boldsymbol{y} + m - p_\pi\pi}{\sum_i \left[p_i y_i - (\boldsymbol{p}\cdot\boldsymbol{y} + m)\frac{\partial\left(\frac{p_\pi\pi}{\boldsymbol{p}\cdot\boldsymbol{y} + m}\right)}{\partial \ln y_i} - \left(\frac{p_\pi\pi}{\boldsymbol{p}\cdot\boldsymbol{y} + m}\right) p_i y_i - (\boldsymbol{p}\cdot\boldsymbol{y} + m)\frac{\partial\left(\frac{p_\pi\pi}{\boldsymbol{p}\cdot\boldsymbol{y} + m}\right)}{\partial \ln k}\frac{\partial \ln k}{\partial \ln y_i}\right]} .$$

The final expression in (21) is stated in terms of derivatives of the profit share equation (17).

We estimate scale economies for BHCs of different size levels, different levels of geographic diversity (the number of states in which they operate), and organizational form (one-bank vs. multi-bank holding companies), to see how optimal size varies with geography.

C. Efficiency, Expected Profit, and Risk

How efficiently a bank operates may be affected by the geographic extent of its operations. Many banks argue that the restrictions placed on geographic expansion have led to increased liquidity risk, as they are unable to diversify their core deposit gathering. These restrictions might then hinder a bank's ability to deliver financial services in an efficient manner. The newly granted interstate branching privileges might lead to increased efficiency, but geographic expansion might also mean a change in the price of risk in terms of expected return. Thus, we might see an increase in risk along with an increase in expected return as banks expand geographically. The outcome of geographic expansion on risk, expected return, and efficiency is not a priori known.

To investigate these issues we look at how BHCs' liquidity risk, expected return, risk, and efficiency are affected by the organizational structure and geographic diversity of their operations. Here, we measure a BHC's liquidity risk, Vol, by the volatility of its transactions deposits, relative to that BHC's trend level of transactions deposits, divided by its level of transactions deposits.

We use our estimated production model to compute the expected return, the standard deviation of the return (i.e., risk), and efficiency scores for each BHC. Using our estimated profit share equation, we derive each BHC's expected return, ER, by taking the profit predicted for that bank from the estimated equation (17), i.e., $E(p_\pi\pi)$ and dividing by the BHC's capital level, k, i.e., $ER = \frac{E(p_\pi\pi)}{k}$. The BHC's risk, RK, is computed as the standard error of predicted profit, $S(E(p_\pi\pi))$, divided by k, i.e., $RK = \frac{S(E(p_\pi\pi))}{k}$. Note that both ER and

RK are dependent on the BHC's production plan and so are functions of (**y**,**w**,**p**,r,n).

A risk-return frontier is then estimated. Expected return (normalized by its standard deviation), ER′, is regressed on a constant term, risk (normalized by its standard deviation), RK′, and RK′^{2}.[8] That is,

$$ER_i^{\prime} = \Gamma_0 + \Gamma_1 RK_i^{\prime} + \Gamma_2 RK_i^{\prime 2} + \varepsilon_i, \tag{22}$$

$$\text{where } \varepsilon_i = v_i - u_i$$
$$v_i \sim \text{iid } N(0,\sigma_v^2)$$
$$u_i(\geq 0) \sim \text{iid } N(0,\sigma_u^2), \text{ truncated at } 0 .$$

As in the stochastic econometric cost frontier literature (see Mester (1994) for a review), the error term on the regression, ε_i, is composed of two parts. One part, v_i, represents statistical noise, which can be positive or negative. The other part, u_i, represents inefficiency. A bank is inefficient in terms of risk and return if it is receiving a lower expected return for a given level of risk; so u_i is a one-sided error term that is always negative.

The log-likelihood function of this frontier model is

$$\ln L = \frac{N}{2}\ln\frac{2}{\pi} - N\ln\sigma - \frac{1}{2\sigma^2}\sum_{i=1}^{N}\varepsilon_i^2 + \sum_{i=1}^{N}\ln\left[\Phi\left(-\frac{\varepsilon_i\lambda}{\sigma}\right)\right] \tag{23}$$

where N is the number of BHCs, $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \frac{\sigma_u}{\sigma_v}$, and $\Phi(\cdot)$ is the standard normal cumulative distribution function. We estimate this frontier using maximum-likelihood techniques.[9]

Once the model is estimated, we calculate three different firm-level efficiency scores based on the estimated frontier. In theory, these three scores can give different rankings of the firms, but here, as will be discussed below, the correlation between the three measures is very high.

Orthogonal risk efficiency, Eff^{ORK}, measures the decrease in risk that would occur if the BHC moved to the frontier along the orthogonal ray to the frontier (this orthogonal ray gives the shortest distance to the frontier), relative to the risk at the frontier. Thus, if BHC i has risk, RK_i', and the closest point on the frontier has risk, RK_e',then

$$Eff_i^{ORK} = 1 - \frac{RK_i^{\prime} - RK_e^{\prime}}{RK_e^{\prime}} . \tag{24}$$

Orthogonal return efficiency, Eff^{OER}, measures the increase in expected return that would occur if the BHC moved to the frontier along the orthogonal ray to the frontier, relative to the expected return on the frontier. Thus, if the BHC i has expected return, ER_i', and the closest point on the frontier has expected return, ER_e',then

$$Eff_i^{OER} = 1 - \frac{ER_e' - ER_i'}{ER_e'} . \tag{25}$$

Vertical return efficiency, Eff^{VER}, is similar to that typically used in other stochastic frontier production studies. A drawback of the orthogonal measures is that they do not account for random error's effect on the placement of the bank relative to the frontier; this measure does. Eff^{VER} measures the increase in the expected return that would occur if the BHC became efficient and moved to the frontier along a vertical ray to the frontier, i.e., holding risk constant, relative to the expected return on the frontier at that level of risk. The estimated increase in the expected return takes into account that random noise rather than inefficiency may be part of the reason a BHC's expected return is less than if the BHC were on the frontier. Thus, an estimate of the increase in the BHC's expected return if it were to become fully efficient is given by the mean of the conditional distribution of u_i given ε_i , and the efficiency measure is

$$Eff^{VER} = 1 - \frac{E(u_i|\varepsilon_i)}{\Gamma_0 + \Gamma_1 RK_i' + \Gamma_2 RK_i'^2} \tag{26}$$

where

$$E(u_i|\varepsilon_i) = \left(\frac{\sigma_u \sigma_v}{\sigma}\right)\left[\frac{\varphi\left(\frac{\varepsilon_i\lambda}{\sigma}\right)}{\Phi\left(-\frac{\varepsilon_i\lambda}{\sigma}\right)} - \frac{\varepsilon_i\lambda}{\sigma}\right] \tag{27}$$

is the conditional expectation of u_i given ε_i.[10]

We then use three-stage least squares to estimate the following model:

$$\begin{aligned} Vol &= f_1(\boldsymbol{X}) + \xi_1 \\ ER &= f_2(Vol,\ \boldsymbol{Z}) + \xi_2 \\ RK &= f_3(Vol,\ \boldsymbol{Z}) + \xi_3 \\ Eff^{ORK} &= f_4(Vol,\ \boldsymbol{Z}) + \xi_4 \\ Eff^{OER} &= f_5(Vol,\ \boldsymbol{Z}) + \xi_5 \\ Eff^{VER} &= f_6(Vol,\ \boldsymbol{Z}) + \xi_6 , \end{aligned} \tag{28}$$

where Vol is the volatility of the BHC's transactions deposits per unit of transactions deposits, and **X** and **Z** are vectors of exogenous variables including, among other things, measures of geographic expansion and organizational form. We also estimated the model separately for the set of inefficient BHCs, and after dropping the three efficiency score equations, for the set of efficient BHCs.[11]

5. THE DATA

We used 1994 data on U.S. BHCs taken from the FRY-9 Financial Statements filed with the Federal Reserve System. (The BRANCH variable was constructed using Summary of Deposits data.) We excluded holding companies that started operating after June 1986 (as being de novos), those headquartered in unit banking states, and those that consisted mainly of nonbank banks or special purpose banks. A total of 443 BHCs, ranging in size from $32.5 million to $249.7 billion in consolidated assets, are included in our sample. A summary of the data is available from the authors.

For the production model estimation, we specify five outputs, each measured as the average amount reported by the BHC across the four quarters of 1994: y_1 = liquid assets, which include cash, interest-bearing balances due from depository institutions, federal funds sold, and securities purchased under agreements to resell; y_2 = securities with a maturity of one year or less; y_3 = securities with a maturity over one year; y_4 = loans and leases net of unearned income; and y_5 = other assets, including assets held in trading accounts, investments in unconsolidated subsidiaries, customers' liability on bankers' acceptances, intangible assets, and those reported as other assets on the Financial Statement.

Financial capital, k, is the average amount over the four quarters of 1994 of equity capital, loan-loss reserves, and subordinated debt. In addition to financial capital, five other inputs are incorporated into the model: x_1, labor, whose price, w_1, is measured by salaries and benefits paid in 1994 divided by the average number of employees in 1994; x_2, physical capital, whose price, w_2, is proxied by the ratio of premises expense in 1994 to the average dollar value of net premises in 1994; x_3, insured domestic deposits, whose price, w_3, is computed as the ratio of interest paid in 1994 on deposits in domestic offices excluding time deposits over \$100,000 to the average amount in 1994 of deposits in domestic offices excluding time deposits over \$100,000; x_4, uninsured domestic deposits, whose price, w_4, is the ratio of the interest expense in 1994 of domestic time deposits over \$100,000 to the average amount in 1994 of those deposits; and x_5, all other borrowed money, whose price, w_5, is the ratio of the total expense of foreign deposits, federal funds purchased, securities sold under agreement to repurchase, other borrowed funds, subordinated debt, and mandatory convertible debt in 1994 to the average amount of these funds in 1994.

In addition to financial capital, another indicator of a bank's underlying financial condition is its amount of nonperforming assets, n, which is measured by the sum of the average level of loans, leases, and other assets past due 90 days or more and still accruing interest and the average level of nonaccruing loans, leases, and other assets.[12]

The price or yield, p_i, on the i^{th} output is measured by the ratio of total interest income from the i^{th} output to the average amount of the i^{th} output that is accruing interest. This price is not just a component of revenue. Its magnitude relative to the risk-free rate indicates the risk premium incurred by the output and, hence, suggests the average quality of the asset. The weighted-average output price, $\tilde{p}$, is defined as

$$\tilde{p} \;=\; \sum_i p_i \left[\frac{y_i}{\sum_j y_j} \right] .$$

The variable, m, is measured by the amount of noninterest income received in 1994. Revenue is the sum, $\mathbf{p} \cdot \mathbf{y} + m$, and accounting profit is, $\mathbf{p} \cdot \mathbf{y} + m - \mathbf{w} \cdot \mathbf{x}$. Since actual or realized profit may be quite different from the expected profit that motivated the production plan ($\mathbf{y}$,$\mathbf{x}$,k), instead of using actual earnings, we use *potential revenue* as a proxy for expected revenue. *Potential revenue* is the revenue that would be earned if all assets accrued interest. Since **p** measures the average interest rates on accruing assets and **y** includes all assets, accruing and nonaccruing, the product $\mathbf{p} \cdot \mathbf{y}$ captures *potential interest income*; total potential income is $\mathbf{p} \cdot \mathbf{y} + m$; and *potential profit* is, $\mathbf{p} \cdot \mathbf{y} + m - \mathbf{w} \cdot \mathbf{x}$.

Banks pay both federal and state taxes on their income. The federal tax rates are similar for banks in the data set. Thus, the main variation comes from the state tax component of p_π. The state tax rates are obtained for each state from *The Book of the States*, published by the Council of State Governments, and from

Significant Aspects of Fiscal Federalism, published by the U.S. Advisory Commission on Intergovernmental Relations.

To measure deposit volatility, Vol, for each BHC we first estimated its linear time trend of transactions deposits using quarterly data over 1994. Vol is then measured as the root mean squared error of actual transactions deposits from predicted transactions deposits (based on the trend model) over the four quarters of 1994, divided by the quarterly average level of deposits over 1994. There is some chance that this measure will be biased for those BHCs that were involved in out-of-company mergers or acquisitions (M&As) in 1994. Thus, we estimated model (28) dropping the 191 BHCs involved in this type of M&A in 1994; this left 252 BHCs in the sample and we present the results for this sample in Tables 3 and 4 below. (We also estimated model (28) including the full sample of 443 BHCs and will point out any differences in our discussion of the results.[13]) Note that Vol is not that different across the sample of BHCs that were not involved in M&As and the sample of BHCs that were; e.g., in the no-merger sample the mean of Vol is 0.0279 and in the merger sample it is 0.0332; these are not significantly different at the 5 percent level. However, the means of several of the independent variables we will be using in estimating model (28) are statistically different across the subsamples. For example, BHCs involved in mergers were larger, operated in more states, and had more branches. As will be seen below, the results for inefficient BHCs are similar for the two samples, but there are some differences in results for efficient BHCs between the two samples.

The **X** variables in model (28) are: CONST= constant term, OBHC= 1 if the BHC is a one-bank HC, and 0 if it is a multi-bank HC, NUMST = number of states in which the BHC operated in 1994, BRANCH = number of branches in commercial banks in the BHC, CHASST = percentage change in BHC's assets over 1994 = (quarterly average assets in 1994/quarter average assets in 1993) − 1, DEPGROW = BHC's transactions deposit growth from 1993Q4 to 1994Q4, DEPAVG = BHC's quarterly average of transactions deposits in 1994, DEPAVG×DEPAVG, OBHC×CHASST, OBHC×BRANCH, BRANCH×NUMST, CHASST×NUMST, DEPGROW×OBHC, DEPGROW×BRANCH, DEPAVG×OBHC, DEPAVG×BRANCH, DEPAVG×CHASST, DEPAVG×DEPGROW.[14] The **Z** variables in model (28) are:

CONST= constant term, OBHC, NUMST, BRANCH, CHASST, DEPGROW, DEPAVG, and TOTA = total assets.

In order to save space, we omit the table of parameter estimates here; it is available from the authors.

6. THE EMPIRICAL FINDINGS

A. Managerial Objectives

The first thing to note is that BHC managers are not behaving in a risk-neutral manner. A Wald test of the conditions (1), (2), and last part of (3) (i.e., $\kappa = 0$) given in section 4.A strongly rejects profit-maximizing behavior: the test statistic is 441.95, with p-value close to 0.

B. Scale Economies

We calculated the degree of scale economies using equation (21) for each BHC in the sample. Table 1 reports the mean of the scale economies measures and its standard error across all BHCs in the sample and in various groups. The first grouping is by asset size: we report the statistics for the following five size categories: assets $\leq$ \$300 million; \$300 million < assets $\leq$ \$2 billion; \$2 billion < assets $\leq$ \$10 billion; \$10 billion < assets $\leq$ \$50 billion; and \$50 billion < assets.

The second grouping is by holding company structure: we report the statistics for one-bank HCs and for multi-bank HCs. And the final grouping is by the number of states in which the BHC operates; we report statistics for the following four categories: 1 state; 2-4 states; 5-10 states; over 10 states.

All of the measures are significantly greater than one, indicating there are scale economies in production. The overall mean level of scale economies is 1.144. This is considerably larger than is found in other papers that assume bank managers are risk neutral, but is comparable to estimates found in Hughes, Lang, Mester and Moon (1995), which allowed for nonneutrality toward risk on the part of commercial banks. The scale economies estimates increase as banks grow larger: on average, banks with assets under \$3 million have scale economies of 1.120, while banks with over \$50 billion in assets have scale economies of 1.254. These measures are significantly different from each other at the 5% level, allowing us to conclude that scale economies increase with bank size. This is consistent with the recent merger wave in the banking industry.

There is not a significant difference between the degree of scale economies for one-bank and multi-bank HCs. However, as banks expand geographically into more states (at least up to 10), the degree of scale economies increases and the increase is statistically significant. Thus, there is the potential for greater operational efficiency through interstate branching. While scale economies are still present in expansion beyond 10 states, the degree is smaller, perhaps reflecting the complexity of operating in a very large number of states (although there are not many BHCs in this category in our sample).

C. Efficient Frontier

Table 2 shows the parameter estimates for the efficient frontier, and Figure 1 plots the frontier and each BHC observation. As indicated, there is a significant degree of inefficiency in the sample. The estimate of the expected value of u = $\left(\frac{2}{\pi}\right)^{\frac{1}{2}} \sigma_u$, which can be used as a measure of the average level of inefficiency, is 0.732 with standard error 0.0482, and so is significantly different from zero. The frontier estimation is used to derive our three efficiency measures; the means are shown in Table 2 for the no-merger sample of 252 BHCs. The measures are closely, but not perfectly, correlated. In the no-merger sample, the correlation between Eff^{OER} and Eff^{ORK} is 0.847; between Eff^{OER} and Eff^{VER} is 0.987; and between Eff^{ORK} and Eff^{VER} is 0.885. Also shown in the table are the means of expected return, ER, and risk, RK, as well as deposit volatility, Vol, which are dependent variables in model (28), whose results we now turn to. The parameter estimates from the estimation of model (28) are available from the authors.

D. Deposit Volatility and Geographic Expansion

If the volatility of transactions deposits depends in part on the types of loans and loan customers as well as other aspects of bank production, then it is partially endogenous. Hence, geographic diversification may not manifest itself in a simple reduction in volatility even if diversification lowers volatility, ceteris paribus.

To examine this relationship we look at the derivatives of deposit volatility with respect to the key variables in model (28) that indicate the degree of diversification: the number of states (NUMST) in which the

BHC operates, the number of branches (BRANCH), the volume of transactions deposits (DEPAVG), which proxy for the number of deposit accounts, and the proportional variation in these three variables. These derivatives are reported in the top panels of Tables 3 and 4 for the subsample of efficient and inefficient BHCs, respectively.[15]

For efficient banks the derivatives of volatility with respect to NUMST and DEPAVG are negative, with NUMST being significantly so. On the other hand, the derivative with respect to BRANCH is significantly positive, suggesting that efficient BHCs with larger branch networks have more volatile deposits. But the effect of number of states appears to dominate, as a proportionate increase in all three variables is significantly negative, suggesting that more geographically diverse efficient BHCs operate in ways that tend to decrease deposit volatility. Note, however, that for the full sample that includes BHCs involved in mergers in 1994, we obtain the opposite result. For the full sample, NUMST and DEPAVG are significantly positively related to volatility, while BRANCH is significantly negatively related to volatility; and the effect of a proportionate increase is positive. This probably is due to the fact that our volatility measure overstates true volatility for BHCs that were involved in mergers, and more geographically diversified BHCs were more likely to have been involved in mergers.

In the case of inefficient BHCs, the signs of the derivatives reverse, with DEPAVG and NUMST being positively related and BRANCH negatively related to volatility, with DEPAVG and BRANCH significantly so. On balance though, a proportionate increase in geographic diversity is insignificantly positively related to volatility. (These results are similar for the sample that includes mergers.)

Hence, the impact of diversification on BHCs is clear for the efficient subsample and ambiguous for the inefficient subsample. These results confirm the prediction made at the outset that there is no a priori prediction of the effect of diversification on volatility. However, if there is a diversification effect, then it should be apparent in a higher expected return and greater efficiency.

E. Volatility, Expected Return, Risk, and Efficiency

Tables 3 and 4 report both partial and total derivatives of expected return, risk, and efficiency with respect to our geographic diversity variables: the partial derivatives hold deposit volatility constant, while the total derivatives take into account the change in deposit volatility that occurs when one of the exogenous variables changes.

Deposit volatility is positively related to expected return and risk in all of our estimates. This result is statistically significant for efficient BHCs whether we exclude or include those BHCs that have been involved in M&A activity. The increased risk and increased expected return associated with higher deposit volatility suggests a movement along the efficient risk-return frontier where BHCs are taking more risk in exchange for higher return.

The estimated derivatives of expected return and risk with respect to deposit volatility are also positive for inefficient holding companies; however when we exclude BHCs involved in M&As the estimates are not significant at the 10% level. (For the sample that includes mergers, volatility and risk are significantly positively related.)

To see whether the return effect dominates the risk effect, we examine the impact of deposit volatility on all three measures of efficiency for our inefficient BHC subsample. A positive (negative) effect on efficiency would indicate that the return (risk) effect dominates. While the point estimates are all positive, they are not statistically significant.[16]

To summarize, BHCs whose production plans involve more deposit volatility appear to be trading off higher expected return for increased risk. This indicates a movement along the frontier for efficient banks. The impact of deposit volatility on efficiency measures is not statistically significant.

F. Geographic Expansion, Expected Return, Risk, and Efficiency

To determine the effects of geographic diversification on expected return, risk, and efficiency, the endogeneity of deposit volatility must be taken into account. The total derivatives do this. They account for the direct effects on expected return, risk, and efficiency of changes in measures of diversification, holding volatility constant, plus the indirect effects caused by changes in deposit volatility in response to changes in the diversification measures.

An increase in the volume of deposits can be interpreted as a proxy for an increase in the number of accounts. Holding geographic diversification constant (i.e., the number of states and branches), an increase in the volume of deposits would represent an increase in diversification over depositors. An increase in the number of states or in the number of branches, ceteris paribus, represents an increase in geographic diversity. A proportional variation in these three measures captures the effect of a scaled variation in geographic and depositor diversification.

The effect of geographic and/or depositor diversification on expected return and risk depends on whether the BHC is efficient or inefficient. For the efficient BHCs, three of our four measures of diversification are positively and significantly related to expected profit and risk for the sample that excludes M&As (only number of states has an insignificant (negative) relationship).[17] Thus, for the efficient institutions, greater geographic and/or depositor diversification increases risk, but it also increases the expected return; in other words, it induces these BHCs to move along the efficient risk-return frontier.[18]

For the inefficient BHCs, none of our measures of diversification has a significant total effect on expected return or risk. For the sample that includes all inefficient BHCs, a proportionate change in deposit level, branches, and number of states is significant and positively related to expected return.

The results concerning the effect of diversification on efficiency are stronger than those concerning risk and return, with the sample including all inefficient BHCs and the sample excluding the M&As yielding similar results. In both, an increase in branches is significantly positively related to all three efficiency measures in both samples, lending some support that increases in geographic diversification improve efficiency. Our other measures are insignificantly related to efficiency.

6. CONCLUSION

Using a structural model of production that is sufficiently general to account for nonneutrality toward risk as well as risk neutrality, we have uncovered evidence of large and increasing scale economies that apply to geographic expansion as well as to local expansion. Using the structural model to obtain measures of expected return and risk for each bank, we have measured efficiency relative to a stochastic risk-return frontier and have isolated distinct gains in return and in efficiency.

Our results suggest that increasing geographic and/or depositor diversification enhances expected return and that an increase in branches improves efficiency by moving inefficient institutions closer to the efficient frontier in both the return and risk dimensions. There might be the suspicion that this improvement is due, not to the diversification of risk, but rather to the large and increasing scale economies that we found. Although such scale economies can be expected to improve operating efficiency, they do not contribute to the efficiency gains measured by the expansion in branches, since asset size has been held constant in taking this derivative. Hence, the improvement in expected return and efficiency is consistent with risk diversification due to spreading assets over a larger branch network. For the efficient BHCs in our sample, we found that a proportional increase in deposits, number of states, and number of branches is positively and significantly related to return and risk, indicating a move along the efficient frontier.

LITERATURE CITED

Akhavein, Jalal D., Allen N. Berger, and David Humphrey. "The Effects of Megamergers on Efficiency and Prices: Evidence from a Bank Profit Function," *Review of Industrial Organization* (forthcoming).

Berger, Allen N., and Robert DeYoung. “Problem Loans and Cost Efficiency in Commercial Banks,” manuscript, Board of Governors of the Federal Reserve System, October 1995.

Chong, Beng Soon. "The Effects of Interstate Banking on Commercial Banks' Risk and Profitability, " *Review of Economics and Statistics* (1991), 78-84.

Demsetz, Rebecca S., and Philip E. Strahan, "Diversification, Size, and Risk at Bank Holding Companies," Federal Reserve Bank of New York, Research Paper #9506, April 1995.

Hancock, Diana. "The Financial Firm: Production with Monetary and Nonmonetary Goods," *Journal of Political Economy* 93 (1985), 859-80.

Hancock, Diana. "A Model of the Financial Firm with Imperfect Asset and Deposit Liabilities," *Journal of Banking and Finance* 10 (1986), 37-54.

Hughes, Joseph P., William Lang, Loretta J. Mester, and Choon-Geol Moon. "Recovering Technologies that Account for Generalized Managerial Preferences: An Application to Non-Risk-Neutral Banks," Working Paper No. 95-8/R, Federal Reserve Bank of Philadelphia, September 1995.

Hughes, Joseph P., and Loretta J. Mester. "A Quality and Risk-Adjusted Cost Function for Banks: Evidence on the 'Too-Big-to-Fail' Doctrine," *Journal of Productivity Analysis* 4 (1993), 292-315.

Hughes, Joseph P., and Loretta J. Mester. "Bank Capitalization and Cost: Evidence of Scale Economies in Risk Management and Signaling," Working Paper No. 96-2, Federal Reserve Bank of Philadelphia, December 1995.

Hughes, Joseph P. and Choon-Geol Moon. "Measuring Bank Efficiency When Managers Trade Return for Reduced Risk," Working Paper, Department of Economics, Rutgers University, September 1995.

Jondrow, J., C.A.K. Lovell, I.S. Materov, and P. Schmidt. “On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model, *Journal of Econometrics* 19 (1982), 233-238.

McAllister, Patrick H., and Douglas McManus. "Resolving the Scale Efficiency Puzzle in Banking," *Journal of Banking and Finance* 17 (1993), 389-406.

Mester, Loretta J. "How Efficient Are Third District Banks?" *Business Review*, Federal Reserve Bank of Philadelphia (January/February 1994), 3-18.

Olson, Jerome A., Peter Schmidt, and Donald M. Waldman. "A Monte Carlo Study of Estimators of Stochastic Frontier Production Functions," *Journal of Econometrics* 13 (May 1980), 67-82.

Rose, Peter S. "Diversification and Interstate Banking," manuscript, Texas A&M University Graduate School of Business, March 1995.

TABLE 1. Scale Economies Measures

	Number of BHCs	Scale Estimate*	Std. Err.
Over all BHCs	443	1.144799	0.009767
Asset-Size Categories			
assets ≤ $300 mill	109	1.120171	0.008452
$300 mill < assets ≤ $2 bill	217	1.125772	0.008766
$2 bill < assets ≤ $10 bill	67	1.170029	0.011525
$10 bill < assets ≤ $50 bill	35	1.244458	0.017323
$50 bill < assets	15	1.253787	0.016880
Organizational Structure			
OBHCs	176	1.131186	0.008893
MBHCs	267	1.153772	0.010450
Multi-state Operation			
1 state	320	1.127451	0.008782
2-4 states	96	1.170632	0.011555
5-10 states	21	1.271840	0.018624
> 10 states	6	1.212044	0.016384

*All estimates are significantly different from one at the 5% level.

TABLE 2. EFFICIENT FRONTIER AND MEANS OF EXPECTED RETURN, RISK, and EFFICIENCY

Parameter Estimates of the Efficient Frontier

$$ER' = \Gamma_0 + \Gamma_1 * RK' + \Gamma_2 * RK'^2 + v - u$$

where $v \sim N(0,\sigma_u^2)$ and $u(\geq 0) \sim N(0,\sigma_u^2)$ truncated at 0,

$\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\lambda^2 = \sigma_u^2/\sigma_v^2$

Parameter	Estimate	Standard Error	t-statistic
Γ_0	3.06608*	.104976	29.2075
Γ_1	0.928417*	.070125	13.2394
Γ_2	-.014592**	.751180E-02	-1.94253
σ^2	1.04988*	.089829	11.6876
λ^2	4.05452*	1.06342	3.81270

*Significant at the 5% level or better.

All BHCs not involved in mergers in 1994 (252 BHCs)

		Mean
Deposit Volatility	Vol	0.0279
Expected Return	ER	0.3141
Risk	RK	0.006678
Efficiency	EFF^{OER}	0.8776
	EFF^{ORK}	0.5513
	EFF^{VER}	0.8313

Inefficient BHCs not involved in mergers in 1994 (228 BHCs)

		Mean
Deposit Volatility	Vol	0.0283
Expected Return	ER	0.3001
Risk	RK	0.006443
Efficiency	EFF^{OER}	0.8647
	EFF^{ORK}	0.5041
	EFF^{VER}	0.8193

Efficient BHCs not involved in mergers in 1994 (24 BHCs)

		Mean
Deposit Volatility	Vol	0.0245
Expected Return	ER	0.4472
Risk	RK	0.008914

TABLE 3. Derivatives of Deposit Volatility, Expected Return, and Risk: Efficient BHCs

	Estimate	Standard Error	t-statistic
Derivative of Deposit Volatility with respect to:			
DEPAVG	-.798264E-09	.300141E-07	-.026596
DEPGROW	.198318*	.037986	5.22081
NUMST	-.041978*	.012887	-3.25742
BRANCH	.978709E-03*	.398021E-03	2.45894
OBHC	-.064800*	.011389	-5.68978
Prop. increase in DEPAVG, BRANCH, NUMST	-.023973*	.953806E-02	-2.51343
Partial Derivative of Expected Return with respect to:			
VOL	3.86837*	1.30041	2.97472
NUMST	.076175	.076526	.995417
BRANCH	.103586E-02	.138495E-02	.747939
DEPAVG	.175606E-05*	.780687E-06	2.24937
DEPGROW	-.759089*	.216051	-3.51347
Prop. increase in DEPAVG, BRANCH, NUMST	.344434*	.153412	2.24516
Total Derivative of Expected Return with respect to:			
NUMST	-.086211	.097377	-.885331
BRANCH	.482187E-02**	.281308E-02	1.71409
DEPAVG	.175297E-05*	.787917E-06	2.22481
DEPGROW	.807952E-02	.354313	.022803
Prop. increase in DEPAVG, BRANCH, NUMST	.360045**	.193658	1.85918
Partial Derivative of Risk with respect to:			
VOL	.236362*	.070966	3.33065
NUMST	.416817E-02	.417562E-02	.998216
BRANCH	.534078E-04	.755783E-04	.706655
DEPAVG	.905990E-07*	.426834E-07	2.12258
DEPGROW	-.039775*	.011790	-3.37369
Prop. increase in DEPAVG, BRANCH, NUMST	.017667*	.832381E-02	2.12241
Total Derivative of Risk with respect to:			
NUMST	-.575382E-02	.543776E-02	-1.05812
BRANCH	.284738E-03**	.157683E-03	1.80576
DEPAVG	.904103E-07*	.432150E-07	2.09210
DEPGROW	.710039E-02	.019543	.363319
Prop. increase in DEPAVG, BRANCH, NUMST	.017961**	.010637	1.68859

*Significant at the 5% level.
**Significant at the 10% level.

TABLE 4. Derivatives of Deposit Volatility, Expected Return, Risk, and Efficiency: Inefficient BHCs

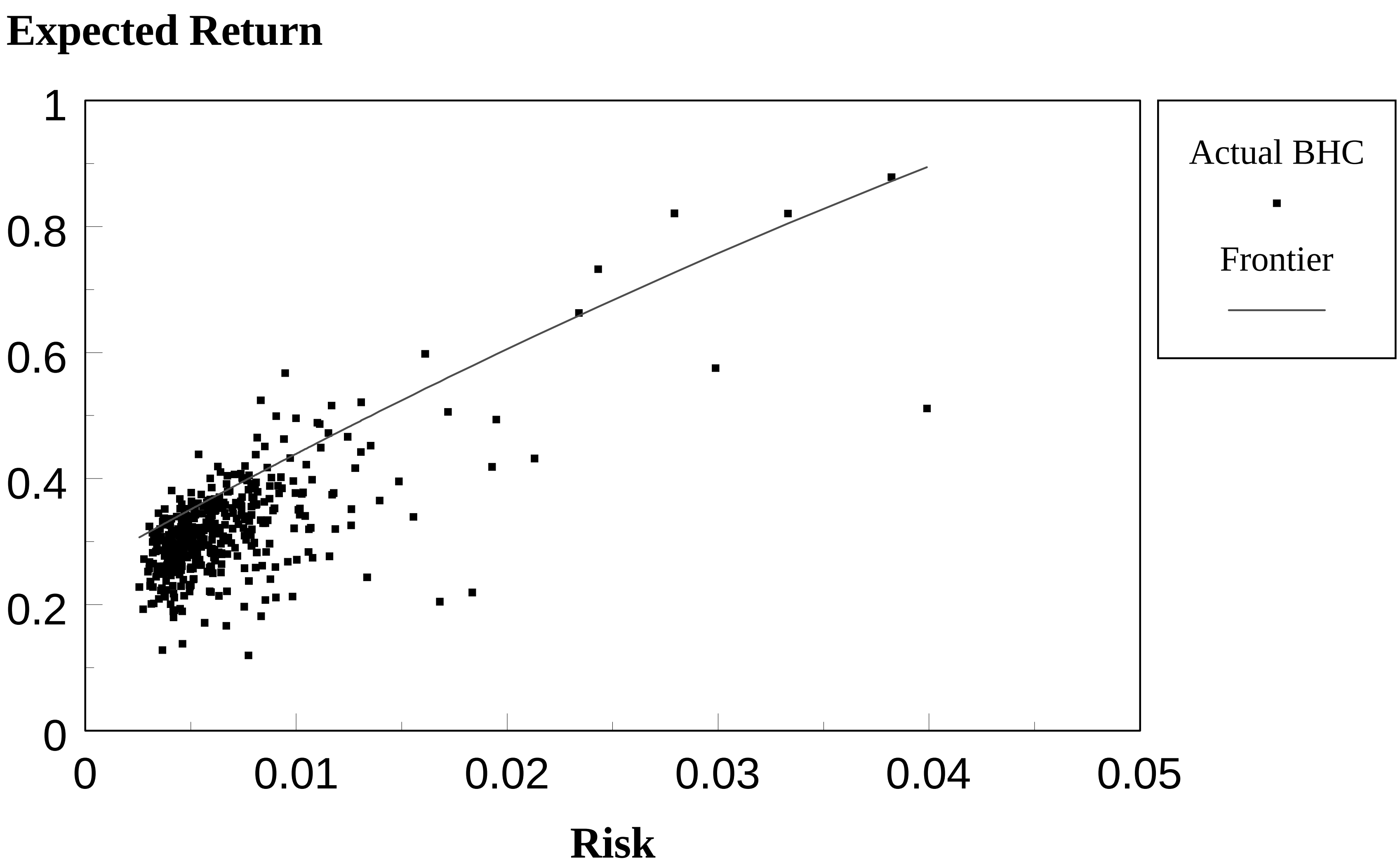
	Estimate	Standard Error	t-statistic
Derivative of Deposit Volatility with respect to:			
DEPAVG	.344282E-07**	.188515E-07	1.82628
DEPGROW	.031862*	.015779	2.01932
NUMST	.416880E-02	.674116E-02	.618410
BRANCH	-.339166E-03**	.193631E-03	-1.75161
OBHC	.676153E-02	.471535E-02	1.43394
Prop. increase in DEPAVG, BRANCH, NUMST	.541196E-02	.728512E-02	.742879
Partial Derivative of Expected Return with respect to:			
VOL	1.39329	.995388	1.39975
NUMST	-.020283	.018944	-1.07070
BRANCH	.111893E-02*	.512490E-03	2.18331
DEPAVG	.232146E-07	.889399E-07	.261014
DEPGROW	-.131058*	.050565	-2.59187
Prop. increase in DEPAVG, BRANCH, NUMST	.350583E-02	.014944	.234604
Total Derivative of Expected Return with respect to:			
NUMST	-.014475	.017471	-.828481
BRANCH	.646368E-03	.445170E-03	1.45196
DEPAVG	.711830E-07	.767999E-07	.926864
DEPGROW	-.086664**	.045627	-1.89942
Prop. increase in DEPAVG, BRANCH, NUMST	.528895E-02	.022307	.237101
Partial Derivative of Risk with respect to:			
VOL	.079982	.055577	1.43911
NUMST	.301045E-03	.105770E-02	.284623
BRANCH	-.137803E-04	.286159E-04	-.481560
DEPAVG	.111486E-08	.497306E-08	.224180
DEPGROW	-.814995E-02**	.282322E-02	-2.88676
Prop. increase in DEPAVG, BRANCH, NUMST	.185681E-03	.828470E-03	.224125
Total Derivative of Risk with respect to:			
NUMST	.634471E-03	.982177E-03	.645984
BRANCH	-.409073E-04	.250854E-04	-1.63072
DEPAVG	.386848E-08	.430982E-08	.897597
DEPGROW	-.560157E-02**	.256080E-02	-2.18743
Prop. increase in DEPAVG, BRANCH, NUMST	.750384E-03	.125310E-02	.598821

*Significant at the 5% level.
**Significant at the 10% level.

TABLE 4. continued

	Estimate	Standard Error	t-statistic
Partial Derivative of Eff^{OER} with respect to:			
VOL	1.39545	1.48639	.938814
NUMST	-.043156	.028286	-1.52572
BRANCH	.268104E-02*	.765699E-03	3.50143
DEPAVG	.489154E-08	.135032E-06	.036225
DEPGROW	-.097638	.075494	-1.29331
Prop. increase in DEPAVG, BRANCH, NUMST	-.103028E-02	.022936	-.044920
Total Derivative of Eff^{OER} with respect to:			
NUMST	-.037339	.026745	-1.39611
BRANCH	.220775E-02*	.659363E-03	3.34831
DEPAVG	.529342E-07	.117081E-06	.452115
DEPGROW	-.053176	.070934	-.749657
Prop. increase in DEPAVG, BRANCH, NUMST	-.302609E-03	.033877	-.893269E-02
Partial Derivative of Eff^{ORK} with respect to:			
VOL	3.59513	5.59777	.642244
NUMST	-.142909	.106519	-1.34162
BRANCH	.011684*	.288446E-02	4.05058
DEPAVG	.266011E-06	.513033E-06	.518505
DEPGROW	-.560942*	.284286	-1.97316
Prop. increase in DEPAVG, BRANCH, NUMST	.017691	.093789	.188627
Total Derivative of Eff^{ORK} with respect to:			
NUMST	-.127922	.102273	-1.25078
BRANCH	.010464*	.248606E-02	4.20924
DEPAVG	.389784E-06	.446539E-06	.872900
DEPGROW	-.446393	.272873	-1.63590
Prop. increase in DEPAVG, BRANCH, NUMST	.075712	.129039	.586739
Partial Derivative of Eff^{VER} with respect to:			
VOL	1.05888	1.23501	.857390
NUMST	-.037103	.023502	-1.57874
BRANCH	.234296E-02*	.636270E-03	3.68234
DEPAVG	.123169E-07	.112565E-06	.109421
DEPGROW	-.092680	.062724	-1.47757
Prop. increase in DEPAVG, BRANCH, NUMST	.665738E-03	.019065	.034920
Total Derivative of Eff^{VER} with respect to:			
NUMST	-.032688	.022360	-1.46193
BRANCH	.198382E-02*	.548773E-03	3.61502
DEPAVG	.487724E-07	.977790E-07	.498802
DEPGROW	-.058942	.059414	-.992042
Prop. increase in DEPAVG, BRANCH, NUMST	.879299E-03	.028282	.031090

FIGURE 1. Efficient Frontier



NOTES

1. The next two sections closely follow Hughes, Lang, Mester, and Moon (1995).

2. The "price," $\tilde{p}_\pi$, facilitates stating the homogeneity conditions: a proportional variable in p_π implies the sample variation in p_π so homogeneity will be stated in terms of the latter.

3. Hancock (1985, 1986) conditioned the profit function on financial capital. Hughes and Mester (1993) and McAllister and McManus (1993) constructed cost functions conditioned on financial capital.

4. As functions of the vectors of outputs and input prices, the input demand functions resemble the standard cost-minimizing ones. As functions of prices and income (revenue), they resemble consumers' demand functions. As functions of the tax rate on profit, they resemble neither.

5. Unlike the standard cost function, the homogeneity properties of the MP cost function include output prices and fixed revenues. The input demand functions $\mathbf{x}(\mathbf{y},n,\mathbf{v},m,k)$ are homogeneous of degree zero in $(\mathbf{v},m)$ while the nominal profit function $p_\pi\pi(\mathbf{y},n,\mathbf{v},m,k)$ is homogeneous of degree one in $(\mathbf{v},m)$. Hence, the MP cost function $\mathbf{w}\cdot\mathbf{x}(\mathbf{y},n,\mathbf{v},m,k)$ is homogeneous of degree one in $(\mathbf{v},m)$.

6. This is the typical way the AI Demand System is handled in the consumer demand literature.

7. To see this, note that if a variation in m does not affect input demands, the $\frac{\partial w_i x_i}{\partial m} = 0$ and $\frac{\partial p_\pi \pi}{\partial m} = 1$. Differentiating the equations (16) and (17) with respect to *ln* m yields the parameter restrictions on ν_i and μ. The restriction that $\kappa = 0$ follows from the fact that changes in m also would not affect the optimal choice of k, which is determined by the first-order condition (20). See Hughes and Mester (1995).

8. We normalized ER and RK by their standard deviations, respectively, before estimating the frontier because their scales of measure were so different.

9. Olson, Schmidt, and Waldman (1980) show that the maximum likelihood estimator is more efficient than the corrected ordinary least squares estimator for stochastic frontier models when the sample size is over 400.

10. See Jondrow, Lovell, Materov, and Schmidt (1982).

11. Obviously, the equations with efficiency scores as dependent variables cannot be estimated for the efficient BHCs, since their orthogonal efficiency scores are identically equal to one.

12. Berger and DeYoung (1995) discuss the various relationships between problem loans and bank efficiency.

13. The results for the full sample are available from the authors.

14. We omitted the two other cross-product terms, DEPGROW×NUMST and DEPAVG×NUMST, because we wanted to compare our results for the full sample with those for the sample excluding M&As. These variables were linearly dependent for the sample of efficient BHCs excluding M&As.

15. The sample was divided into inefficient and efficient BHCs based on the orthogonal efficiency measures, which equal one for efficient BHCs. There are 228 inefficient and 24 efficient BHCs in the no-merger sample; 391 inefficient and 52 efficient BHCs in the full sample. We also estimated the model for the entire sample including both inefficient and efficient BHCs, but since there appear to be significant differences between the two subsamples, we report the subsample results here. Results for the entire sample are available from the authors.

16. For the sample that includes mergers, the relationship between volatility and efficiency is also insignificant, but negative.

17. For the sample of efficient BHCs that includes mergers, the signs on number of states and branches reverse, with states being positively related but branches negatively related to volatility. The effect of a proportionate increase in branches, states, and deposit level, however, is significantly positive, as it is in the no-merger sample.

18. Hughes and Moon (1995) discuss interpreting each BHC's risk-return tradeoff (given its degree of diversification) in terms of a conditional risk-return frontier. Our results suggest that an increase in geographic and/or depositor diversification shifts this conditional frontier more steeply upward. Hence, the marginal return obtained for risk is increased, or, equivalently, the price of risk is reduced. These results suggest that the reduced price of risk caused by greater diversification induces efficient BHCs to take on more risk in exchange for more return.