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**DETERMINANTS OF BANKING INEFFICIENCY OF RURAL BANKS: A SEEMINGLY
UNRELATED REGRESSION APPROACH**

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DETERMINANTS OF BANKING INEFFICIENCY OF RURAL BANKS: A SEEMINGLY UNRELATED REGRESSION APPROACH

Suzhen Zhu, Paul N. Ellinger, & C. Richard Shumway¹

Introduction

The evaluation of inefficiencies in the banking industry has received increased attention in recent years. There has been considerable research to extend and apply parametric and nonparametric models to banking firms. A comprehensive review of inefficiency research on financial intermediaries can be found in the special edition of the *Journal of Banking and Finance* (1993), and a review of issues and approaches in inefficiency analysis of agricultural banks are provided by Ellinger and Neff.

Ellinger outlines the benefits and applications of efficiency analysis to agricultural banks. He identified four changes occurring in rural financial markets that may impact the efficiency and delivery of credit by agricultural banks. These include changes in: (1) the agricultural economy, (2) the competitive environment of rural intermediaries, (3) technology, and (4) borrower demands. The ability of agricultural banks to adapt to this changing environment and efficiently deliver credit and bank services to rural customers will play a large role in determining the efficiency of U.S. agricultural products.

Most bank efficiency analyses have been devoted to estimating inefficiency measures for banking firms. Only a few studies have focused on understanding environmental variables or determinants that influence the level of banking inefficiency. The studies of banking efficiency often have a goal of making policy recommendations. Thus, understanding the characteristics of inefficiency is beneficial in understanding the linkages between specific bank characteristics and firm inefficiency. Moreover, additional information may permit regulators

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to target bank regulatory programs towards firms that could reduce inefficiencies without impeding competitiveness.

Many methods have been used to measure the relationships between bank inefficiency and other bank characteristics. Berger et al. use simple bivariate correlations to identify the correlates between inefficiency and some of the hypothesized factors. Mester applies nonlinear OLS to the logistic function to identify the sources of inefficiency for the savings and loan industry. Gardner and Grace use a cross-sectionally heteroscedastic time-wise autoregressive technique to analyze the attributes of inefficiencies for an insurance company. Using profit function approach, total inefficiency can be decomposed into technical and allocative input and output inefficiencies. A multiple-equation approach can be applied to analyze each component of total inefficiency. The primary objective of this study is to measure the determinants of various components of banking inefficiency by estimating a system of seemingly unrelated equations.

The Choice of Functional Form and Selection of Type of Function

Two econometric problems have caused deviations of estimation results of banking inefficiencies--the choice of functional form and selection of type of function. The choice of functional form is concerned with the question of whether a particular form of function, e.g., translog, normalized quadratic, or other alternative can adequately represent the data structure of the banking industry. To explore this problem, both the Box-Cox transformation and the likelihood dominance criterion proposed by Pollak and Wales were used to conduct tests on the choice of functional form among the translog (TL), normalized quadratic (NQ) and generalized Leontief (GL) (Zhu, Ellinger and Shumway; Zhu, Ellinger, Shumway and Neff) . All three functional forms are locally flexible in the sense that they are second-order Taylor-series

expansions and can reproduce comparative statics at a point without any restrictive across-equation effects. All are quadratic equations. The TL is quadratic in the logarithm of all variables, the NQ is quadratic in normalized values, and the GL is quadratic in the square roots of the exogenous variables. Test results indicate the TL is the preferred functional form and is followed by the NQ for both cost and profit function specifications.

The selection of type of functions has to do with whether the cost function approach or the profit function approach can best represent the behavior of banking firms. In the theoretical framework of the cost function, firms are assumed to minimize their cost for given levels of input prices and quantities of outputs. If banks have significant power to influence either their output levels or input prices, ordinary least-squares (OLS) modeling of the industry by means of the cost function is inappropriate. Similarly, exogenous prices of input and output are assumptions underlying the specification of a profit function. If banks wield significant power over either input or output prices, OLS modeling the industry with the profit function is inappropriate.

Since banks' behavior implied by specification of a profit or a cost function is based on different economic assumptions, nested econometric tests cannot be applied directly to distinguish the preferred approach for estimating banking inefficiency. However, the Hausman exogeneity test can be applied to examine the appropriateness of cost and profit function specifications. Particularly, the test can evaluate whether output prices or output quantities can be regarded as exogenous in the specification of a dual (optimized) model. The Hausman exogeneity tests are performed on the profit and cost functions in both TL and NQ forms (the first and second preferred functional forms) (Zhu, Ellinger, Shumway and Neff). The test results indicate that exogeneity assumptions of both the cost function and the profit

function are not rejected. The results suggest that banks in this study can be regarded as being price takers in both output and input markets. They can also be treated as facing predetermined output levels. Thus, either the profit function or the cost function may be applied in the study of banking inefficiency.

Methods

These previous tests on functional form and exogeneity for profit and cost function provide a solid econometric basis for this study. Since both profit and cost function passed the exogeneity tests, either of them may be applied. However, since the profit function can provide more information on banking inefficiency (i.e., both input and output inefficiencies can be detected using the profit function approach), it is chosen for this study. For some observations, bank profit is negative. Since logarithms are undefined for negative profits, the translog functional form cannot be used. Therefore, the normalized quadratic functional form is the functional form used to measure bank inefficiency.

The estimated model for the normalized quadratic profit function for the problem that incorporates inefficiencies is specified following Berger et al. It includes the profit function and system of netput supply equations:

$$\pi_b = \sum_{i=1}^n (\alpha_i - \xi_{ib}) (p_{ib})^{\tau_i} + \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} \phi_{ij} (1-0.5\tau_i\tau_j) (p_{ib} p_{jb})^{\tau_i\tau_j} + \sum_{i=1}^k \beta_i z_{ib} + 0.5 \sum_{i=1}^k \sum_{h=1}^k \theta_{ih} z_{ib} z_{hb} + \sum_{i=1}^{n-1} \sum_{i=1}^k \gamma_{bi} p_{ib} z_{ib} + e_b \quad (1)$$

$$q_{ib} = (\alpha_i - \xi_{ib})^{\tau_i} \sum_{j=1}^n \phi_{ij} (p_{jb})^{\tau_j} + \sum_{i=1}^k \gamma_{bi} z_{ib} + v_{ib} \quad i=1, \dots, n-1 \quad (2)$$

where b identifies the bank, i identifies the netput (output or input), π is normalized variable

profit, p is normalized price of a variable netput, z is quantity of a fixed netput, q is quantity of a variable netput (positive for output and negative for input), α , ϕ , β , θ , and γ are estimated parameters, τ is the ratio of normalized shadow price divided by the normalized actual price (it measures how far a bank's actual price deviates from its shadow price and is estimated with the other parameters), ξ is the long run or intrinsic technical inefficiency of each netput; ϵ and v are random errors. The profit and price normalization are obtained by dividing by the last input price, i.e, p_n . ξ_{bi} is computed as:

$$\hat{\xi}_{bi} = \begin{cases} \hat{v}_i^{\max} - \hat{v}_{bi} & i=1, \dots, n-1 \\ \hat{\epsilon}^{\max} - \hat{\epsilon}_{bi} & i=n \end{cases} \quad (3)$$

where ϵ^{\max} and v_i^{\max} are the largest residuals for the profit function and netput equation i , respectively.

It should be noted that equation (2) is not derived from equation (1). Equation (1) is the actual profit function, and equation (2) is the actual netput supply equation. Actual netput level equals the desired netput level minus the inefficiency term ξ . The desired netput supply equation is the derivative of the desired profit function equation. When all the τ 's are equal to one and ξ 's are zero (implying no technical nor allocative inefficiency), the desired netput level equals the actual netput level.

Total technical inefficiency is the sum of the technical input inefficiencies ($TI_{b, \text{input}}$) and technical output inefficiencies ($TI_{b, \text{output}}$). The technical input and output inefficiencies are estimated as:

$$TI_{b, \text{input}} = [\xi_{b1} p_{b1} + \xi_{b2} p_{b2} + \dots + \xi_{bm} p_{bm}] p_{bn} \quad (4)$$

$$TI_{b, \text{output}} = [\xi_{bm+1} p_{bm+1} + \xi_{bm+2} p_{bm+2} + \dots + \xi_{bn} p_{bn}] p_{bn} \quad (5)$$

where m is the number of variable inputs and $n - m$ is the number of variable outputs. The total allocative inefficiency consists of three parts -- allocative input inefficiency (AI_{input}), allocative output inefficiency (AI_{output}) and allocative input-output inefficiency ($AI_{input-output}$). These are estimated by:

$$AI_{input} = \left[\sum_{i=1}^{n-1} \sum_{j=1}^{n-1} \phi_y[0.5-(1-0.5\tau_j)\tau_i](p_{bi}, p_{bj}) \right] p_{bn} \quad (6)$$

$$AI_{output} = \left[\sum_{i=1}^m \sum_{j=1}^m \phi_y[0.5-(1-0.5\tau_i)\tau_j](p_{bi}, p_{bj}) \right] p_{bn} \quad (7)$$

$$AI_{input-output} = \left[\sum_{i=1}^m \sum_{j=1}^{n-1} \phi_y[0.5-(1-0.5\tau_j)\tau_i](p_{bi}, p_{bj}) + \sum_{i=m+1}^{n-1} \sum_{j=1}^m \phi_y[0.5-(1-0.5\tau_i)\tau_j](p_{bi}, p_{bj}) \right] p_{bn} \quad (8)$$

The normalized quadratic profit function system of equations is estimated by iterative seemingly unrelated regression (ITSUR). Homogeneity is maintained through normalization of profit and price variables, and symmetry is imposed through linear parameter restrictions. The theoretical derivatives of technical and allocative inefficiencies and the estimation techniques can be found in Berger et al.

After banking inefficiencies have been derived, a seeming unrelated regression model is applied to identify the environmental variables affecting the inefficiencies in the banking firms. Previous studies have applied either correlation analysis (e.g., Berger, et al.) on the relation between total inefficiency and environmental variables or OLS regression analysis (e.g., Aly, et al.) with environmental variables as right hand side regressors of a single equation.

The limitation of correlation analysis is that the pairwise correlations can give little

insight into more complex relationships between three or more variables. The single-equation regression may be a reasonable approach if the study focuses only on total inefficiency. With the development of the profit function approach, total inefficiency can be decomposed into technical and allocative input and output inefficiencies. The estimation of specific inefficiencies provides an opportunity for detailed studies of the effects of environmental variables on each input and output inefficiency. A comprehensive multiple-equation analysis that includes each of the input and output inefficiencies is more compatible with the profit function approach in estimating the determinants of banking inefficiency. In this study, total inefficiency, technical input inefficiency, technical output inefficiency, allocative input inefficiency, and allocative output inefficiency are hypothesized to be represented by the following functions in linear form:

$$\text{TOTAL} = F (\text{LASSET}, \text{ROA}, \text{AGLOAN}, \text{LOANDEP}, \text{HHI}, \text{INDEX}, \text{BHCFLAG}),$$

$$\text{TINPUT} = F (\text{LASSET}, \text{ROA}, \text{AGLOAN}, \text{LOANDEP}, \text{HHI}, \text{BHCFLAG}),$$

$$\text{TOUTPUT} = F (\text{LASSET}, \text{ROA}, \text{AGLOAN}, \text{LOANDEP}, \text{HHI}, \text{INDEX}),$$

$$\text{AINPUT} = F (\text{LASSET}, \text{ROA}, \text{AGLOAN}, \text{LOANDEP}, \text{HHI}, \text{BHCFLAG}),$$

$$\text{AOUTPUT} = F (\text{LASSET}, \text{ROA}, \text{AGLOAN}, \text{LOANDEP}, \text{HHI}, \text{INDEX}).$$

where,

TOTAL	= total inefficiency of each bank,
TOUTPUT	= technical output inefficiency of each bank,
TINPUT	= technical input inefficiency of each bank,
AINPUT	= allocative input inefficiency of each bank,
AOUTPUT	= allocative output inefficiency of each bank,
LASSET	= bank size, measured by the natural log of a bank's total assets,
ROA	= bank profitability, measured by a bank's rate of return on assets,
AGLOAN	= ratio of agricultural loan to total loan for each bank,
LOANDEP	= ratio of loan to deposit for each bank,
HHI	= market concentration, as measured by the Herfindahl-

Hirschmann index,
INDEX = output diversity index-- equal to the sum of the bank's squared
output shares,
BHCFLAG = affiliation with a multibank holding company: 0 if not affiliated
with a multibank holding company,
1 otherwise.

Bank size (LASSET), bank profitability (ROA), ratio of agricultural loans (AGLOAN), output-input ratio (LOANDEP), and market concentration (HHI) are specified as explanatory variables in all five equations. Larger banks are likely to have greater management resources and produce their services more efficiently, so a negative relationship is anticipated between LASSET and inefficiency. Since higher profitability is often generated by more efficient management, a negative relation is expected between ROA and a bank's inefficiency.

Market concentration is measured by the Herfindahl-Hirschmann index (HHI). A higher degree of concentration may inhibit competitive behavior and result in higher levels of inefficiency. However, more competition may result in higher marketing expenses and possibly higher inefficiency. Thus, there is no certain relationship hypothesized between HHI and inefficiency.

Concentration in agricultural lending is measured by a bank's ratio of agricultural loans to total loans (AGLOAN). A higher level of agricultural lending may indicate a less diversified output structure and less efficiency in producing other outputs. On the other hand, a higher level of agricultural lending may be the result of economies of scale in which higher quality management can be acquired at lower costs. Thus, there is no certain relationship hypothesized between AGLOAN and bank inefficiencies.

A bank's output-input ratio (LOANDEP) is also expected to have a negative effect on its inefficiency, since a higher ratio means that more outputs are generated from a given set of

inputs

Output diversity (INDEX) is specified as an explanatory variable in equations of total inefficiency, technical output inefficiency and allocative output inefficiency, assuming that input inefficiency, either technical or allocative, are not affected by the degree of output diversity. This variable is calculated as

$$INDEX = \sum_{i=1}^n S_i^2 \quad (9)$$

where n is the total number of different products produced by the bank and S_i is the proportion of a firm's total dollar value of outputs accounted for by the i th output. The index takes a value of 1 for single-product banks and decreases with product diversity. A highly diversified output structure may reflect the flexibility of a bank's operation which could help improve its efficiency. On the other hand, an overdiversified output structure could be the result of less specialization and less efficiency in operation. Thus, there is no certain relationship hypothesized between INDEX and bank output inefficiency.

Multibank holding company affiliation (BHCFLAG) is specified as an explanatory variable in the equations of total inefficiency, technical input inefficiency and allocative input inefficiency. Output inefficiency, either technical or allocative, is assumed to be unaffected by holding company affiliation. A multibank holding company often establishes banking policies and procedures for affiliated banks. Furthermore, technology and managerial expertise are often shared among affiliated banks; thus, a negative relationship is expected between multibank holding company affiliation and inefficiency.

Data

The value-added approach is used to define bank inputs and outputs (Berger et al.).

The definitions of variables include:

Variable Inputs:

- q_1 : Number of employees
- q_2 : Physical capital (\$)
- q_3 : Small interest-bearing deposits (\$)
- q_4 : Large interest-bearing deposits plus purchase funds (\$)

Fixed Inputs:

- z_1 : Non-interest bearing deposits (\$)

Variable Input Prices:

- p_1 : Labor expense/ q_1
- p_2 : Expense on fixed assets/ q_2
- p_3 : Interest expenses on small interest-bearing deposits/ q_3
- p_4 : Interest expenses on large interest-bearing deposits and purchased funds/ q_4 .

Variable Outputs:

- q_5 : Real estate loans (\$)
- q_6 : Non-real estate wholesale loans(\$)
- q_7 : Non-real estate retail loans (\$)
- q_8 : Securities (\$)

Fixed Outputs:

- z_2 : Other bank outputs (\$) -

Variable Output Prices:

- p_5 : Income on q_5/q_5
- p_6 : Income on q_6/q_6
- p_7 : Income on q_7/q_7
- p_8 : Income on q_8/q_8

With the exception of "other bank output", the definitions of variables are generally consistent with previous value-added approaches in defining commercial bank inputs and outputs (Berger et al). Off-balance sheet activities (e.g., securitization, loan commitments, standby letters of credit, and farm management) have increased significantly over the past decade (Sinkey). A proxy for these activities should be included in models for commercial banks. In this study, "other bank output" is used as a proxy for off-balance sheet activities. "Other bank output" is computed as all noninterest revenues less service charges on deposits and less gains on securities sold. It is treated as a fixed output primarily because of limitations in the banking data preventing a proxy price from being computed.

Four-quarter averages from the 1990 Call and Income Reports are used to obtain the data for rural banks. The advantage of averaging the quarterly data is that it reduces the effects of seasonality on the input and output measures (Ellinger and Neff). Rural banks in this study are selected according to the following criteria:

1. At least 50 percent of branch deposits are located in nonmetropolitan service areas, or the bank has an agricultural loan ratio of 25 percent or higher.
2. The bank has at least \$1 million of agricultural loans in each quarter from March 1987 through December 1990.

In order to reduce outlier and data misspecification effects, the banks selected are required to meet the following criteria: (1) all output (loan and security) prices are between 5% and 21%, (2) the average full-time equivalent wage rate is greater than \$5,000, (3) the number of bank employees is greater than 5, (4) physical capital value is greater than \$50,000, (5) price on small interest-bearing deposits is between 0% and 10%, and (6) price on large interest-bearing deposits is between 0% and 15%. There were 1,805 banks that met the selection criteria.

Results

Inefficiencies estimated by the normalized quadratic profit function system are the dollar values of potential profit that could be gained in the absence of inefficiency. To make the level of inefficiencies comparable among banks of different size, inefficiencies are reported as the percentage of total assets. The average level of total inefficiency is 10.92% of banks total assets (Table 1). This indicates that banks in this sample, on average, lose variable profit by 10.92% of their assets because of technical and allocative inefficiencies.

The five equations of total inefficiency, technical input inefficiency, technical output inefficiency, allocative input inefficiency, and allocative output inefficiency are jointly estimated by SUR. The estimated correlation matrix of cross model disturbances indicates that they are correlated (Table 2). Applying OLS on each equation separately will not yield efficient estimates. By estimating the five equations jointly, SUR estimates would be more

efficient than OLS since the variance of the estimator will be smaller with SUR than with OLS.

Estimation results of the SUR model are presented in Table 3. The system weighted R^2 is 0.69, and 26 of the 36 estimated coefficients are significantly different from zero at the 5% level. Multicollinearity is a concern in the model specification. The collinearity of all the exogenous variables is checked by three cut-off indicators -- correlation coefficients, condition index, and values of inflation factor. The values of these three indicators in the exogenous variables are all lower than the cut-off values suggested by Kmenta and Judge, et.al. Therefore, multicollinearity in this model specification should not seriously affect the accuracy of results.¹

The significant negative effects of bank size (LASSET) and return on assets (ROA) on total inefficiency suggest banks that are larger in size and greater in profitability generally would be more efficient than other banks, a result consistent with hypothesis of this and previous studies (Berger et al.). However, these effects are not consistent for all input and output inefficiency categories. For example, the effect of bank size on technical input inefficiency is significantly positive, meaning that larger banks may be less capable of optimizing their input set than smaller banks.

The ratio of agricultural loans to total loans (AGLOAN) is negatively related to total inefficiency and technical output inefficiency. However, its effects on technical input inefficiency and allocative input inefficiency are significantly positive, indicating that increasing the agricultural loan ratio may improve total efficiency and technical output efficiency, but it may also increase the technical and allocative input inefficiencies. This increase of inefficiency in these two categories may be a result of the small size of agricultural

loans and the increase in cost of information in assessing and monitoring agricultural loans.

The loan-deposit ratio (LOANDEP) also has mixed effects on banking inefficiency. Its significant negative effects on allocative input and output and technical output inefficiencies are anticipated; however, its significant positive effect on technical input inefficiency is unexpected. This result suggests that the loan-deposit ratios among the sample banks are higher than the optimal level.

The effects of output diversity (INDEX) on technical output and total inefficiency are significantly negative, suggesting that a more specialized output structure may help banks improve their efficiency.

Market concentration (HHI) has mixed effects on bank inefficiencies. Its significant positive effect on technical output inefficiency suggests that banks with higher market power may have less incentive to improve their output inefficiency. The significant negative effect of market concentration on technical input inefficiency implies that banks with higher market power may enjoy a technical advantage in producing their outputs more efficiently.

Affiliation with a multibank holding company (BHCFLAG) has a significant negative effect on technical input and total inefficiencies, implying that banks affiliated with multibank holding companies are more efficient than other banks in managing their input resources, a result also consistent with the hypothesis.

Conclusions

Previous studies of characteristics of banking inefficiency have been dominated by correlation analysis of total inefficiency and environmental variables or single equation regression of total inefficiency with selected environmental variables as regressors. The profit function approach used in this paper provides technical input and output and allocative input

and output inefficiency estimates. To provide insight on characteristics of each input and output inefficiency, a coordinated estimation approach was required. The seeming unrelated regression (SUR) method uses the estimates of covariance of residuals across equations in an attempt to improve the efficiency of parameter estimate over the ordinary least squares (OLS) method. Based on previous functional form and model specification tests using the same data set, this study estimates banking inefficiency using the profit function approach and examines the characteristics of banking inefficiency using the SUR approach.

SUR estimation results indicates that effects of environmental variables on input and output inefficiency measures are not consistent across all measures of bank inefficiency. While increasing bank assets, profitability and bank holding company affiliation may help banks improve their total inefficiency, their effects on certain input or output inefficiency are not consistent.

Endnote

- ¹ The cut-off value of conditional index suggested by Kmenta is 30, the cut-off value of inflation factor (VIP) suggested by Judge et al. is 5 and the cut-off value of correlation coefficient suggested by Judge et. al. is 0.8. If any value of these indicators exceed the suggested cut-off value, multicollinearity is thought to be harmful. The values of the condition index, VIP, and correlation coefficient of the dependent variables in this data set are 4.01, 3.08 and 0.73, respectively.

Table 1. Inefficiencies Estimates as Percentage of Assets.

Asset Class	Number of Banks	Frontier	Total Inefficiency	Technical Inefficiency		Allocative Inefficiency		
				Input	Output	Input	Output	Input-Output
Total Sample	1,805	Profit	10.92	2.17	6.58	0.30	1.88	0.00
Assets < \$50M	911	Profit	13.30	2.10	8.29	0.40	2.51	0.00
\$50M < Assets < \$150M	839	Profit	8.79	2.29	5.02	0.20	1.28	0.00
\$150M < Assets < \$250M	48	Profit	4.15	1.41	2.19	0.06	0.50	0.00
Assets > \$250M	7	Profit	2.5	1.18	0.96	0.04	0.32	0.00

Table 2. The Cross Model Correlation Matrix.

	TOTAL	TINPUT	TOUTPUT	AINPUT	AOUTPUT
TOTAL	1.00	0.41	0.65	0.08	-0.17
TINPUT		1.00	-0.43	0.13	-0.24
TOUTPUT			1.00	-0.03	0.03
AINPUT				1.00	0.35
AOUTPUT					1.00

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