INTERNATIONAL COMPARISON OF BANK EFFICIENCY: AN EMPIRICAL STUDY OF LARGE COMMERCIAL BANKING IN THE UNITED STATES AND JAPAN

DISSERTATION

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ABSTRACT

There have been many papers estimating the bank efficiencies in the United States. However, there are very few bank efficiency studies outside of the United States and there are no prior frontier efficiency comparisons across international borders.

This paper uses a stochastic cost frontier approach to estimate the bank efficiencies in the United States and Japan. The paper examines scale efficiency (whether banks are operating with the efficient level of outputs) and input X-efficiency (whether banks are using their inputs efficiently).

The results indicate that significant overall inefficiencies exist in commercial banking and these inefficiencies result from input X-inefficiency (technical inefficiency). On average, U.S. multinational banks and Japanese banks are operating at cost-efficient output levels, but are not efficiently using their inputs. U.S. domestic banks are found to enjoy an increasing return to scale, implying that the average size of U.S. domestic banks has not reached the optimal size at which operating cost will be lowest. Results also show that large banks in Japan had the largest measure of input X-inefficiency amounting to 38.5 percent of total costs as well as significant levels of diseconomies of scale. Finally, U.S. multinational banks are able to fully exploit economies of scale and lower input X-inefficiencies than U.S. domestic banks.

Dedicated to my wife and my son.

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This dissertation is for my late mother, late father, my wife, my son and all my family members.

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CHAPTER 1

INTRODUCTION

Large U.S. banks in particular (and banks in general) are facing an environment of increasingly contestable international markets for most wholesale products such as corporate loans, corporate deposits, etc.. Banking industry is by far one of the most tightly regulated industries in the United States, facing limits on geographic expansion and product diversification, and capital and reserve requirements. In recent years, however, restrictions on interstate banking and interstate branching have been liberalized in many states. In addition, limitations have been narrowed on the types of services financial institutions can offer. Many new domestic competitors such as securities firms, savings and loans, finance companies and newly merged superregional banks are escalating competition. Moreover, as global markets continue to develop, many foreign banks, with the dominance of Japanese banks, entered U.S. markets and undercut their U.S. competitors in extending loans and deposits. Thus, domestic commercial banks compete at home not only with other domestic financial institutions, but also increasingly with foreign banks.

With an increasing competition, the U.S. commercial banking industry has consolidated from 14,500 banks in 1983 to fewer than 10,500 in 1994 due to bank failures and mergers. As a result, the U.S. commercial bank share of assets among U.S. financial institutions fell from 60 percent in 1960s to below 40 percent today. On the other hand, with an increasing presence of foreign banks in the United States, total assets of foreign banks, which was about 10 percent of all banking assets in the United States as early as 1980, exceeded 22 percent in 1989. Among foreign banks, Japanese banks stand out since 15 of the 25 largest foreign banks operating in the United States are Japanese.

While these changes have created new opportunities for individual commercial banks to grow, they have raised questions about the future structure of the banking industry. The industry structure might come to be dominated by a small number of large commercial banks. How banks will be affected by the increased competitive pressures depends in part on how efficiently they are run. As regulatory policy and market realities bring banks into closer competition with their domestic and international counterparts, their success will depend on their ability to adapt and operate efficiently in the new environment. Banks that fail to do so will be driven from the market by more efficient ones. That is, the most efficient banks will have a competitive advantage. Cost efficiency becomes critically important in an environment of increasingly contestable international markets. Competitive pressures in the banking industry force banks to try to be as efficient as possible, both by staying closely to the production frontier, and by the choice of an appropriate scale of operation. The further a bank falls off the production frontier, the higher will be its degree of inefficiency and the larger the possibility of its failing or being subjected to a take-over.

To analyze the competitive advantages of U.S. commercial banks, we will provide answers to the following questions. (1) Do larger banks enjoy a cost advantage over smaller banks? In so doing, we can determine whether consolidation in the banking industry will improve or worsen resource utilization in commercial banking. This is the question of economies of scale. (2) Do all banks operate on or close to the best practice cost frontier? This is the question of input X-efficiency. (3) Does there exist cost advantage associated with foreign expansion? This is the question of multinational banking. And (4) more importantly, do U.S. commercial banks have cost advantages over Japanese banks? How else can the average U.S. bank of $0.26 billion in assets compete with much larger banks in Japan ($37 billion), Germany ($2.5 billion), or the United Kingdom ($16 billion)? As yet, none of the studies generates insights into such important questions as whether Japanese banks are more or less efficient than US banks in any particular size-class and whether the range of inefficiency is as wide as that found for U.S. banks.

This study extends the literature on bank efficiency in several ways. First, this study applies a cost frontier approach while conventional bank cost studies generally apply a cost function framework. The use of a conventional cost function is inappropriate for the measurement of input X-efficiency since this precludes the disentanglement of scale economies from input X-efficiency. That is, previous banking efficiency studies assumed input X-efficiency, but, for this study, it is assumed that the bank is attempting to minimize costs and that managerial mistakes are made in input usage. Second, the present study examines the cost structures of multinational banks (MNBs) and domestic banks (DBs) to shed light on the cost advantage of becoming multinational banks. Third, this study measures and compares input X-efficiencies as well as scale economies of large commercial banks in the United States and Japan. Although there have been extensive bank efficiency studies in the United States, there are very few studies outside of the United States.[1] Moreover, there are no frontier efficiency comparisons across international borders, perhaps owing to data limitations. Recently, Allen and Rai (1993), Saunders and Walter (1994), and Altunbas and Molyneux (1993) tried to compare bank efficiencies across countries by using several international databases (Global Vantage, Worldscope, and IBCA, respectively). However, their studies pooled banks in different countries and their methodology does not control for input X-inefficiencies.

The present study is the first attempt to undertake a systematic comparison of economies of scale and input X-inefficiencies for the large commercial banks in the United States and Japan, distinguished by different regulatory environments. We use the stochastic econometric cost frontier approach using the FDIC insured bank data set for U.S. domestic banks, U.S. multinational banks, Japanese banks operating in the United States, and the Kaisha Nenkan bank dataset for Japan as observed in 1994, which are

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[1] For example, Murray and White (1983), M. Kim (1985), and Kolari and Zardkoohi (1990), respectively, studied scale and scope efficiencies in Canadian, Israeli and Finnish financial institutions without using frontier methods. More recently, Saunders and Walter (1994) studied scale and scope economies among the world's 200 largest banks during the 1980s.

considered appropriate for the intermediation approach.[2] Our findings have implications for regulatory policy pertaining to the size and competitiveness of U.S. banks in both domestic and international markets.

The rest of the study is organized as follows. Chapter 2 reviews the techniques used to estimate frontier functions and summarizes previous studies concerning bank efficiency in the United States. Chapter 3 discusses the stochastic econometric cost frontier model and derives the formula to measure the scale economy and the technical inefficiency. Chapter 4 outlines banking systems in the United States and Japan, and discusses the data sources and data construction. Chapter 5 provides and compares the empirical results for the large U.S. domestic banks, U.S. multinational banks, Japanese banks, and Japanese banks operating in the United States. Chapter 6 summarizes and concludes the paper.

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[2] In this paper, the stochastic cost frontier model is adopted for two basic reasons. First, stochastic frontier model avoids some of the problems associated with DEA by explicitly considering the stochastic properties of the data, and distinguishing through a composite error term between firm-specific effects and random shocks or statistical noise. Second, in the case of multiple-input/multiple-output technology, the thick frontier approach (TFA) may be problematic as the ordering criterion implies a different model from that estimated.

CHAPTER 2

A REVIEW OF THE CURRENT LITERATURE

2.1 Methodology

Bank efficiency studies can be divided into those that examine scale and scope efficiency (output efficiency) alone, and those that examine allocative and pure technical efficiency (input X-efficiency).

Economies of scale, which are associated with firm size, exist if, over a given range of output, per unit costs decline as output increases (increasing returns to scale). Conversely, if per unit costs rise with output, diseconomies of scale present (decreasing returns to scale). A scale efficient firm will produce where there are constant returns to scale. Economies of scope, which relate to the joint production of two or more products, arise if two or more products can be jointly produced at a lower cost than produced separately. Diseconomies of scope are present if the cost of joint production is less than the cost of independent production.

Productive efficiency requires optimizing behavior with respect to inputs as well as outputs. Input X-inefficiency means that, for a given level of output, the firm is not optimally using the factors of production. Overall input X-inefficiency resulting from the sub-optimal use of inputs can be decomposed into allocative and pure technical inefficiency. Allocative inefficiency occurs when inputs are combined in sub-optimal proportions. Regulation is typically given as a major reason for this occurrence. Pure technical inefficiency occurs when more of each input is used than should be required to produce a given level of output. The intuition of a measure of overall input X-efficiency proposed by Farrell (1954) can be seen from Figure 1. A firm uses two inputs k and l to produce a given level of a single output y. Isoquant AB depicts various efficient combinations of the two inputs which can be used to produce a specific level of output y. For a given set of input prices, the isocost line, DD' represents the various combinations of inputs which generate the same level of expenditures. If the objective of the firm is to produce a particular level of output y at minimum cost, then the optimal input combination is at point Q'. That is, firm Q' is both technically and allocatively efficient. Comparing the input utilization at point P to that at Q', we can derive the level of inefficiency resulting from sub-optimal use of inputs. Suppose that the firm uses the input combination given by point P to produce y. Then two types of inefficiencies arise: (a) It is technically inefficient, since by moving to point Q, it could produce the same output with less inputs. The degree of technical efficiency is measured by the ratio OQ/OP. (b) It is allocatively inefficient, since by moving from point Q to point Q', and thereby adjusting to the given factor prices, it could produce the same output at a lower total cost. The extent of its allocative efficiency is measured by the ratio *OR/OQ*. Overall input X-efficiency can be defined by the ratio *OR/OP*, which corresponds to the product of technical efficiency (*OQ/OP*) and allocative efficiency (*OR/OQ*). All these ratios are in the interval (0,1), where a value of one indicates full efficiency. Obviously, Farrell's method is a step beyond simple cost comparisons. That is, by measuring pure technical efficiency relative to an achieved efficiency frontier, Farrell was able to separate the allocative and pure technical decisions.

Although the concepts of efficiencies are rather straightforward, various difficulties are encountered when attempting to measure them. The traditional scale and scope economy studies estimate an average practice cost function, which relates bank cost to output levels and input prices. The techniques implicitly assume that there is no input X-inefficiency and that banks are using the same production technology. A two-sided error term is included in the cost function to represent measurement errors or any unpredicted factors. Most traditional scale and scope economy studies do not use a frontier estimation method. Scale or scope economies, however, theoretically apply only to the efficient frontier, and the use of data from banks off the frontier could confound sale or scope efficiencies with differences in input X-efficiency. Recently, however, studies concerned with frontier model estimate a best practice cost function, which represents the predicted cost function of banks in the sample, relative to this best practice technology. The use of frontier models for estimating bank efficiency is becoming increasingly widespread for a variety of reasons. First, the notion of a frontier is consistent with the underlying economic theory of optimizing behavior. Second, deviation from a frontier have a natural interpretation as a measure of the efficiency with which banks pursue the technical objectives. Finally, information about the structure of the frontier and about the relative efficiency of banks has many policy applications. However, it was only after the pioneer work of Farrell (1957) that serious consideration has been given to the possibility of estimating frontier models, in an effort to bridge the gap between theory and empirical work. Once the best practice cost function (the cost frontier) is established, input related pure technical and allocative efficiency, and output related scale and scope efficiency, can be measured.

There are four common approaches of generating the best practice cost function: Data Envelopment Analysis (DEA), Thick Frontier Approach (TFA), Stochastic Econometric Cost Frontier Approach (EFA), and Distribution-Free Approach (DFA).[3] Each of these approaches maintains a different set of assumptions about the probability distribution of the input X-inefficiency differences and random error to distinguish between these two explanations of cost dispersion. None of these approaches is without problems.

DEA determines which bank in the sample produces a particular output combination at the given input prices at least cost. This defines the 'best practice bank' for that output/input prices combination. DEA generally assumes that there are no random errors, so that all deviations from the estimated frontier (best practice bank) represent inefficiency. A chief advantage of DEA is that no particular functional form needs to be imposed for the best practice banks' cost function. But, a serious drawback of DEA is that it does not allow for any error in the data. Banks that have been lucky or whose costs have been under-measured would be labeled as most efficient; any unfavorable influence

[3] For more detailed discussion of methodology, see L. J. Mester (1996).

beyond a bank's control would be attributed to inefficiency. Some examples are Rangan et. al. (1988), Aly et. al. (1990), Elyasiani and Mehdian (1990), and Ferrier and Lovell (1990).

TFA, first developed by Berger and Humphrey (1991), divides the banks in the sample into several fractiles based on total cost per unit of assets. By assumption, deviations from predicted costs within the lowest average cost fractile of the banks represent random measurement error and luck, while deviations in predicted costs between the highest and lowest cost fractiles represent input X-inefficiency. But, as Berger and Humphrey (1991) themselves point out, these assumptions about the error term do not hold exactly and are sensitive to whether banks are divided into quartiles or another number of groups. Further, there is the potential for econometric problems, since the banks are pre-sorted using average cost, which is essentially a dependent variable. On the other hand, in addition to being uncomplicated to implement, an advantage of the thick frontier approach is that it is more flexible regarding the statistical properties of the inefficiency measures than is the stochastic econometric frontier approach. For examples, see Berger and Humphrey (1991,1992a), Bauer et. al. (1993), Mahajan et. al. (1996).

In the stochastic econometric frontier approach (EFA), which is used in this study, a bank is labeled as inefficient if its costs are higher than the costs predicted for an efficient bank producing the same output/input price combination and the difference cannot be explained by statistical noise. The cost frontier is obtained by estimating a cost function with a composite error term, the sum of two-sided error representing random fluctuations in cost and a one-sided positive error representing inefficiency. Most studies have assumed that the two-sided error is normally distributed and the one-sided error is half-normally distributed. An advantage of this approach is that it can handle statistical noise. But, a drawback of this approach is that assumptions have to be maintained about the form of frontier and error terms. Some examples are Ferrier and Lovell (1990), Bauer et. al. (1992), and Mester (1993, 1996). But if panel data are available, some of the stochastic frontier's maintained assumptions can be weakened.

DFA, the distribution free approach, employs the average residuals of the cost function estimated with panel data to construct a measure of cost of input X-inefficiency. DFA assumes that the efficiency differences are stable over time, while random error averages out over time. Examples are Berger and Humphrey (1992b), and Berger (1993).

2.2 Studies of Bank Efficiencies

The studies reviewed in this paper attempted to estimate output inefficiency and/or input X-inefficiency for banks.[4] Each study used a translog statistical cost function and similar measures of economies of output efficiency, but different measures of input X-inefficiency.

[4] In the present paper, a discussion of the scope economies is omitted because there is no consistent evidence of economies of scope. Studies to date find very slight or no potential efficiency gains, e.g., Benston et al. (1982), Cebenoyan (1990), Clark (1988), Hunter, Timme, and Yang (1990), Lawrence and Shay (1986), Mester (1987), and Berger et. al. (1993). One of the problems in applying the translog specification to evaluate or test for scope economies is that it predicts costs of zero for specialized firms, since the translog is multiplicative in outputs.

Berger et. al. (1987) apply conventional cost function to examine the scale and scope economies of 413 branching state banks and (separately) 214 unit state banks with asset size of less than $1 billion in 1983. Employing two inputs (i.e., labor and capital) and five outputs (i.e., demand deposits, time and savings deposits, real estate loans, commercial loans, installment loans), they find an average scale economies of 0.96 (0.98) for unit (branching) state banks. They report diseconomies of scale for larger unit state banks with assets of more than $100 million, but no significant diseconomies for branching state banks.

Gilligan et. al. (1984) also apply conventional cost function to examine the scale and scope economies of 714 banks with asset sizes of less than $1 billion in 1978. Employing two inputs (i.e., labor and capital) and two outputs (i.e., sum of demand and time deposits, sum of real estate, commercial and installment loan), they find an average scale economies of 0.97 (0.98) for unit (branching) state banks. Scale economies are exhausted above $100 million in deposits for both unit state and branching state banks.

Hunter and Timme (1991) investigate scale economies and technological change for 219 large banks using data from 1980 to 1986. Employing three inputs (i.e., labor, capital and funds) and two outputs (i.e., total loans and produced outputs), they find that the banks with assets in excess of $5.0 billion have fully exhausted available scale economies, and banks with total assets in excess of $10.0 billion exhibit slight diseconomies of 2 percent.

Berger and Humphrey (1991) use TFA to measure the bank efficiencies for a sample of 7,653 banks in branch banking states and for a sample of 6,298 banks in unit banking states operating in 1984. Employing three inputs (labor, capital, and purchased fund) and five outputs (demand deposits, time and saving deposits, real estate loans, commercial and industrial loans, and installment loans), they find that input X-inefficiency is 19.1 percent for unit banking states and 23.6 percent for branch banking states, and technical inefficiencies strongly dominate the allocative inefficiencies. Scale economies are exhausted at the asset size of $75-100 million ($300-500 million) for the unit (branching) state banks.

Mahajan et. al. (1996) also apply TFA to measure the bank efficiency of 238 multinational banks and 5,257 domestic banks with assets above $62.9 million for 1987-90. Employing three inputs (i.e., labor, capital, and purchased fund) and three outputs (i.e., total loans, demand deposits, and government securities), they find the input X-inefficiency ranges of 22 to 50 percent for multinational banks and 25 to 28 percent for domestic banks, with input X-inefficiency most pronounced at the highest asset size category. Also, they find diseconomies of scale at all size levels for multinational banks and economies of scale for banks with asset size of over $500 million.

Rangan et. al. (1988) apply DEA to examine the technical efficiency of 215 banks with deposits of less than $400 million in 1986. Employing three inputs (i.e., labor, capital, and purchased fund) and five outputs (i.e., commercial and industrial loans, consumer loans, real estate loans, demand deposits, and time and savings deposits), they find an average input X-inefficiency of 31 percent, implying that banks can produce the same output with 31 percent fewer inputs. Decomposing total input X-inefficiency produces pure technical inefficiency of 28 percent and allocative inefficiency of 3 percent, implying that pure technical inefficiency dominates allocative inefficiency. Further, they find that bank size positively affects input X-efficiency.

Grabowski et. al. (1994) also apply DEA to consider the efficiency for a group of 670 banks in 1979, 1983, and 1987. Employing three inputs (i.e., labor, capital, and loanable funds) and five outputs (i.e., commercial and industrial loans, consumer loans, real estate loans, securities, and demand deposits), they conclude that pure technical inefficiency provides the main source of technical inefficiency. Input X-inefficiency was reduced over time, with 1983 being lowest, while scale efficiency remained fairly constant over time. Finally, largest banks with deposits in excess of $1 billion had the highest technical efficiency.

Aly et. al. (1990) apply DEA to explore various measures of efficiency for 322 randomly chosen independent banks in 1986. Employing three inputs (i.e., labor, capital, and loanable funds) and five outputs (i.e., commercial and industrial loans, consumer loans, real estate loans, other loans, and demand deposits), they discover that pure technical inefficiency dominates scale inefficiency. Specifically, scale, allocative and pure technical inefficiencies are 3, 13, and 23 percent, respectively. Once again, they find that bank size and efficiency are positively related.

Elyasiani and Mehdian (1990b) apply DEA to investigate bank efficiency, as well as technological change, for a sample of 191 banks with assets in excess of $300 million in both 1980 and 1985. Employing four inputs (i.e., labor, capital, demand deposits, and savings and time deposits) and four outputs (i.e., commercial and industrial loans, real estate loans, other loans, and investment), they find that average technical inefficiency is

22.3 percent (1980) and that significant non-neutral (labor-biased) technological progress, on average, is 13.0 percent from 1980 to 85.

Ferrier and Lovell (1990) use both EFA and DEA to evaluate bank efficiency for a sample of 575 banks operating in 1984. Employing three inputs (i.e., total number of employees, occupancy costs and expenditure on furniture and equipment, and expenditure on materials) and five outputs (i.e., the number of demand deposit accounts, the number of time deposit accounts, the number of the real estate loans, the number of installment loans, and the number of industrial loans), they report an overall X-inefficiency of 21.6, using the non-stochastic cost frontier and 26.4 percent, using the stochastic cost frontier. Surprisingly, they find, unlike the other studies cited, that small banks (i.e., banks with under $25 million in assets) are the most efficient.

Elyasiani and Mehdian (1990a) apply EFA (deterministic econometric cost frontier) to measure bank efficiency for a random sample of 144 banks operating in 1985. Employing four inputs (i.e., labor, capital, demand deposits, and savings and time deposits) and two outputs (i.e., loans and investment), they find that scale inefficiency is 27.2 percent (1980) and pure technical inefficiency is 11.7 percent, indicating that the most of the inefficiency is due to scale inefficiency rather than pure technical inefficiency. In addition, they also find that larger banks (assets greater than $300 million) are more efficient than smaller banks and that there is no effect of bank holding company status.

Kaparakis et. al. (1994) use EFA (stochastic econometric cost frontier) to evaluate bank efficiency for a sample of 5,548 banks with total assets above $50 million operating in 1986. Employing four inputs (i.e., deposits, funds, labor and capital), and four outputs (i.e., consumer loans, real estate loans, commercial and industrial loans, federal fund sold, and securities), and one quasi-fixed input (demand deposit). They report a technical inefficiency of 9.8 percent. Surprisingly, they find, unlike the other studies cited, that average inefficiency rises with bank size. For banks with over $10 billion in assets, the average technical inefficiency is 17 percent.

Several general conclusions emerge from this literature. First, the prior literature on scale inefficiency in banking suggests that the average cost curve has a relatively flat U-shape, with medium-sized banks being slightly more scale efficient than either very large or very small banks. Second, studies that used only banks with under $1 billion in assets, usually found that scale advantages are fully exhausted once an institution achieves a size of approximately $100-200 million, a relatively small bank in the United States.[5] Higher output levels result in either constant or decreasing return to scale. The extent of the inefficiency, however, would not appear to be very large. Scale economies typically range from 0.91 to 1.02. Table 1 summarizes the results from small banking efficiency studies. Third, recent studies that have analyzed larger banks with over $1 billion in assets found that scale economies exist well beyond the $100-200 million range. That is, scale advantages are exhausted in the $0.3-37.0 billion range in assets. Table 2 provides a summary of results from recent studies of larger banks. Again, the scale elasticity

[5] Most of the studies used the Federal Reserve's Functional Cost Analysis (FCA) survey data which typically includes only institutions with less than one billion dollars in assets. Although banks in this size group constitute over 95 percent of all banks in the Unites States, they constitute only about 30 percent of the nation's banking assets [Call Report and financial statement data, 1994].

measures tend to range from 0.89 to 1.16. Therefore, the studies employing data for larger banks tend to argue against the finding that inefficiencies resulting from diseconomies of scale set in at relatively low levels of output. Table 2 also indicates that the representative cost minimizing commercial bank is operating at output levels where there are slightly increasing returns to scale. Fourth, input X-inefficiency (allocative and pure technical inefficiency) across banks are relatively large and dominate output inefficiency (scale and scope inefficiency). These results indicate that there is substantial room for improvement at U.S. banks and that elimination of input X-inefficiency could produce larger cost savings than if banks change the scale or scope of their operations. This also implies that the assumption of input efficiency, common in most studies of bank production, is typically violated. Fifth, while substantially different techniques were used in the studies reviewed, the results are surprisingly similar. Studies that used either the TFA or EFA find input X-inefficiency on the order of 20 to 30 percent in banking, meaning the average bank could produce a cost savings of about 20 to 30 percent if it eliminated input X-inefficiency. Since DEA attributes statistical noise to inefficiency, DEA studies have found input X-inefficiencies on the order of 30 to 40 percent. Table 3 presents summary findings for recent studies evaluating input X-efficiency in banking. Sixth, the major source of input efficiency in banking is pure technical inefficiency. Breaking down the study findings into more detail, allocative inefficiency is typically found to be relatively minor, and with one exception, dominated by technical inefficiency. This implies that bank managers do a relatively good job of choosing the proper input mix, but then simply use too much input per unit of output. This inefficiency obviously cannot be sustained over time if the banks are subject to competitive forces. While the typically small allocative inefficiency estimates cannot be ignored as a potential source of future cost savings in banking, the optimal mix of factor inputs is only marginally affected by regulation. Finally, a positive relationship appears to exist between the level of efficiency and bank size.

CHAPTER 3

THE STOCHASTIC ECONOMETRIC FRONTIER MODEL

3.1 The Stochastic Cost Frontier Model

The stochastic econometric frontier approach was first proposed by Aigner, Lovell, and Schmidt (1977), Meeusen and Van den Broeck (1977), and Battese and Corra (1977). Most applications of the stochastic econometric frontier methodology have been to estimating production frontiers. The behavioral assumption underlying direct estimation of the production frontier is generally the Zellner-Kmenta-Dreze assumption of expected profit maximization, which implies exogenous input quantities. It is well known that either the cost function or production function uniquely defines the technology. [6] Which one is to be estimated depends on one's assumptions and/or data. The behavioral assumptions underlying direct estimation of the cost frontier is generally cost minimization with output

[6] A general multiproduct production function that transforms a vector of inputs X into a vector of outputs Y can be presented by $f(Y_1, Y_2, \cdots\cdots\cdots, Y_n, X_1, X_2 \cdots\cdots\cdots, X_m) = 0$. It has been shown that there exists a unique multiproduct cost function with factor prices P, $C = g(Y_1, Y_2, \cdots\cdots\cdots, Y_n, P_1, P_2 \cdots\cdots\cdots, P_m)$, which is the dual to the production function and is more convenient to estimate.

exogenous. (e.g., because firm is regulated) . It requires data on input prices but not input quantities. For the present study, the stochastic frontier model is employed because it allows for statistical noise resulting from events outside the bank's control, such as luck and weather, as well as disturbances resulting from within bank's control. Employing a stochastic frontier can also be seen as allowing for some types of specification error and for omitted variables uncorrelated with the included regressors. In this specification, the cost of each bank is above by a frontier that is stochastic in the sense that its location is allowed to vary randomly across banks. From an economic standpoint, this technique permits banks to be technically inefficient relative to their own frontier rather than to some sample norm. Interim variation of the frontier presumably captures the effects of exogenous shock, favorable and unfavorable, beyond the control of the banks. Errors of observation and measurement constitute another source of variation in the frontier. That is, this approach posits that a bank's observed cost will deviate from the cost frontier because of random noise and possible inefficiency. In developing the stochastic frontier model, it is assumed that the bank seeks to minimize the cost of producing its desired rate of output subject to a stochastic production frontier constraint. Also, the bank is permitted to be technically inefficient by allowing it to operate beneath its stochastic production frontier, but it is also assumed that the bank is allocatively efficient by requiring it to operate on its least cost expansion path without any loss. This is because most empirical studies report minor allocative inefficiency in banking, as compared to technical inefficiency. Then, using Farrell's (1957) definitions of inefficiency, a stochastic cost frontier model that allows for input X- inefficiency can be written as

$$\ln C_i = \ln C(y_i, w_i; \beta) + \varepsilon_i \qquad i=1,.............N. \qquad (1)$$

$$\varepsilon_i = u_i + v_i$$

where C_i is the observed cost of bank *i*, y_i is the vector of output levels for bank *i*, w_i is the vector of input prices, β is a vector of parameters to be estimated, u_i is a one-sided disturbance (nonnegative for cost frontiers) capturing the effects of inefficiency, and v_i is a two-sided disturbance capturing the effects of noise. This is reasonable since v represents the influence of factors outside the control of the bank, while u represents technical errors of the bank. Technical inefficiency relative to the stochastic cost frontier is given by u percent. The $v_i s$ are assumed to be independently and identically distributed, and the $u_i s$ are assumed to be distributed independently of the $v_i s$. ε_i is the composite error term, which is the sum of a one-sided disturbance and a two-sided disturbance terms. The deterministic kernel of the cost frontier is $C(y_i, w_i; \beta)$, and the stochastic frontier is $C(y_i, w_i; \beta)\exp(v_i)$. This model has the characteristic that disturbances $u_i s$ representing technical inefficiency increase observed cost, whereas statistical noises $v_i s$ can either increase or decrease observed cost. Here, it is assumed that the $u_i s$ are the absolute values of a variable that is normally distributed with mean 0 and variance σ_u^2, and the $v_i s$ are normally distributed with mean 0 and variance σ_v^2 as usually assumed in bank efficiency literature.[7] That is,

$$u_i \sim |N(0, \sigma_u^2)| \ ,$$

$$v_i \sim N(0,\ \sigma_v^2) \qquad (2)$$

and $\varepsilon_i = u_i + v_i$.

3.2 Estimation

With these distributional assumptions, the joint density function for ε_i is derived as

$$f(\varepsilon) = \int_0^{\infty} \frac{1}{\pi\sigma_u\sigma_v} \exp\left[-\tfrac{1}{2}\left(\left(\tfrac{u}{\sigma_u}\right)^2 + \left(\tfrac{\varepsilon - u}{\sigma_v}\right)^2 \right) \right] du, \qquad (3)$$

which integrates to

$$f(\varepsilon) = \frac{2}{\sigma} f^{*}\left(\tfrac{\varepsilon}{\sigma}\right)\left[F^{*}\left(\tfrac{\varepsilon\lambda}{\sigma}\right)\right], \qquad -\infty \le \varepsilon \le +\infty, \qquad (4)$$

---

[7] Other distributions have also been used. For example, Stevenson (1980) used the normal-truncated model, in which $v_i \sim N(0, \sigma_v^2)$ and u_i is the absolute value of a variable that is independent of v and is distributed as $N(\mu, \sigma_u^2)$. Stevenson (1980) and Green (1990) also used the normal-gamma model. They suggest a limited effect of distributional assumptions on the obtained estimates and the relative ranking of firms based on inefficiency calculations seem unaffected. Mester (1996) also shows that the inefficiency results appear to be robust to different distributional assumptions on inefficiency term u.

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \sigma_u / \sigma_v$, and $f^*(\cdot)$ and $F^*(\cdot)$ are the standard normal density and the standard normal cumulative functions, respectively.[8] This density is asymmetric around zero.

The mean and variance of ε are

$$E(\varepsilon) = E(u) = \sqrt{\frac{2}{\pi}}\sigma_u \ ,$$

$$\begin{aligned} V(\varepsilon) &= V(u) + V(v) \\ &= \left(\frac{\pi - 2}{\pi}\right)\sigma_u^2 + \sigma_v^2 \ . \end{aligned} \tag{5}$$

The particular parameterization in (4) is convenient because λ is thereby interpreted to be an indicator of the relative variability of the two sources of random error that distinguish banks from one another. $\lambda^2 \to 0$ implies $\sigma_v^2 \to \infty$ and /or $\sigma_u^2 \to 0$; i.e. that the symmetric error dominates in the determination of ε. Density function (4) then becomes the density of a $N(0,\sigma^2)$ random variable. Similarly, when $\sigma_v^2 \to 0$, the one-sided error becomes the dominant source of random variation in the model.

Assuming we have available a sample of N observations for this single equation model, we can write the log likelihood function as

$$\ln L(C|\beta,\lambda,\sigma^2) = \tfrac{N}{2}\ln\tfrac{2}{\pi} - N\ln\sigma - \tfrac{1}{2\sigma^2}\sum_i \varepsilon_i^2 + \sum_{i=1} \ln F^*(\tfrac{\varepsilon_i\lambda}{\sigma}). \tag{6}$$

[8] See E. Stevenson (1980) for the derivation of the density function of ε_i.

The model can be estimated using maximum likelihood techniques. Various solution algorithms are available for finding the optimizing values of β, λ and σ^2.[9]

3. 3 The Cost Frontier Specification

It remains to choose a functional form for the cost frontiers $\ln C(y_i, w_i; \beta)$. In developing these functions, researchers begin with the microeconomic principle that production costs depend on input prices, and the level and composition of output. We specifically chose the transcendental logarithmic (translog) cost function as the basic functional form for this study. The translog function is the most frequently selected statistical function to measure bank efficiency (Christensen, Jorgenson, and Lau, 1973). This function is usually selected because it is a flexible functional form that places no priori restrictions on substitution possibilities among the factors of production and hence allows both economies and diseconomies of scale at different output levels. That is, the translog form can estimate a U-shaped cost curve if one exists in the data because the translog has linear output terms, like the Cobb-Douglas, but also squared output terms. If a U-shaped cost curve were in fact estimated, it would show scale economies at smaller banks and diseconomies at larger ones. Unlike the Cobb-Douglas form, quadratic forms capture variations of scale economies across banks of different sizes.

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[9] For a good discussion of the available algorithms, see Goldfeld-Quandt (1971) and Cosslett's lecture notes (1995).

The translog cost frontier for n outputs (y_i), and m input prices (w_j) in country K can be written as follows :

$$\ln C^K = \alpha_0^K + \sum_{i=1}^{n} \alpha_i^K \ln y_i^K + \sum_{j=1}^{M} b_j^K \ln w_j^K + \tfrac{1}{2}\sum_{i}^{N}\sum_{k}^{N} s_{ik}^K \ln y_j^K \ln y_k^K$$

$$+\tfrac{1}{2}\sum_{j=1}^{m}\sum_{l=1}^{m} g_{jl}^K \ln w_j^K \ln w_l^K + \sum_{i}^{n}\sum_{j}^{m} d_{ij}^K \ln y_i^K \ln w_j^K + u^K + v^K \quad (7)$$

where

$\ln C$ = the natural logarithm of the total cost.

$\ln y_i$ = the natural logarithm of the i^{th} output $(i = 1 \cdots\cdots n)$

$\ln w_j$ = the natural logarithm of the j^{th} input price $(j = 1 \cdots\cdots m)$

$v \sim N(0, \sigma_v^2)$ and $u \sim |N(0, \sigma_u^2)|$

and α, b, s, g and d are coefficients to be estimated.

We impose two sets of parametric restrictions on the above translog cost frontier function. Symmetry requires $s_{ik} = s_{ki}$ for all i and k, and $g_{jl} = g_{lj}$ for all j and l. Not all of the parameters are free, however, since every cost function must exhibit homogeneity of degree one in input prices in order to correspond to a well-behaved production function. If the prices of all of the inputs are doubled, the price of output should also double. Mathematically, this requires that the sum of the elasticities of total cost with respect to factor prices equal 1, that is,

$$\delta \ln(C)/\delta \ln(w_1)+\delta \ln(C)/\delta \ln(w_2)+\cdots+\delta \ln(C)/\delta \ln(w_m)=1. \tag{8}$$

By alternatively setting the factor levels at 1 (so their logs are 0), we can see that equation (8) implies the following linear restrictions on (7), which are necessary and sufficient for linear homogeneity in factor prices.

$$\sum^{m} b_j = 1, \quad \sum^{m} g_{jl} = 0 \text{ for all } l, \text{ and } \sum^{m} d_{ij} = 0 \text{ for all } i \tag{9}$$

These restrictions reduce the number of parameters in (7) to (n+m+1)(n+m)/2. For example, consider the stochastic cost frontier model with two outputs (y_1, y_2) and three input prices (w_1, w_2, w_3), which is used for this study. Then, restrictions imposed on the model are:

$s_{12} = s_{21}$,

$g_{12} = g_{21}$,

$g_{13} = g_{31}$, for symmetry, and

$b_1 + b_2 + b_3 = 1$,

$g_{11} + g_{12} + g_{13} = 0$, (10)

$g_{21} + g_{22} + g_{23} = 0$,

$g_{31} + g_{32} + g_{33} = 0$,

$d_{11} + d_{12} + d_{13} = 0$,

$d_{21} + d_{22} + d_{23} = 0$,

$d_{31} + d_{32} + d_{33} = 0$, for linear homogeneity.

By substituting these restrictions directly into (7), the following model to be estimated is derived :

$$
\begin{aligned}
\ln C = {} & \alpha + \beta_1 \ln y_1 + \beta_2 \ln y_2 + \beta_3(\ln w_2 - \ln w_1) + \beta_4(\ln w_3 - \ln w_1) + \\
& \beta_5(\tfrac{1}{2}\ln y_1 \ln y_1) + \beta_6(\ln y_1 \ln y_2) + \beta_7(\tfrac{1}{2}\ln y_2 \ln y_2) + \\
& \beta_8[\tfrac{1}{2}(\ln w_1 \ln w_2 + \ln w_2 \ln w_1 - \ln w_1 \ln w_1 - \ln w_2 \ln w_2)] + \\
& \beta_9[\tfrac{1}{2}(\ln w_2 \ln w_3 + \ln w_3 \ln w_2 - \ln w_2 \ln w_2 - \ln w_3 \ln w_3)] + \\
& \beta_{10}[\tfrac{1}{2}(\ln w_1 \ln w_3 + \ln w_3 \ln w_1 - \ln w_1 \ln w_1 - \ln w_3 \ln w_3)] + \\
& \beta_{11}(\ln y_1 \ln w_2 - \ln y_1 \ln w_1) + \beta_{12}(\ln y_1 \ln w_3 - \ln y_1 \ln w_1) + \\
& \beta_{13}(\ln y_2 \ln w_1 - \ln y_2 \ln w_2) + \beta_{14}(\ln y_2 \ln w_3 - \ln y_2 \ln w_2) + u + v
\end{aligned}
\tag{11}
$$

where α and β_s are coefficients to be estimated. Subscript *i (i=1,....N)* for the i^{th} bank and superscript *K* for the K^{th} country have been omitted in all variables.

3.4 Scale Economy and Technical Inefficiency

Once the model is estimated, scale economy and technical inefficiency measures are calculated. First, economies of scale in banking are measured by the reciprocal of the elasticity of cost with respect to output. For the translog cost frontier function, the cost elasticities are :

$$\partial \ln C(y,w) / \partial \ln y_i = \alpha_i + \sum_k^n s_{ik} \ln y_k + \sum_j^m d_{ij} \ln w_j . \qquad (12)$$

And, although variations are possible, we will define scale economies as

$$SC(y,w) = \left(\sum_{i=1}^n \partial \ln C(y,w) / \partial \ln y_i \right)^{-1} \qquad (13)$$

Increasing returns to scale (or economies of scale) are present if SC>1, decreasing returns to scale (or diseconomies of scale) are present if SC<1, and constant returns to scale are present if $SC=1$. For example, a U-shaped cost curve would have $SC>1$ at lower output with values falling to $SC=1$ at the minimum cost output level and falling thereafter such that $SC<1$ as diseconomies occur.

On the other hand, input X-inefficiency (technical inefficiency) measures are calculated using residuals. First, the average level of input X-inefficiency can be measured as average (u), which is estimated as average$(\hat{\varepsilon}_i)$, where $\hat{\varepsilon}_i$ is the estimated residual for bank i, since u is independent of v and $E(v) = 0$. The mean input X-inefficiency is given by $E(u)$, which for the half-normal case is $(2/\pi)^{1/2}\sigma_u$. This is estimated as $(2/\pi)^{1/2}\hat{\sigma}_u$, where $\hat{\sigma}_u$ is the estimate of σ_u. Since the distribution of the maximum likelihood estimates is known, one can calculate an approximate standard error of $(2/\pi)^{1/2}\hat{\sigma}_u$. Bank-specific estimates of input X-inefficiency, u, can be obtained by using the distribution of the inefficiency term (u_i) conditional on the estimate of the entire composed error term (ε_i), as suggested by Jondrow, Lovell, Materov, and Schmidt (1982). We can use either the mean value or the mode of this conditional distribution as an estimate of u_i. For the normal-half normal stochastic model, these are

$$E[u_i|\varepsilon_i] = E[u_i|u_i + v_i] = \frac{\sigma_u \sigma_v}{\sigma}\left[\frac{f^*(\varepsilon_i \lambda/\sigma)}{F^*(\varepsilon_i \lambda/\sigma)} + \frac{\varepsilon_i \lambda}{\sigma}\right], \quad \lambda = \frac{\sigma_u}{\sigma_v}$$

$$M[u_i|\varepsilon_i] = \begin{cases} \frac{\sigma_u^2}{\sigma^2}\varepsilon_i & \text{if } \varepsilon_i \geq 0 \\ 0 & \text{if } \varepsilon_i < 0 \end{cases} \qquad (14)$$

where $f^*(\cdot)$ and $F^*(\cdot)$ are the standard normal density and the standard normal cumulative functions, respectively.[10] To get estimates, $\hat{E}(u|\varepsilon)$ and $\hat{M}(u|\varepsilon)$, of these measures, we evaluate (14) at the estimates of σ_u and σ_v. It is easily verified that the expressions in (14) are non-negative, and monotonic in ε. Also, the more general truncated normal case of Stevenson (1980) yields similar results, with minor algebraic complications.

[10] These can be seen by adapting for the cost function the equation for the production function derived in Jondrow et. al. (1982)

CHAPTER 4

BANKING SYSTEM AND DATA

4.1 Banking System[11]

4.1.1 Banking System in the United States

Commercial banks in the United States are one of the several financial institutions that serve the economy. Others include thrifts (savings and loan associations, mutual savings banks), credit unions, investment companies, pension funds, insurance companies, and finance companies.[12] The U.S. financial system is the largest in the world, and in many respects, the most advanced. It also has the greatest diversity of institutions, the widest variety of instruments, and the most highly developed derivative markets. In many areas of

[11]This section draws partly from George G. Kaufman (1992) and Hazel J. Johnson (1994).

[12] The classification of depository institutions are commercial banks, savings and loan associations, mutual savings banks, and credit unions. That is, they all issue deposits-money that can be withdrawn upon demand or according to terms of the deposit agreement.

finance, it leads innovation. It is also one of the most idiosyncratic financial systems in the world, characterized by an oddly parochial set of laws and regulations that both impair competition and shield inefficiency.

The U.S. financial system is characterized by its fragmentation. The extreme fragmentation of the U.S. financial system is most evident in the structure of the banking industry. Unlike banking systems in other countries, the banking system in the United States has a large number of both state-chartered and national chartered banks of greatly varying sizes and diversification. The number peaked at 30,000 in 1920, but, because of failures and mergers, is now less than 12,000. Among these, the commercial banks have consolidated from 14,500 banks to fewer than 10,500 as of 1994. One-third of these are nationally chartered, hold 60 percent of U.S. bank assets, and control 53 percent of U.S. bank offices. The fragmented nature of U.S. banking is likely to place U.S. banks in a weak position as they compete for market share in a globally integrated market for banking services.

Commercial banks have been the dominant type of financial institution in the United States throughout its history. The assets of commercial banks expanded rapidly during the 1970s and early 1980s because of a general expansion in the U.S. money supply. Assets of FDIC-insured commercial banks almost quadrupled between 1970 and 1982, when they reached $2,194 billion. In 1994, U.S. bank assets amounted to $4,011 billion. As a result, the average asset size of all commercial banks increased from $260 million in 1989 to $384 million in 1994.

The degree of dominance of commercial banks and other depository institutions has declined significantly since the latter part of the nineteenth century. In 1964, depository institutions had 58 percent of total financial assets held by financial institutions. That share is now below 50 percent. The primary beneficiary of this shift has been investment companies (mutual funds) and pension funds. Clearly, the competitive rates of return available through investment companies have attracted investors, particularly small investors, away from depository institutions. At the same time, the significant growth in assets at both investment companies and pension funds has given corporations alternatives to bank loans. Thus, banks face competitions in both their deposits base and their loan portfolio.

Although U.S. commercial banks have shrunk, they are still by far the most important type of financial institutions in the United States, in terms of their total assets, accounting for roughly 40 percent of total assets in the United States.

4.1.2 Banking System in Japan

The emergence of a modern financial framework in Japan is a relatively recent event compared to the financial history of other industrialized countries. The banking system's role was to mobilize the country's financial resources to support industrialization and economic growth. The banking and financial systems were one and the same in the early years of Japanese finance. Despite the evolution of nonbank financial institutions and direct markets, bank finance continues to dominate the flow of funds in Japan.

Japan's emergence in recent years as a major financial force in the world economy is fully reflected by the domestic and international growth of banks. Japanese banks have become the largest in the world. Seventeen of the world's top 25 banks were Japanese. Table 15 shows the world's top 25 banks ranked by asset size in 1992. Dai-Ichi Kangyo is the largest bank in the world, with assets totaling $460 billion as of June, 1992. Japanese banks have expanded internationally in ways significantly different than the way they did in the 1970s. Prior to 1980, the majority of international activities on the part of Japanese banks were associated with trade financing. However, since 1980, Japanese international banking activities have broadened significantly to directly compete with domestic banks for both retail and whole sale business in the United States.

Japan possesses a variety of financial institutions: banks, other private financial institutions, and public financial institutions. The Japanese banking system is composed of five different types of banks: city banks, regional banks, long-term credit banks, trust banks, and foreign banks. There are 13 city banks. City banks are generally the largest banks and primarily service the cooperates or the large business sector, having branches located throughout the country and the world. In comparison, regional banks cater to the needs of small to medium sized business enterprises. Prior to 1989, there were 64 regional banks; however, almost all sogo, or mutual banks converted to regional bank status, so there are now 130 regional banks.

In the late 1920s, there were approximately 1,000 city and regional banks in Japan. During World War II, many were liquidated or consolidated, so that, by 1945, only 61 city and regional banks remained. Today, there are 145 ordinary banks in Japan. Among these, 13 city banks hold almost 70 percent of total bank assets. With nationwide branch networks, these 13 banks control over 20 percent of all bank offices. The largest includes Dai-Ichi Kangyo Bank, Fuji Bank, Sumitomo Bank, Sanwa Bank, Sakura Bank, and Mitsubishi Bank.

Japanese bank assets have grown rapidly. From a total of $1.2 trillion dollars in 1981, Japanese bank assets increased at the rate of 20 percent a year to reach $5.3 trillion by the end of the decade, which is more than 1.5 times as large as the total assets of all U.S. banks. The average asset size for the 145 banks were $37 billion in 1989.

4.2 Data Sources

4.2.1 Intermediation Approach vs. Production Approach

There continues to be some debate about what constitutes the outputs and inputs of a bank. The banking literature is divided over the conceptual issue of the appropriate definition of bank output, input, and consequently, on the related issue of defining bank costs. It is not clear which variables provide good proxy measures of economic values, such as, the proxy measure of total costs. Several authors have supported the exclusion of interest expense from total costs, reasoning that interest costs are purely financial and hence are not pertinent in measuring efficiency. Others have argued that excluding interest costs disregards the process of financial technology by which deposits are transformed into loans. Considerable disagreement also exists in prior studies on the definition of outputs and inputs for banks. Benston, Hanweck, and Humphrey (1982) have succinctly described the problem in the following manner:

> *"One's view of what banks produce depends on one's interest. Economists who are concerned with economy-wide (macro) issues tend to view the bank's output as dollars of deposits or loans. Monetary economists see banks as producers of money-demand deposits. Others see banks as producing loans, with demand and time deposits being analogous to raw materials."*

Further, the lack of a consensus in the literature on the theory of banking leaves the definition of output an unsettled issue. Hence, it is obvious that a precise definition of bank output is not possible at the present.

In general, prior researchers take one of two approaches.[13] These alternative approaches are labeled the intermediation approach and the production approach. The intermediation approach views financial institutions as collecting deposits and purchased funds to be subsequently intermediated into loans and other assets. In this approach, deposits are treated as inputs along with capital and labor. Those authors who adopt this approach generally define the institution's various dollar volumes of earning assets as measures of output. Also, consistent with this approach, costs are defined to include both interest expense and total cost of production.[14] The production approach, on the other hand, views depository institutions as producers of services associated with individual loan

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[13] Humphrey (1985) and Clark (1988) provide extended discussion of the issues involved in the debate about intermediation and production approaches.

[14] For this study, the intermediation approach is employed, since the number of accounts for each output category in Japanese bank data are unavailable.

and deposit accounts. These account services are produced using capital and labor. Under the production approach, total costs are exclusive of interest expense and outputs are measured by the number of accounts serviced as opposed to dollar values.

4.2.2 U.S. Bank Data

In general, the data for estimating statistical cost functions for U.S. banks are drawn either from Call and Income Reports as reported to the Federal Deposit Insurance Corporation or from the Functional Cost Analysis (FCA) program conducted by the Federal Reserve System. Each of these two data sources has advantages and disadvantages. The FCA data include information on the number and average size of a variety of deposit and loan products. Therefore, this source of data is suitable for the production approach. However, generalization of the results obtained using FCA data to all banks may be inappropriate, since FCA data are dominated by small banks with under $1 billion in assets. Furthermore, the FCA program is voluntary. On the other hand, Call and Income Reports provide information on a much wider range of institutional sizes and impose uniform reporting requirements. This source of data is suitable for the intermediation approach, since it contains dollar volume of loans and deposits for much wider range of banks. The empirical results obtained using these data, therefore, should be more generally applicable. However, the absence of information on numbers of deposit and loan accounts and average account size makes this source of data unsuitable for use under the production approach.

The data for the study were drawn from the Call and Income Report for the year 1994. The data set is available on a magnetic tape from the National Technical Information Service (NTIS) of the Department of Commerce and includes data for about 12,000 banks. To get the sample banks for this study, the banks were sorted by types of institution and asset size, and then only large commercial banks were sampled. That is, to obtain an appropriate data set for the study, only banks with total assets of $300 million or more, as defined in the NTIS tape documents as large banks, were selected. And, after the banks with missing values of outputs and /or inputs were dropped, a total of 744 large domestic banks and 167 large multinational banks remained in the final sample and were used for empirical analysis.[15] Table 4 presents summary statistics for domestic banks and multinational banks as reported in the 1994 Call and Income report.[16] The average asset size of domestic banks in the sample was $1,225 million, and the maximum asset size was $22,918 million. On the other hand, the average asset size of multinational banks included in this study was $24,303 million, which is about 20 times more than that of domestic banks, and the maximum asset size was $283,056 million.

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[15] To define multinational banks, we applied the criterion established by the Federal reserve system in determining which banks should file the consolidated Reports of Condition and Income for a bank with domestic and foreign offices. Utilizing this criterion, multinational banks are defined as those banks which have a branch or a subsidiary in foreign countries, a majority owned Edge or Agreement Subsidiary, or an International Banking Facility. Those banks with no foreign offices are classified as domestic banks in this study.

[16] Disaggregate data for the foreign operations of multinational banks were not available in the Call Reports. As a result, the data for the multinational banks were domestic plus foreign values for outputs, inputs, and total costs.

4.2.3 Japanese Bank Data

The Japanese data set was collected from the 1994 Kaisha Nenkan dataset. This dataset includes data for 118 commercial banks. After the banks with missing values of outputs and /or inputs were dropped, a total of 116 banks remained in the final sample and were used for empirical analysis. Table 5 presents summary statistics for 116 banks in the sample.[17] The average asset size of Japanese banks was $64,541 million, and the maximum asset size was $513,466 million. Data for the Japanese banks operating in the United States are extracted from Call and Income Report, which also includes foreign-based banks operating in the United States. Again, after the banks with missing values of outputs and/or inputs were dropped, a total of 17 banks remained in the final sample and were used for empirical analysis. Summary statistics are also presented in Table 5. The average asset size of Japanese banks operating in the United States was $2,000 million, and maximum asset size was $7,309 million.

4.3 Output, Input and Cost Specification

For empirical estimation, this study uses the intermediation approach and employs two outputs. Consistent with the intermediation approach, which is also the most common

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[17] Purchased fund for Japanese banks includes borrowed money, call money and certificate of deposit. All input and output variables are translated from local currencies to U.S. dollars using the exchange rate prevailing as of the end of 1994.

in the conventional cost function literature for commercial banking, outputs are measured in dollars and interest expenses are included in total cost. The first output, denoted y_1 and called total loans, consists of the dollar volume of all real estate, agricultural, commercial and industrial, personal, credit card, and other loans. The second output, denoted y_2 and called produced deposits, consists of demand deposits and small (i.e., less than $100,000) time and savings deposits. In the present study, both loans and produced deposits are treated as outputs. The reason is that both activities are highly resource-consuming, with substantial value added. Under the value-added approach, loans and produced deposits are considered as bank outputs. On the other hand, while produced deposits are found to be an output, purchased funds, which consist of purchased federal funds and CDs of $100,000 or above, are not bank outputs, according to empirical estimates of an output criterion. Thus, purchased funds are excluded from produced deposits, since its suppliers receive negligible nonpecuniary benefits.[18]

Ideally, in specifying bank outputs, only those outputs exhibiting similar cost characteristics should be combined into a scalar measure. However, in the present international setting, the need for comparable data from different countries imposes strong restrictions on variables that we are able to use. In addition, unavailability of data also precludes the use of disaggregate loans. Our choice of the number of output measures is tempered by our primary objective, which is to compare the scale economies and the input

[18] The exclusion of purchased funds from bank outputs is consistent with work by Hancock (1986), who has reported results concerning the identification of bank outputs and inputs. Recently, Hunter and Timme (1991) used this definition of output in their study "Technological Change in Large U.S. commercial Banks".

X-efficiencies in two countries rather than to examine product-specific cost complementarities. And, it should be noted that various categories of bank loans can differ significantly in terms of their cost per dollar lent and in the return per dollar lent. Although our use of aggregate loans does not directly control for cost differences across loan categories, our decision to examine only the larger banks in the economy should temper any potential problems associated with the use of highly aggregated output measures. In addition, the potential adverse effects on the estimated cost function characteristics resulting from differences in the composition of loan portfolios are mitigated by performing the empirical analysis using subsamples of the smaller and larger sample banks.

The three inputs used in this study are labor, capital, and purchased funds. Labor is measured by the number of full-time employees on the payroll at the end of the time period and capital by the book value of premises and fixed assets (including capitalized leases). Purchased funds, as defined above, are purchased federal funds and CDs of $100,000 or above. The price of labor, w_1, was derived by taking total expenditures on employees divided by the total number of employees. A proxy for the price of capital, w_2, was derived by taking total expenditures on premises and fixed assets divided by book value. The price of purchased funds, w_3, was derived by taking the sum of interest expenses in purchased funds divided by the amount of purchased funds.

Finally, total cost was constructed by summing the loanable funds expenditures (including expenses on purchased fund), expenditures on labor, capital, and other non-interest expenses incurred by the banks in the production of outputs and services. That is, consistent with the intermediation approach, interest costs are included in total cost.

Outputs

y_1 = the dollar volume of produced deposits (demand deposits, small time and savings deposits).

y_2 = the dollar volume of loans and leases, net of unearned income.

Inputs

z_1 = total number of full-time equivalent employees on payroll at end of current period.

z_2 = the amount of premises and fixed assets (including capitalized leases).

z_3 = the amount of purchased funds.

Input prices

w_1 = salaries and employee benefits/ z_1.

w_2 = expenses of premises and fixed assets/ z_2.

w_3 = interest expense on z_3 / z_3.

Total cost = total interest expense + total noninterest expense

CHAPTER 5

EMPIRICAL RESULTS

I estimated the cost frontier model (11) using maximum likelihood techniques discussed in Chapter 3 and tested whether U.S. domestic banks and multinational banks, U.S. domestic banks and Japanese banks, and U.S. multinational banks and Japanese banks should be pooled and a single cost function should be estimated for all banks or whether cost functions should be estimated for each sample. The F-test strongly rejects pooling at well under the 0.01 level of significance.[19] This means that the cost frontiers (and, hence, the production technologies) differ between bank samples. That is, the data support estimating separate cost frontiers for each sample. Thus, the efficiency estimates reported below are based on the results from separate estimation of cost frontiers.

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[19] The F-statistics are calculated as follows: $F = \frac{(RRSS-URSS)/(k+1)}{URSS/(n_1+n_2-2k-2)}$, where *RRSS* is the restricted residual sum of squares, *URSS* is the unrestricted residual sum of squares, *n* is the size of data, and *k+1* is the number of the restrictions. The values of the F-test statistics for three cases are 25.77, 7.49, and 9.59, respectively.

5.1 Bank Efficiency in the United States

5.1.1 Parameter Estimates

Tables 6 and 7 exhibit the results of estimating the translog stochastic cost frontiers for U.S. domestic banks and U.S. multinational banks for 1994. The results for the domestic banks show that all but three parameter estimates are significant at the 10 percent level (or less). For U.S. multinational banks, all but 5 parameter estimates are significant at the 10 percent level (or less). The estimated parameters and sample data are used to construct empirical measures of scale and technical efficiencies.

5.1.2 Economies of Scale

Table 9 shows the estimates of scale economies by asset size groups for large domestic banks and multinational banks. The reported estimates are for the mean levels of output and input prices in each of six asset size categories. The mean values of outputs and input prices for different size ranges are substituted into equation (13) to obtain estimates of average scale economies for banks of different sizes. These measures can be thought of as the scale economies for the representative efficient commercial banks. The measures indicate whether a commercial bank that was minimizing the cost of producing a particular output bundle could lower costs proportionately by choosing another level of output. Scale economy estimates for each bank in domestic and multinational banks are presented in Appendices D and F, respectively.

Table 9 shows the scale economy estimates for asset size groups. Panel A in Table 9 contains results for the domestic bank sample and panel B provides results obtained from the multinational bank sample which can be used for comparison purposes to discern if multinationality indeed influences cost structures of banks. Column D reports standard errors on estimates in scale economies.[20] The results shown in Table 9 reveal the following conclusions. First, U.S. large domestic banks enjoy scale economies well beyond the $100-200 million asset size range. That is, U.S. large domestic commercial banks have a scale advantage up to $3,000 million in assets. The scale elasticity measure is close to 1.04, which is significantly different from 1. The measures range from 0.91 to 1.07, with diseconomies monotonically increasing with size. Second, results for U.S. multinational banks show that scale economy exists even up to $5,000 million in assets. The average scale economy measure is close to 1.0. The measures range from 0.97 to 1.11, again with diseconomies slightly increasing with size. Third, comparing domestic banks to multinational banks, it appears that multinational banks exploit the scale economies more fully than domestic banks. That is, cost benefits are more fully exploited by multinational banks. Finally, although potential gains from altering scale via internal growth or merge

[20] The t statistic is calculated using the output values and the input prices for the average bank size in each bank-size range. The variances for scale economies are calculated as $\left(\frac{1}{CE^2}\right)^2 Var(CE)$, with *Cost Elasticity* $(CE) = \sum_{i=1}^{2}\left(\partial \ln C / \partial \ln y_k\right)$.

activity are relatively minor, U.S. domestic banks can obtain cost advantages with foreign expansion by exploiting greater scale economies in multinational banks.

5.1.3 Technical Efficiency

The estimates of the conditional distribution of u given ε, $\hat{E}(u_i|\varepsilon_i)$, for each observation in domestic banks and multinational banks, are presented in Appendices E and G, respectively. And, Tables 11 and 13 report estimates of the inefficiency measures discussed in Chapter 3. The estimates include an estimate of the mean of u_i (≡ $(2/\pi)^{1/2}\hat{\sigma}_u$), an estimate of the average value of the bank-specific, input X-inefficiency estimates, $\hat{E}(u_i|\varepsilon_i)$, and an estimate of the average value of $\hat{M}(u_i|\varepsilon_i)$ and the minimum and maximum of $\hat{E}(u_i|\varepsilon_i)$ for domestic banks and multinational banks.

Since the correlation between $\hat{E}(u_i|\varepsilon_i)$ and $\hat{M}(u_i|\varepsilon_i)$ is extremely high, we can focus on one of the inefficiency measures without any loss. From Tables 11 and 13, we can find several important results. First, in general, multinational banks are more efficient than domestic banks, except for the first group. The average X-inefficiency is 19.5 percent for domestic banks and 16 percent for multinational banks. Thus, the average domestic bank uses its inputs less efficiently than the average multinational bank. If the average bank were to use its inputs as efficiently as possible, it could reduce its production cost by roughly 16 to 20 percent. Second, when compared with results of other studies using U.S. samples that found average X-inefficiency on the order of 20 to 40 percent, large banks seem to be outperforming U.S. banks on average. However, it is very difficult to determine whether this is significantly different from other studies. It may just reflect that this study is based on more recent data, or it may be because banks in the U.S. samples are more diverse, making efficiency measurement more difficult. Third, for domestic banks, average inefficiency falls with bank size, except for banks with between $300 million and $1,000 million in assets. For banks over $5,000 million in assets, the average inefficiency measure is 17.2 percent, which is less than 10 percent lower than the average for all large domestic banks combined (i.e., 19.5 percent inefficient). The largest banks are almost 35 percent more efficient than the most inefficient group with assets between $1,000 million and $3,000 million, where the inefficiency measure is 23 percent. Fourth, the input X-efficiency of U.S. larger domestic banks appears to be positively correlated with size. This implies that larger banks may offset scale diseconomies, compared to the findings in scale economies. Figure 4 shows the relationship between the scale economies and the input X-inefficiencies of large domestic banks. Finally, for multinational banks, the average input X-inefficiency for subgroups is stable between 13 to 18 percent, and banks with an asset range of $1,000-3,000 million are the most efficient (13.8 percent inefficient). Figure 4 shows the relationship between the scale economies and the input X- inefficiencies of large multinational banks.

5.2 Bank Efficiency in Japan

5.2.1 Parameter Estimates

Table 8 exhibits the results of estimating the translog stochastic cost frontier for the banks in Japan for 1994. The results show that all but seven parameter estimates are significant at the 10 percent level (or less). Again, the estimated parameters and sample data are used to construct empirical measures of scale and technical efficiencies.

5.2.2 Economies of Scale

Table 10 shows the estimates of scale economies by asset size groups for Japanese sample banks. The reported estimates are for the mean levels of output and input prices in each of the three asset size categories. Again, we substituted the mean values of outputs and input prices for different size ranges into equation (13) to obtain estimates of average scale economies for banks of different sizes. These measures indicate whether a commercial bank could lower costs proportionately by moving to another level of output. Appendix H shows scale economy estimates for 116 sample banks in Japan.

Column D in Table 10 reports standard errors on differences in scale economies. The results shown in Table 10 support the following conclusions. First, Japanese banks exhaust scale economies at the asset size of over $40,000 million. That is, Japanese banks have a slight scale advantage up to $40,000 million in assets. Second, the scale elasticity measure is close to 0.998, which is not significantly different from 1. That is, Japanese banks, on average, enjoy constant returns to scale. However, the measures range from 0.86 to 1.02 and diseconomies of scale increase rapidly with asset size. Finally, Japanese banks seem to fully exploit the scale economies. Also, scale inefficiency is 15 percent for the largest group. That is, it appears that there is no cost advantage from increasing scale through internal growth or merge activity.

5.2.3 Technical Efficiency

Appendix I provides the estimates of the conditional distribution of u given ε, $\hat{E}(u_i|\varepsilon_i)$, for each Japanese bank. And, Table 12 reports an estimate of the mean of u_i ($\equiv (2/\pi)^{1/2}\hat{\sigma}_u$), an estimate of the average value of the bank-specific, X-inefficiency estimates, $\hat{E}(u_i|\varepsilon_i)$, and an estimate of the average value of $\hat{M}(u_i|\varepsilon_i)$ and the minimum and maximum of $\hat{E}(u_i|\varepsilon_i)$ for Japanese banks.

Identical to U.S. banks, since the correlation between $\hat{E}(u_i|\varepsilon_i)$ and $M(u_i|\varepsilon_i)$ is extremely high in Japanese banks, we will see $\hat{E}(u_i|\varepsilon_i)$. From Tables 12 and 14, we can see several important results. First, in general, Japanese banks, on average, are 20-22 percent technically inefficient. That is, the average Japanese bank uses 20-22 percent more inputs to produce a given output. Second, the average technical inefficiency is very high in the upper middle size group of assets. For banks between the asset range of $40,000-

$500,000 million, the average technical inefficiency measure is 38.5 percent, which is 18.4 percent points higher than the average for all Japanese banks combined (i.e., 20.1 percent). The largest banks are almost 20.7 percent technically inefficient. Finally, input X-efficiency of Japanese banks appears to be not correlated with size. For the several largest banks, technical inefficiency falls, but scale inefficiency is too high to offset. Figure 10 shows the relationship between the scale economies and the input X-inefficiencies of Japanese banks.

5.3 Comparison of Bank Efficiencies Between the U.S. and Japan

5.3.1 The Structural Differences

When the banking system of the United States is compared to the system in Japan, the contrasts are striking. First, the amount of total assets in the U.S. banking system is smaller than that in the Japanese. In 1989, Japanese bank assets amounted to $5,321 billion (for 145 banks), while U.S. bank assets amount to $3,283 billion (for 12,689 banks). That is, the amount of Japanese bank assets is 1.6 times that of U.S. banks. Second, as a result, the average size of U.S. banks is much smaller than that of Japanese banks. As of 1989, while average bank size for the U.S. was $0.26 billion, Japan's was $36.69 billion. That is, the average size of U.S. banks is 0.7 percent of the size of the average Japanese bank. This significant size difference is important because an increasing number of Japan-based foreign banks operate in the United States and compete directly with U.S. domestic banks. To the extent that U.S. banks are smaller and less able to offer a full range of services, domestic banks will continue to lose market share to their foreign counterparts. Third, the growth rate of U.S. bank assets is slower than that of Japanese banks. The annual growth rates of U.S. bank assets during the 1980s is 6.2 percent, while that of Japanese bank assets is 20.0 percent in U.S. dollars. This means that the competitive disadvantage of smaller U.S. banks will only be compounded in the future. It will be difficult for the large number of banks to all increase in size and market share, particularly given a slow rate of growth within the U.S. domestic economy. The problem can be alleviated, however, if banks are all allowed to branch nationwide and to merge and consolidate freely across state lines. Permitting U.S. banks to compete in other forms of financial services, such as securities underwriting, can also add to bank profitability and growth potential. Fourth, in terms of bank powers, the Japanese system is most similar to the United States. Table 17 is a comparison of the bank powers in the United States and four of its major trading partners. The powers indicated for the United States are for national banks as permitted by federal law. One major difference is that Japanese banks are permitted to invest in equities, or stocks. It is through these equity investments that Japanese banks maintain their close relationships with industry, making them a part of Keiretsu arrangements, that is, cross-holdings of stock among companies in the same group. Finally, different from the U.S. banks, Japanese banks are more aggressive in entering foreign markets. Table 16 is a list of the 25 largest foreign banks operating in the United States and their U.S. assets. As shown, fourteen of the 25 are Japanese banks. These 25 banks control $551 billion in assets, or 15.7 percent of the total assets of all

FDIC-insured banks in 1992. Total assets of foreign banks exceeded 10 percent of all banking assets in the United States as early as 1980. By 1989, the percentage exceeded 22 percent. Foreign banking organizations played virtually no role in the retail segment of the U.S. banking market. However, they are playing an increasingly important role in the wholesale banking market. The share of outstanding commercial and industrial loans held by U.S. branches of foreign banks rose from 8.6 percent to 14.4 percent in 1988. All of this increase was accounted for by branches of Japanese banks, whose share of commercial and industrial loans rose from 2.7 percent in 1980 to 8.5 percent in 1988. Over the same period, the market share of the U.S. branches of other foreign banks remained steady at 5.9 percent. The growth in commercial and industrial loans held by foreign banks chartered in the United States has been less dramatic, rising from 4.4 percent in 1980 to 6.3 percent in 1988. In contrast to the striking inroads made by branches of Japanese banks, the share of commercial and industrial loans held by Japanese-owned U.S. banks has remained relatively small, rising from 0.1 percent in 1980 to 2.4 percent in 1988.

5.3.2 Comparison of Scale Economies

Comparing the results in scale efficiency measures, we can arrive at the following conclusions. First, U.S. domestic banks are more scale efficient than Japanese banks, but U.S. multinational banks enjoy the same level of scale efficiency as Japanese banks. As seen in Tables 9 and 10, the mean scale economies for U.S. domestic banks and multinational banks are 1.04, 1.00, respectively, while that for Japanese banks is 0.99. Second, looking at scale economies by groups, in general, scale diseconomies increase with asset size. The largest asset group of Japanese banks suffers from higher diseconomies than those of U.S. domestic and multinational banks. Scale economies for the largest asset groups in U.S. domestic banks and multinational banks are 0.91, 0.97, respectively, while scale economy for the largest asset group of Japanese banks is 0.87. Third, U.S. domestic banks exhaust scale economies at the asset size of $3,000-5,000 million, while Japanese banks exhaust scale economies at the asset size of $40,000 million. U.S. multinational banks, however, enjoy scale economies up to the asset size of $5,000 million. Fourth, for the same asset groups, however, Japanese banks enjoy more of a cost advantage than U.S. banks. Specifically, scale economies for asset size of $3,000-23,000 million are 1.0361 for Japanese banks, 0.9292 for U.S. domestic banks, and 0.9993 for multinational banks.[21] Finally, Japanese banks operating in the Unite States have more scale advantage than U.S. domestic banks.[22] The scale efficiency for these banks is 1.18, which is, however, not significantly different from 1.0.

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[21] This same asset group is the asset group that each bank sample (i.e., U.S. domestic, and multinational bank sample, and Japanese bank sample) has commonly.

[22] For the Japanese banks operating in the United States, the results of scale efficiency and technical efficiency are from pooling result with U.S. domestic banks, since this data set is not large enough to estimate a separate cost frontier.

5.3.3. Comparison of Technical Efficiency

Comparing the technical efficiency measures between U.S. banks and Japanese banks, we can see several results. First, on average, U.S. banks are more efficient than Japanese banks. That is, U.S. banks use inputs more efficiently than Japanese banks do. Overall average technical efficiencies for U.S. domestic banks, multinational banks, and Japanese banks are 20 percent, 16 percent, and 22 percent, respectively. Second, when compared by asset size groups, technical inefficiencies for U.S. domestic banks and Japanese banks first rise, then falls, with asset size. This implies that banks in the middle asset size group in each country use more inputs than banks in other asset size groups to produce the same level of output. Technical inefficiency for this asset size group for U.S. domestic banks and Japanese banks are 22.9 percent, 38.5 percent, respectively. Third, unlike U.S. domestic banks and Japanese banks, for multinational banks, the banks in the middle asset size group are the most efficient, with the first asset group being the most inefficient. Fourth, asset groups for the most technically efficient banks in each country are \$5,000-23,000 million in assets for U.S. domestic banks, \$1,000-3,000 million in assets for U.S. multinational banks, and \$3,000-40,000 million in assets for Japanese banks, with the technical inefficiencies of 17.2, 13.8 and 13.9, respectively. For these groups, scale economies are 0.9098, 1.0665, and 1.0286, respectively. Fifth, Japanese banks operating in the United States are even more technically inefficient than U.S. domestic banks. Technical inefficiency of Japanese banks operating in the United States is 37.7 percent. This implies that U.S. domestic banks still have a competitive advantage against their

Japanese counterparts. Sixth, for the same level of asset group in the $3,000-23,000 million range, the technical inefficiency for U.S. domestic banks is 19.7 percent, 16.5 percent for U.S. multinational banks, and 14.4 percent for the Japanese banks. This indicates that, if bank asset sizes in each country are the same, then Japanese banks are more technically efficient than U.S. banks. Combined with scale efficiencies for this group, overall inefficiencies are 26.8 percent for U.S. domestic banks, 16.6 percent for U.S. multinational banks, 10.8 percent for Japanese banks. On the other hand, the most efficient asset size groups for banks (scale plus technical inefficiency) are $300-700 million for U.S. domestic banks (10.5 percent), $700-1,000 million for U.S. multinational banks (4.4 percent), and $3,000-40,000 million for Japanese banks (11.1 percent). In addition, most inefficient groups are those with assets of $3,000-5,000 million for U.S. domestic banks (27.3 percent), $40,000-500,000 million for Japanese banks (46.0 percent), and $5,000-283,056 million for U.S. multinational banks (18.7 percent). Finally, it appears that there is a positive relationship between input X-efficiency and asset size in U.S. domestic banks, while this relationship is less obvious for U.S. multinational banks and Japanese banks.

CHAPTER 6

CONCLUSION AND SUMMARY

The years following the 1980s' deregulation have seen considerable changes in the operations and structure of the banking industry in the United States. The increased opportunities for banks provided by the deregulation have accelerated competition within and outside commercial banks, and with foreign banks due to the globalization of the financial market, as evidenced by a record number of bank failures and an increased number of consolidations within the banking industry. While these changes have created new opportunities for individual commercial banks to grow, they have raised questions about the future structure of the banking industry. A consensus is that a small number of banks will emerge from the current consolidation and the average size of banks will increase.

This paper has examined evidence concerning the efficiencies of U.S. domestic banks, U.S. multinational banks, and Japanese banks to analyze cost advantages for commercial banks in the United States and Japan. To measure the scale economies and technical efficiencies for banks, we estimated the individual translog cost frontier function for each country using the 1994 Call and Income Report dataset for the United States and the 1994 Keisha Nenkan dataset for Japan.

Our results suggest several conclusions. Results for scale economies reveal the following.

First, on average, U.S. domestic banks enjoy increasing return to scale. The average scale economy estimate is 1.04. This implies that the average size of U.S. domestic banks has not reached the optimal size at which operating cost will be lowest, and this average size has to increase in order to reach the size at which banks can fully exploit economies of scale. In addition, scale economies of U.S. domestic banks exist up to an asset size of $3,000 million, and scale diseconomies enter slowly with size in contrast to Japanese banks.

Second, for U.S. multinational banks, there exists constant return to scale, on average. They enjoy scale economies up to an asset size of $5,000 million. The scale diseconomies, however, appear to be very small. The scale economy estimate for the largest asset group is 0.97. While U.S. domestic banks face greater diseconomies with increase in size, U.S. multinational banks experience lesser diseconomies than U.S. domestic banks, in general.

Third, Japanese banks, on average, seem to enjoy constant return to scale, but diseconomies of scale enter very rapidly with size. That is, some banks are too large, having moved into the region of decreasing returns to scale. The scale economy estimate for the largest asset group is 0.87.

On the other hand, results for input X-inefficiency show the following.

First, for large commercial banks in the U.S. and Japan, the input X-inefficiency far outweighs that of output inefficiency. And, U.S. domestic and multinational banks, on average, are more efficient than Japanese banks.

Second, although scale economies for U.S. domestic banks decrease as asset sizes grow, technical efficiency increases. That is, larger banks have lower pure technical inefficiency. This result indicates that technical efficiency somewhat offsets scale inefficiency for larger banks. It seems that bigger scale/size does not necessarily erode international competitiveness of U.S. banks. Increase in scale of operations allows exploitation of gains from input X-efficiency.

Third, U.S. multinational banks are both more scale and technically efficient than U.S. domestic banks. This evidence implies that U.S. domestic banks can obtain more cost savings by becoming multinational banks. That is, there appear some gains from foreign expansion.

Fourth, in general, Japanese banks use more inputs than U.S. banks to produce the same level of output. The mean input X-inefficiency estimate for Japanese banks is 22.2 percent, which is higher than that found in U.S. banks.

Fifth, U.S. domestic banks have a competitive advantage at the asset size of $300-700 million, while U.S. multinational banks have a competitive advantage at the asset size of $700-1,000 million, and Japanese banks at the asset size of $3,000-40,000 million. For these asset groups, the average inefficiencies for U.S. domestic banks, U.S. multinational banks and Japanese banks, including both pure technical and scale, are 10.5 percent, 4.4 percent, and 11.1 percent, respectively. On the other hand, middle-sized banks in U.S.

domestic banks and Japanese banks exhibit the largest measures of input X-inefficiency amounting to 22.9 percent, 38.5 percent of costs as well as significant levels of diseconomies of scale. Multinational banks, however, suffer from high inefficiency (18.4 percent) at the asset size of $300-700 million, which is the smallest asset group.

Finally, U.S. domestic banks have a competitive advantage over Japanese banks operating in the United States.

In this paper, the stochastic cost frontier model was employed to measure cost inefficiencies of large commercial banks in the United States and Japan. As mentioned earlier, a drawback of this approach is that assumptions have to be maintained about the form of the frontier and error terms. Thus, more research is needed to investigate whether these results are robust to other specifications of the composite error structure and cost frontier, and whether data from other recent years support similar conclusions.

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APPENDIX A

Derivation of Stochastic Cost Frontier from Stochastic Production Frontier.

For simplicity, assume that the firm is allocatively efficient and firm's production technology is characterized by a production of the form

$$y = a\prod_{i=1}^{n} x_i^{\alpha_i} e^{\varepsilon}, \tag{A.1}$$

where y is the output of the firm, the x_i are the inputs to the production process, ε is a random disturbance, and the α_i are parameters to be estimated. Assume that the disturbance is the form of

$$\varepsilon = v - u. \tag{A.2}$$

Then, we can write the production function in log-linear form as

$$\ln y = A + \sum_{i=1}^{n} \alpha_i \ln x_i + (v - u),$$

$$\text{where } A = \ln a. \tag{A.3}$$

Note that $\ln y$ is bounded from above by the stochastic production frontier

$$A + \sum_{i=1}^{n} \alpha_i \ln x_i + v \tag{A.4}$$

with technical efficiency relative to frontier given by u percent. Since the firm is assumed to be allocatively efficient, it makes no mistakes in selecting the cost minimizing factor proportions, which are given by the solution to

$$\ln x_1 - \ln x_i = B_{i,} \qquad i = 2, \ldots\ldots, n,$$

$$\text{where } B_i = \ln(p_i \alpha_1 / p_1 \alpha_i), \tag{A.5}$$

and $p_1, p_2, \ldots, p_n$ are prices of the m inputs. From these, we can derive the factor demand equations

$$\ln x_i = \ln k_i + \frac{1}{r}\ln y + \ln\left[\prod_{j=1}^{m} p_j^{\alpha_j/r} / p_i\right] - \frac{1}{r}(v-u), \qquad i = 1, \ldots\ldots, m. \tag{A.6}$$

where

$$r = \sum_{i=1}^{m} \alpha_i = \textit{returns to scale}$$

and

$$k_i = \alpha_i \left[a \prod_{i=1}^{m} \alpha_i^{\alpha_i}\right]^{-\frac{1}{r}}.$$

Finally, we find that the cost function is of the form

$$\ln C = K + \frac{1}{r}\ln y + \sum_{i=1}^{m} \tfrac{\alpha_i}{r} \ln p_i - \frac{1}{r}(v-u),$$

where

$$K = \ln\left[\sum_{i=1}^{m} k_i\right] = \ln r - \frac{1}{r}A - \frac{1}{r}\ln\left[\prod_{i=1}^{m} \alpha_i^{\alpha_i}\right] \tag{A.7}$$

Note that $\ln C$ is also bounded from below by the stochastic cost frontier $K + \frac{1}{r}\ln y + \sum_{i=1}^{m} \frac{\alpha_i}{r} \ln p_i - \frac{1}{r}v$.

APPENDIX B

Derivation of Joint Density Function

Let us assume the frontier relationship we seek to estimate is the dual cost function. We assume the error of the cost function is

$$\varepsilon = u + v$$

where u and v are independently distributed. Given cost minimization behavior, u will be non-negative. Let us further assume that u and v are distributed as

$$k(u) = \frac{1}{\left(1 - F^*\left(-\frac{\mu}{\sigma_u}\right)\right)\sqrt{2\pi}\sigma_u} \exp\left[-\frac{1}{2}\left(\frac{u-\mu}{\sigma_u}\right)^2\right] \quad \text{for} \quad u>0, \qquad (B.1)$$

$$= 0 \qquad \text{otherwise,}$$

and

$$g(v) = \frac{1}{\sqrt{2\pi}\sigma_v} \exp\left[-\frac{1}{2}\left(\frac{v}{\sigma_v}\right)^2\right] \qquad \text{for all } v, \qquad (B.2)$$

where $F^*(\cdot)$ is the distribution function for a standard normal random variable. Simply stated, u is assumed to be distributed as a truncated normal with mode μ, and v is assumed to be distributed as a normal with zero mean and variance σ_v^2. The joint density function is given as

$$h(\varepsilon) = \int_0^\infty \frac{1}{\left(1 - F^*\left(-\frac{\mu}{\sigma_u}\right)\right)2\pi\sigma_u\sigma_v} \exp\left[-\frac{1}{2}\left(\left(\frac{u-\mu}{\sigma_u}\right)^2 + \left(\frac{\varepsilon-u}{\sigma_v}\right)^2\right)\right]du \qquad (B.3)$$

which integrates to

$$h(\varepsilon) = \sigma^{-1} f^*\left(\frac{\varepsilon-\mu}{\sigma}\right)\left[1 - F^*\left(-\frac{\mu}{\sigma\lambda} - \frac{\varepsilon\lambda}{\sigma}\right)\right]\left[1 - F^*\left(-\frac{\mu}{\sigma_u}\right)\right]^{-1} \qquad (B.4)$$

where $\sigma = \left(\sigma_u^2 + \sigma_v^2\right)^{\frac{1}{2}}$, $\lambda = \sigma_u / \sigma_v$ and f^* is the standard normal density evaluated at $\frac{\varepsilon - \mu}{\sigma}$. Note that at $\mu = 0$, $h(\varepsilon)$ becomes

$$h(\varepsilon)\big|_{\mu=0} = \frac{2}{\sigma} f^*\left(\tfrac{\varepsilon}{\sigma}\right)\left[1 - F^*\left(-\tfrac{\varepsilon\lambda}{\sigma}\right)\right] \tag{B.5}$$

The mean and variance of ε are

$$E(\varepsilon) = E(u) = \frac{\mu a}{2} + \frac{\sigma_u a}{\sqrt{2\pi}} \exp\left[-\tfrac{1}{2}\left(\tfrac{\mu}{\sigma_u}\right)^2\right] \tag{B.6}$$

$$V(\varepsilon) = V(u) + V(v) = \mu^2 \frac{a}{2}\left(1 - \tfrac{a}{2}\right) + \sigma_u^2 \frac{a}{2}\left(\frac{\pi - a}{\pi}\right) + \sigma_v^2 \tag{B.7}$$

where $a = \left(1 - F^*\left(-\mu / \sigma_u\right)\right)^{-1}$. At $\mu = 0$, the mean and variance of ε becomes

$$E(\varepsilon)\big|_{\mu=0} = E(u) = \sqrt{\frac{2}{\pi}}\sigma_u \tag{B.8}$$

$$V(\varepsilon)\big|_{\mu=0} = \sigma_u^2\left(\frac{\pi - 2}{\pi}\right) + \sigma_v^2 \tag{B.9}$$

APPENDIX C

Derivation of Distribution of *u* Conditional on ε

The stochastic cost frontier model that allow for input X- inefficiency can be written as

$$\ln C_i = \ln C(y_i, w_i; \beta) + \varepsilon_i \qquad i=1,\ldots\ldots\ldots\ldots.N. \qquad \text{(C.1)}$$
$$\varepsilon_i = u_i + v_i$$

where C_i is the observed cost of bank *i*, y_i is the vector of output levels for bank *i*, w_i is the vector of input prices, β is a vector of parameters to be estimated, u_i is a one-sided disturbance capturing the effects of inefficiency, and v_i is a two-sided disturbance capturing the effects of noise. The $v_i s$ are assumed to be independently and identically distributed, and the $u_i s$ are assumed to be distributed independently of the $v_i s$. ε_i is the composite error term, which is the sum of a one-sided disturbance and a two-sided disturbance terms

Assume that the $u_i s$ are the absolute values of a variable that is normally distributed with mean 0 and variance σ_u^2, and the $v_i s$ are normally distributed with mean 0 and variance σ_v^2. That is, $\varepsilon_i = u_i + v_i$, $u_i \sim |N(0, \sigma_u^2)|$, and $v_i \sim N(0, \sigma_v^2)$.

Then, the joint density of u and v is the product of their individual densities; since they are independent,

$$f(u,v) = \frac{1}{\pi\sigma_u\sigma_v}\exp\left[-\tfrac{1}{2}\left(\left(\tfrac{u}{\sigma_u}\right)^2 + \left(\tfrac{v}{\sigma_v}\right)^2\right)\right], \quad u \geq 0 \qquad \text{(C.2)}$$

Making the transformation $v = \varepsilon - u$, the joint density of u and ε is

$$\begin{aligned} f(u,\varepsilon) &= \frac{1}{\pi\sigma_u\sigma_v}\exp\left[-\tfrac{1}{2}\left(\left(\tfrac{u}{\sigma_u}\right)^2 + \left(\tfrac{\varepsilon-u}{\sigma_v}\right)^2\right)\right] \\ &= \frac{1}{\pi\sigma_u\sigma_v}\exp\left[-\tfrac{1}{2}\left(\left(\tfrac{u}{\sigma_u}\right)^2 + \left(\tfrac{u^2+\varepsilon^2-2u\varepsilon}{\sigma_v}\right)\right)\right] \end{aligned} \qquad \text{(C.3)}$$

The density of ε is derived by equation (B.5) of Appendix B,

$$f(\varepsilon) = \frac{2}{\sqrt{2\pi}\sigma}\left[1 - F^*\left(-\tfrac{\varepsilon\lambda}{\sigma}\right)\right]\exp\left[-\tfrac{1}{2\sigma^2}\varepsilon^2\right] \qquad \text{(C.4)}$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \sigma_u / \sigma_v$, and F^* is the standard normal distribution function. Therefore, the conditional density of u given ε is the ratio of (C.3) to (C.4), which we can write as

$$f(u|\varepsilon) = \frac{1}{\sqrt{2\pi}\sigma_*}\frac{1}{1-F^*}\exp\left[-\tfrac{1}{2\sigma_*^2}u^2 + \tfrac{1}{\sigma_v^2}u\varepsilon - \tfrac{\lambda^2}{2\sigma^2}\varepsilon^2\right], \quad u \geq 0, \qquad \text{(C.5)}$$

where $\sigma_*^2 = \sigma_u^2\sigma_v^2 / \sigma^2$. With a little algebra, this simplifies to

$$f(u|\varepsilon) = \frac{1}{1-F^*}\frac{1}{\sqrt{2\pi}\sigma_*}\exp\left[-\tfrac{1}{2\sigma_*^2}\left(u + \sigma_u^2\varepsilon / \sigma^2\right)^2\right], \quad u \geq 0. \qquad \text{(C.6)}$$

Except for the term involving 1-F^*, this looks like the density of $N(\mu_*, \sigma_*^2)$, with $\mu_* = \sigma_u^2\varepsilon / \sigma^2$. Finally, note that F^* is evaluated at $-\varepsilon\lambda / \sigma = \mu_* / \sigma_*$, and thus $(1 - F^*)$ is just the probability that a $N(\mu_*, \sigma_*^2)$ variable positive. Thus, (C.6) is the density of a $N(\mu_*, \sigma_*^2)$ variable truncated at zero.

APPENDIX D

Scale Economies for U.S. Domestic Banks

OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE
1	1.0331	2	1.1296	3	1.0810	4	1.0997	5	1.1466	6	1.0786
7	1.0332	8	1.0982	9	1.0920	10	1.1174	11	1.0740	12	1.0984
13	1.0707	14	1.1179	15	1.1341	16	1.0890	17	1.1396	18	1.1070
19	1.0451	20	1.0469	21	1.0959	22	1.0677	23	1.1611	24	1.0962
25	1.0895	26	1.0635	27	1.0809	28	1.0704	29	1.0437	30	1.0719
31	1.0900	32	1.0700	33	1.0715	34	1.0874	35	1.1958	36	1.0755
37	1.1031	38	1.0729	39	1.0938	40	1.0914	41	1.1403	42	1.0570
43	1.1035	44	1.0910	45	1.0932	46	1.0491	47	1.0875	48	1.0733
49	1.0714	50	1.0570	51	1.0804	52	1.0587	53	1.0904	54	1.0655
55	1.0682	56	1.1185	57	1.0868	58	1.1020	59	1.0706	60	1.0776
61	1.0419	62	1.0918	63	1.0692	64	1.0809	65	1.1116	66	1.1029
67	1.1098	68	1.0954	69	1.1083	70	1.0679	71	1.0506	72	1.1262
73	1.0676	74	1.1312	75	1.0822	76	1.1079	77	1.0709	78	1.0651
79	1.0865	80	1.1003	81	1.0904	82	1.1697	83	1.0797	84	1.1174
85	1.0701	86	1.0807	87	1.1175	88	1.0765	89	1.0727	90	1.1078
91	1.0663	92	1.1042	93	1.0786	94	1.0593	95	1.0764	96	1.0762
97	1.0915	98	1.1313	99	1.0606	100	1.0977	101	1.0827	102	1.0687
103	1.1048	104	1.0694	105	1.0757	106	1.0685	107	1.0345	108	1.0309
109	1.1036	110	1.0807	111	1.0864	112	1.0959	113	1.0780	114	1.1042
115	1.0817	116	1.1105	117	1.0913	118	1.0460	119	1.0888	120	1.0814
121	1.0838	122	1.0749	123	1.1098	124	1.0842	125	1.0307	126	1.0876
127	1.1091	128	1.0861	129	1.0454	130	1.1080	131	1.0527	132	1.0718
133	1.1024	134	1.0862	135	1.0590	136	1.0826	137	1.0684	138	1.0721
139	1.0588	140	1.0613	141	1.0668	142	1.0947	143	1.0795	144	1.0501
145	1.0795	146	1.0538	147	1.0723	148	1.0958	149	1.0899	150	1.0713
151	1.0867	152	1.0563	153	1.0916	154	1.0708	155	1.1018	156	1.0590
157	1.0549	158	1.0888	159	1.0799	160	1.0854	161	1.0722	162	1.0406
163	1.0830	164	1.0662	165	1.1066	166	1.0987	167	1.0834	168	1.0865

1. OBS: Obsevations
2. SCE: Scale Economy

OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE
169	1.0958	170	1.0792	171	1.0767	172	1.1111	173	1.0880	174	1.0692
175	1.0848	176	1.0691	177	1.0632	178	1.1012	179	1.0823	180	1.0759
181	1.0795	182	1.0783	183	1.0790	184	1.0686	185	1.0724	186	1.0851
187	1.0772	188	1.0960	189	1.0783	190	1.0751	191	1.0917	192	1.6334
193	1.0337	194	1.0542	195	1.0616	196	1.0819	197	1.0669	198	1.0928
199	1.0622	200	1.0794	201	1.0847	202	1.0894	203	1.0665	204	1.0665
205	1.0836	206	1.0683	207	1.0540	208	1.0584	209	1.0929	210	1.0650
211	1.0729	212	1.0623	213	1.0710	214	1.0823	215	1.0636	216	1.0662
217	1.0386	218	1.1042	219	1.0262	220	1.0830	221	1.0641	222	1.0769
223	1.0729	224	1.0456	225	1.0674	226	1.0610	227	1.0670	228	1.0563
229	1.0572	230	1.0757	231	1.0649	232	1.0934	233	1.0878	234	1.0509
235	1.0685	236	1.0879	237	1.0680	238	1.0655	239	1.0623	240	1.0602
241	1.0924	242	1.0488	243	1.0855	244	1.0403	245	1.0441	246	1.0383
247	1.0587	248	1.0981	249	1.0669	250	1.0636	251	1.0512	252	1.0873
253	1.0581	254	1.0661	255	1.0627	256	1.0460	257	1.0767	258	1.0760
259	1.0605	260	1.0697	261	1.0529	262	1.1371	263	1.0765	264	1.0448
265	1.0690	266	1.0723	267	1.0893	268	1.0345	269	1.0679	270	1.0470
271	1.0550	272	1.0742	273	1.0784	274	1.0427	275	1.0181	276	1.0768
277	1.0592	278	1.0585	279	1.0667	280	1.0643	281	1.0862	282	1.0792
283	1.0837	284	1.0522	285	1.0755	286	1.0709	287	1.0590	288	1.0300
289	1.0495	290	1.0500	291	1.0296	292	1.0888	293	1.0453	294	1.0297
295	1.1012	296	1.0840	297	1.0568	298	1.0890	299	1.0549	300	1.0831
301	1.0588	302	1.0486	303	1.1190	304	1.0650	305	1.1658	306	1.0698
307	1.0771	308	1.0272	309	1.0532	310	1.0474	311	1.0517	312	1.0670
313	1.0363	314	1.0850	315	1.0618	316	1.0443	317	1.0620	318	1.0399
319	1.0569	320	1.0582	321	1.0525	322	1.0684	323	1.0598	324	1.0535
325	1.0472	326	1.0605	327	1.0664	328	1.5829	329	1.0619	330	1.1188
331	1.0608	332	1.0519	333	1.0445	334	1.0580	335	1.0495	336	1.0570
337	1.0506	338	1.0424	339	1.0424	340	1.0601	341	1.0496	342	1.0451
343	1.0677	344	1.0480	345	1.0821	346	1.0790	347	1.0635	348	1.0246
349	1.0553	350	1.0426	351	1.0844	352	1.0737	353	1.0425	354	1.0246
355	1.0442	356	1.0695	357	1.0462	358	1.0499	359	1.0364	360	1.0876
361	1.0633	362	1.0684	363	1.0558	364	1.0683	365	1.2311	366	1.0550
367	1.0154	368	1.0337	369	1.0746	370	1.0569	371	1.0730	372	1.0288
373	1.0414	374	1.0326	375	1.0473	376	1.0082	377	1.0308	378	1.0683
379	1.0420	380	1.0539	381	1.0517	382	1.0448	383	1.0624	384	1.0378

OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE
385	1.0326	386	1.0442	387	1.0473	388	1.0244	389	1.0402	390	1.0565
391	1.0405	392	1.0268	393	1.0087	394	1.0527	395	1.0010	396	1.0418
397	1.0601	398	1.0312	399	1.0202	400	1.0130	401	1.0303	402	1.0152
403	1.0537	404	1.0368	405	1.0493	406	1.2311	407	1.0359	408	1.0447
409	1.0257	410	1.0340	411	1.0301	412	1.0356	413	1.0004	414	1.0379
415	1.0433	416	1.0494	417	1.0331	418	1.0318	419	1.0451	420	1.0233
421	1.0800	422	1.0260	423	1.0253	424	1.0215	425	1.0113	426	1.0504
427	1.0334	428	1.0273	429	1.0123	430	1.0425	431	0.9991	432	1.0186
433	1.0752	434	1.0236	435	1.0352	436	1.0231	437	1.0383	438	1.0479
439	1.0548	440	1.0122	441	1.0137	442	1.0459	443	1.0237	444	1.0186
445	1.0186	446	1.0553	447	1.0278	448	1.0203	449	1.0657	450	1.0553
451	1.0331	452	1.0173	453	1.0288	454	1.0139	455	0.9917	456	1.0534
457	1.0289	458	1.0254	459	1.0293	460	1.0275	461	1.0008	462	1.0167
463	1.0233	464	0.9957	465	1.0288	466	1.3105	467	1.0286	468	1.0090
469	1.0230	470	1.0403	471	1.0355	472	1.0511	473	1.0222	474	1.0529
475	1.0309	476	1.0654	477	0.9835	478	1.0253	479	1.0268	480	1.0115
481	0.9878	482	1.0334	483	1.0197	484	0.9967	485	1.0378	486	1.0323
487	1.0218	488	1.0311	489	1.0128	490	1.0275	491	1.0239	492	1.0259
493	1.0047	494	1.0044	495	1.0113	496	0.9975	497	0.9875	498	1.0278
499	1.0417	500	1.0088	501	0.9891	502	1.0194	503	1.0098	504	0.9987
505	1.0341	506	1.0241	507	1.0144	508	0.9885	509	1.0005	510	1.0071
511	0.9822	512	1.0346	513	1.0333	514	1.0169	515	1.0107	516	1.0239
517	1.0221	518	1.0367	519	0.9960	520	1.0216	521	1.0238	522	1.0033
523	1.0249	524	1.0218	525	1.0157	526	0.9843	527	1.0125	528	1.0355
529	0.9548	530	1.0443	531	0.9909	532	1.0594	533	0.9809	534	0.9962
535	1.0026	536	1.0349	537	1.0480	538	1.0257	539	1.0247	540	0.9937
541	1.0271	542	1.0117	543	0.9930	544	1.0099	545	1.0008	546	1.0498
547	1.0177	548	1.0424	549	0.9982	550	1.0210	551	1.0046	552	0.9959
553	1.0035	554	1.0113	555	0.9982	556	1.0333	557	1.0046	558	0.9420
559	1.0116	560	1.0052	561	1.4078	562	0.9889	563	1.0154	564	1.0157
565	0.9818	566	0.9954	567	0.9941	568	0.9943	569	0.9993	570	0.9943
571	1.0249	572	1.0107	573	0.9803	574	1.0065	575	0.9913	576	1.0052
577	0.9977	578	1.0074	579	0.9823	580	1.0094	581	1.0030	582	1.0142
583	1.0257	584	0.9837	585	0.9985	586	1.0047	587	0.9800	588	1.0241
589	1.0023	590	0.9788	591	0.9924	592	0.9990	593	1.0265	594	1.0257
595	1.0053	596	0.9943	597	1.0163	598	0.9769	599	1.0131	600	0.9707
601	0.9962	602	1.0076	603	0.9744	604	0.9740	605	0.9826	606	0.9943

OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE
607	0.9655	608	0.9606	609	0.9920	610	0.9953	611	0.9923	612	0.9787
613	1.0000	614	0.9726	615	0.9857	616	0.9758	617	0.9818	618	0.9808
619	0.9741	620	0.9752	621	0.9813	622	1.0059	623	0.9799	624	0.9836
625	0.9749	626	0.9747	627	0.9833	628	1.0088	629	0.9914	630	0.9816
631	0.9582	632	1.0102	633	0.9689	634	0.9704	635	0.9621	636	0.9731
637	0.9889	638	0.9209	639	0.9599	640	0.9862	641	0.9534	642	0.9741
643	0.9577	644	0.9952	645	0.9821	646	0.9664	647	0.9691	648	0.9726
649	0.9694	650	0.9845	651	1.0006	652	0.9470	653	0.9872	654	0.9629
655	1.0064	656	0.9480	657	0.9895	658	0.9655	659	0.9573	660	0.9638
661	0.9927	662	0.9683	663	1.2667	664	0.9565	665	0.9828	666	0.9509
667	0.9429	668	0.9655	669	0.9348	670	1.3032	671	0.9553	672	0.9529
673	0.9569	674	0.9703	675	0.9407	676	0.9448	677	0.9420	678	0.9409
679	1.0122	680	1.3359	681	0.9296	682	0.9583	683	0.9416	684	0.9590
685	0.9401	686	0.9555	687	0.9866	688	0.9344	689	0.9221	690	0.9586
691	0.9365	692	0.9754	693	0.9368	694	0.9371	695	0.9665	696	0.9466
697	0.9675	698	0.9421	699	0.9403	700	0.9228	701	0.9477	702	0.9375
703	0.9277	704	0.9576	705	0.9535	706	0.9262	707	0.9101	708	0.9456
709	0.9216	710	0.9267	711	0.9476	712	0.9345	713	0.9699	714	0.9323
715	0.9264	716	0.9263	717	0.9225	718	0.9284	719	0.9361	720	0.9335
721	0.9072	722	0.9296	723	0.9303	724	0.9066	725	0.9175	726	0.9263
727	0.9117	728	0.9133	729	1.1635	730	0.9013	731	0.9000	732	0.9067
733	0.8926	734	0.8919	735	0.8836	736	0.8930	737	0.9028	738	0.8856
739	0.8946	740	0.8715	741	0.8759	742	0.8768	743	0.8606	744	0.8490

APPENDIX E

Technical Inefficiencies for U.S. Domestic Banks

OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI
1	0.1153	2	0.1713	3	0.4065	4	0.2171	5	0.1611	6	0.1962
7	0.1670	8	0.1334	9	0.2294	10	0.0961	11	0.1114	12	0.0692
13	0.1572	14	0.1496	15	0.1381	16	0.0997	17	0.2762	18	0.1942
19	0.1587	20	0.4280	21	0.1641	22	0.1156	23	0.3690	24	0.2282
25	0.2120	26	0.1272	27	0.1149	28	0.3736	29	0.0614	30	0.1758
31	0.1645	32	0.1964	33	0.1064	34	0.1583	35	0.8980	36	0.1523
37	0.1296	38	0.2467	39	0.1608	40	0.1635	41	0.1119	42	0.2441
43	0.1477	44	0.1200	45	0.1564	46	0.3631	47	0.1082	48	0.1734
49	0.0957	50	0.1949	51	0.1266	52	0.1198	53	0.2179	54	0.2971
55	0.1034	56	0.0703	57	0.1215	58	0.0822	59	0.1174	60	0.1328
61	0.0694	62	0.2686	63	0.1260	64	0.1199	65	0.1098	66	0.2078
67	0.1474	68	0.1123	69	0.1544	70	0.1246	71	0.1475	72	0.2886
73	0.1094	74	0.1015	75	0.1701	76	0.2514	77	0.0943	78	0.1778
79	0.1776	80	0.1641	81	0.1506	82	0.6226	83	0.1149	84	0.1475
85	0.1428	86	0.1190	87	0.1749	88	0.1385	89	0.1019	90	0.2113
91	0.2886	92	0.1580	93	0.1783	94	0.2656	95	0.1080	96	0.1311
97	0.2061	98	0.1476	99	0.1506	100	0.2165	101	0.2714	102	0.1594
103	0.1183	104	0.1181	105	0.1454	106	0.2124	107	0.1527	108	0.1449
109	0.1536	110	0.1228	111	0.1171	112	0.0948	113	0.1300	114	0.1348
115	0.1929	116	0.1945	117	0.1083	118	0.2772	119	0.1816	120	0.1276
121	0.1885	122	0.1541	123	0.2142	124	0.0954	125	0.1499	126	0.1442
127	0.1152	128	0.1782	129	0.0978	130	0.0907	131	0.1108	132	0.2474
133	0.3319	134	0.1956	135	0.0936	136	0.2947	137	0.1500	138	0.1088
139	0.2778	140	0.1195	141	0.0994	142	0.0692	143	0.1641	144	0.1513
145	0.1623	146	0.1540	147	0.1328	148	0.0630	149	0.1116	150	0.1112
151	0.1374	152	0.1243	153	0.1811	154	0.0720	155	0.1360	156	0.8546
157	0.3561	158	0.1129	159	0.1200	160	0.2127	161	0.1640	162	0.1135
163	0.1192	164	0.1511	165	0.1320	166	0.1960	167	0.1668	168	0.1696
169	0.0958	170	0.1189	171	0.1620	172	0.1375	173	0.1497	174	0.1388
175	0.0787	176	0.1767	177	0.0908	178	0.0981	179	0.1823	180	0.1051
181	0.1625	182	0.1961	183	0.1330	184	0.1870	185	0.3273	186	0.1915

1. OBS: Obsercations
2. TEI: Technical Inefficiency

OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI
187	0.2062	188	0.3729	189	0.1581	190	0.2350	191	0.3605	192	0.1896
193	0.0443	194	0.1381	195	0.3147	196	0.1055	197	0.0858	198	0.0870
199	0.1930	200	0.1333	201	0.2125	202	0.1427	203	0.2843	204	0.1128
205	0.2125	206	0.1669	207	0.1948	208	0.1637	209	0.0886	210	0.1537
211	0.1606	212	0.0986	213	0.1617	214	0.1747	215	0.2599	216	0.1553
217	0.1460	218	0.0971	219	0.0686	220	0.1500	221	0.0878	222	0.1636
223	0.6262	224	0.0308	225	0.1369	226	0.1900	227	0.2034	228	0.2271
229	0.1355	230	0.1060	231	0.1968	232	0.1810	233	0.2169	234	0.2171
235	0.2187	236	0.2194	237	0.2291	238	0.1050	239	0.2017	240	0.1290
241	0.0941	242	0.1532	243	0.4585	244	0.1155	245	0.1478	246	0.5063
247	0.1756	248	0.1829	249	0.1479	250	0.2498	251	0.2295	252	0.1873
253	0.1089	254	0.1189	255	0.1740	256	0.1009	257	0.2369	258	0.0802
259	0.1024	260	0.0977	261	0.1609	262	0.1930	263	0.1066	264	0.1574
265	0.1883	266	0.2020	267	0.1718	268	0.1194	269	0.1075	270	0.1554
271	0.1811	272	0.2208	273	0.1514	274	0.1928	275	0.1477	276	0.2032
277	0.2139	278	0.2455	279	0.1657	280	0.0932	281	0.1502	282	0.2224
283	0.2356	284	0.1090	285	0.1107	286	0.1706	287	0.0981	288	0.0285
289	0.1775	290	0.1237	291	0.1183	292	0.1034	293	0.1327	294	0.1317
295	0.2852	296	0.1396	297	0.1490	298	0.2179	299	0.1213	300	0.2853
301	0.1387	302	0.1842	303	0.1330	304	0.2093	305	0.7146	306	0.1775
307	0.1456	308	0.1012	309	0.1393	310	0.1935	311	0.1195	312	0.0880
313	0.3307	314	0.2606	315	0.1442	316	0.1372	317	0.1273	318	0.1746
319	0.2616	320	0.1344	321	0.1837	322	0.1497	323	0.1890	324	0.2037
325	0.1328	326	0.1181	327	0.2558	328	0.1041	329	0.1003	330	0.2125
331	0.1687	332	0.2500	333	0.1137	334	0.1544	335	0.1910	336	0.1234
337	0.1489	338	0.1551	339	0.3297	340	0.1583	341	0.1578	342	0.1054
343	0.1699	344	0.1858	345	0.2553	346	0.1451	347	0.3447	348	0.2590
349	0.1646	350	0.1003	351	0.2343	352	0.1316	353	0.2697	354	0.1324
355	0.1322	356	0.2513	357	0.3183	358	0.1023	359	0.3316	360	0.1574
361	0.0927	362	0.2779	363	0.1177	364	0.1655	365	0.8712	366	0.3750
367	0.1104	368	0.3943	369	0.1517	370	0.0908	371	0.2391	372	0.2620
373	0.1464	374	0.1645	375	0.2858	376	0.1345	377	0.1324	378	0.2922
379	0.1370	380	0.1168	381	0.1226	382	0.1329	383	0.3105	384	0.1177
385	0.1284	386	0.2177	387	0.2587	388	0.1996	389	0.1553	390	0.3918
391	0.1289	392	0.2518	393	0.1869	394	0.1116	395	0.1439	396	0.1615
397	0.1765	398	0.4362	399	0.1236	400	0.1785	401	0.1131	402	0.0939
403	0.0858	404	0.2786	405	0.0567	406	0.2700	407	0.3012	408	0.1648

OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI
409	0.2268	410	0.2102	411	0.2104	412	0.0919	413	0.1130	414	0.1765
415	0.0867	416	0.3734	417	0.2050	418	0.2009	419	0.1480	420	0.2562
421	0.3454	422	0.1172	423	0.1277	424	0.1381	425	0.0822	426	0.1486
427	0.2000	428	0.4791	429	0.1033	430	0.2249	431	0.1700	432	0.5048
433	0.3143	434	0.1292	435	0.2183	436	0.1028	437	0.1459	438	0.1329
439	0.1880	440	0.1927	441	0.0844	442	0.1091	443	0.1329	444	0.0682
445	0.0982	446	0.1826	447	0.1727	448	0.2286	449	0.4977	450	0.2858
451	0.2746	452	0.1155	453	0.2162	454	0.1590	455	0.2087	456	0.2047
457	0.1527	458	0.6293	459	0.1787	460	0.2440	461	0.1072	462	0.2251
463	0.4212	464	0.1613	465	0.1066	466	1.1855	467	0.4327	468	0.1190
469	0.1090	470	0.1862	471	0.3192	472	0.2645	473	0.1730	474	0.1568
475	0.1784	476	0.3218	477	0.0819	478	0.2290	479	0.1053	480	0.1272
481	0.2111	482	0.1901	483	0.1549	484	0.0953	485	0.2965	486	0.1765
487	0.0983	488	0.1695	489	0.2085	490	0.1213	491	0.2390	492	0.1810
493	0.1732	494	0.1144	495	0.1917	496	0.2038	497	0.2288	498	0.0555
499	0.1649	500	0.1254	501	0.2419	502	0.1186	503	0.1438	504	0.0894
505	0.1349	506	0.3070	507	0.1100	508	0.1639	509	0.0974	510	0.2092
511	0.1106	512	0.1609	513	0.1672	514	0.1784	515	0.1445	516	0.4106
517	0.3277	518	0.1541	519	0.1274	520	0.1925	521	0.1633	522	0.1664
523	0.2502	524	0.3211	525	0.1130	526	0.0960	527	0.2905	528	0.2233
529	0.0852	530	0.2455	531	0.1857	532	0.3371	533	0.1737	534	0.1739
535	0.2483	536	0.1198	537	0.1936	538	0.1691	539	0.1807	540	0.1760
541	0.1958	542	0.2378	543	0.1731	544	0.1383	545	0.0990	546	0.2864
547	0.2038	548	0.2453	549	0.3509	550	0.3639	551	0.1628	552	0.2004
553	0.1452	554	0.2981	555	0.2639	556	0.1599	557	0.0324	558	0.0760
559	0.0863	560	0.3289	561	0.2470	562	0.1454	563	0.2159	564	0.2019
565	0.1128	566	0.1748	567	0.1772	568	0.1049	569	0.1969	570	0.1763
571	0.1318	572	0.2118	573	0.2433	574	0.6979	575	0.2872	576	0.0980
577	0.2007	578	0.1481	579	0.1549	580	0.2323	581	0.2975	582	0.2133
583	0.2661	584	0.2560	585	0.2009	586	0.2732	587	0.2285	588	0.3212
589	0.2210	590	0.4455	591	0.2029	592	0.2654	493	0.3801	594	0.2264
595	0.1255	596	0.1682	597	0.3947	598	0.1689	599	0.3051	600	0.1206
601	0.2075	602	0.0940	603	0.9828	604	0.2882	605	0.1351	606	0.2149
607	0.1000	608	0.3400	609	0.1001	610	0.2972	611	0.2185	612	0.1251
613	0.1772	614	0.1403	615	0.2251	616	0.2468	617	0.2177	618	0.0241
619	0.2048	620	0.2139	621	0.3074	622	0.1820	623	0.4080	624	0.2317
625	0.21889	626	0.2431	627	0.2081	628	0.8788	629	0.5810	630	0.2538

OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI
631	0.3225	632	0.2495	633	0.1366	634	0.1559	635	0.1678	636	0.1736
637	0.1193	638	0.5913	639	0.1083	640	0.0714	641	0.1243	642	0.2935
643	0.2560	644	0.3235	645	0.2007	646	0.1898	647	0.1781	648	0.1835
649	0.1877	650	0.1552	651	0.6793	652	0.3056	653	0.1631	654	0.2835
655	0.3032	656	0.2607	657	0.2839	658	0.3437	659	0.1367	660	0.1503
661	0.2049	662	0.2706	663	0.7498	664	0.2045	665	0.1601	666	0.1068
667	0.1356	668	0.1302	669	0.5144	670	0.0676	671	0.1943	672	0.1237
673	0.0943	674	0.2389	675	0.1026	676	0.1357	677	0.2926	678	0.1233
679	0.6094	680	0.0561	681	0.1257	682	0.1738	683	0.2007	684	0.2364
685	0.1550	686	0.1589	687	1.0078	688	0.1405	689	0.1168	690	0.2593
691	0.1632	692	0.1803	693	0.0882	694	0.1630	695	0.4081	696	0.1253
697	0.1836	698	0.2051	699	0.3517	700	0.0714	701	0.2986	702	0.0835
703	0.0762	704	0.3248	705	0.1948	706	0.1201	707	0.1190	708	0.1941
709	0.2459	710	0.1777	711	0.1886	712	0.1396	713	0.5574	714	0.2192
715	0.2533	716	0.0444	717	0.1306	718	0.1894	719	0.2891	720	0.2631
721	0.1649	722	0.2475	723	0.2247	724	0.1395	725	0.2236	726	0.0816
727	0.3685	728	0.2093	729	0.0718	730	0.1220	731	0.1575	732	0.1380
733	0.1949	734	0.0973	735	0.1667	736	0.2058	737	0.1516	738	0.1446
739	0.1882	740	0.1697	741	0.1459	742	0.1084	743	0.1302	744	0.0836

APPENDIX F

Scale Economies for U.S. Multinational Banks

OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE
1	1.1175	2	1.0588	3	1.1406	4	1.0783	5	1.1188	6	1.1214
7	1.1155	8	1.1047	9	1.1390	10	1.1413	11	1.0987	12	1.1092
13	1.2490	14	1.0377	15	1.0711	16	1.1037	17	1.1089	18	1.0810
19	1.1514	20	1.0712	21	1.0126	22	1.0940	23	1.0865	24	1.1387
25	1.4337	26	1.0357	27	0.9495	28	1.0642	29	1.0056	30	1.0136
31	1.0616	32	1.0517	33	1.0019	34	1.0337	35	1.0574	36	1.0116
37	1.0227	38	1.0325	39	1.0180	40	1.0014	41	0.9626	42	1.0438
43	1.0340	44	0.9748	45	1.0244	46	1.0548	47	1.0616	48	1.0958
49	1.0056	50	0.9928	51	1.1021	52	0.9996	53	0.9833	54	1.0719
55	0.9954	56	1.0424	57	1.0420	58	0.9815	59	1.0023	60	0.9722
61	0.9831	62	1.0603	63	1.0323	64	0.9932	65	0.9642	66	0.9815
67	1.0237	68	0.9921	69	1.0087	70	0.9936	71	1.0153	72	0.9844
73	0.9777	74	1.0001	75	0.9731	76	0.9919	77	0.9990	78	1.0021
79	0.9684	80	0.9873	81	0.9748	82	0.9431	83	0.9866	84	0.9922
85	0.9570	86	0.9646	87	0.9904	88	0.9793	89	0.9616	90	1.0035
91	0.9699	92	0.9896	93	0.9655	94	0.9926	95	0.9951	96	0.9960
97	1.1214	98	0.9988	99	0.9827	100	0.9724	101	0.9767	102	0.9886
103	0.9765	104	0.9973	105	0.9739	106	0.9544	107	0.9737	108	0.9912
109	0.9915	110	0.9792	111	0.9553	112	1.0292	113	0.9642	114	0.9585
115	1.0297	116	1.1931	117	0.9717	118	0.9616	119	0.9671	120	0.9748
121	0.9775	122	0.9437	123	0.9838	124	1.0022	125	0.9439	126	0.9838
127	0.9655	128	0.9351	129	0.9794	130	0.9812	131	0.9660	132	0.9677
133	0.9165	134	0.9306	135	0.9456	136	0.9500	137	0.9638	138	0.9683
139	0.9505	140	0.9563	141	0.9625	142	0.9348	143	0.9215	144	0.9403
145	0.9601	146	0.9517	147	0.8935	148	0.9270	149	0.9058	150	0.9371
151	0.9316	152	0.9512	153	0.9312	154	0.9278	155	0.9493	156	0.9387
157	0.8982	158	0.9143	159	0.9636	160	0.9729	161	0.8593	162	0.8992
163	0.8635	164	0.8395	165	0.8667	166	0.8620	167	0.8629		

1.OBS: Observations.
2. SCE: Scale Economy

APPENDIX G

Technical Inefficiencies for U.S. Multinational Banks

OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI
1	0.2848	2	0.1666	3	0.1922	4	0.1792	5	0.1198	6	0.14093
7	0.2053	8	0.1817	9	0.1113	10	0.1434	11	0.2513	12	0.22750
13	0.1552	14	0.1039	15	0.1222	16	0.1307	17	0.1447	18	0.25717
19	0.1668	20	0.0418	21	0.1694	22	0.1242	23	0.1319	24	0.10548
25	0.1595	26	0.1435	27	0.1241	28	0.1046	29	0.0893	30	0.14264
31	0.1722	32	0.2000	33	0.0938	34	0.1559	35	0.2335	36	0.10145
37	0.1458	38	0.1535	39	0.1481	40	0.1858	41	0.1617	42	0.11888
43	0.1673	44	0.1696	45	0.1623	46	0.1560	47	0.1369	48	0.14237
49	0.3403	50	0.1566	51	0.1129	52	0.1387	53	0.1460	54	0.17459
55	0.1859	56	0.2069	57	0.1531	58	0.1472	59	0.1952	60	0.09803
61	0.1692	62	0.1364	63	0.1653	64	0.1635	65	0.1183	66	0.11579
67	0.1263	68	0.1169	69	0.1453	70	0.1205	71	0.1720	72	0.17412
73	0.1322	74	0.1848	75	0.2682	76	0.1727	77	0.1294	78	0.14479
79	0.1196	80	0.1139	81	0.1662	82	0.1140	83	0.1967	84	0.17284
85	0.1562	86	0.1495	87	0.1334	88	0.1472	89	0.4002	90	0.16765
91	0.1400	92	0.1778	93	0.1570	94	0.1598	95	0.3326	96	0.13283
97	0.1352	98	0.1469	99	0.1207	100	0.1974	101	0.1241	102	0.46917
103	0.1274	104	0.1775	105	0.1431	106	0.1402	107	0.1283	108	0.12571
109	0.1426	110	0.1570	111	0.2053	112	0.2746	113	0.1174	114	0.14338
115	0.1839	116	0.1135	117	0.1307	118	0.1138	119	0.2003	120	0.20594
121	0.1722	122	0.1515	123	0.1525	124	0.1357	125	0.1443	126	0.13627
127	0.2009	128	0.1318	129	0.1526	130	0.1904	131	0.1406	132	0.20627
133	0.1353	134	0.1431	135	0.1585	136	0.0827	137	0.1536	138	0.17924
139	0.1284	140	0.1642	141	0.1335	142	0.2119	143	0.1470	144	0.12675
145	0.1523	146	0.1504	147	0.1378	148	0.1268	149	0.0977	150	0.14143
151	0.1633	152	0.1277	153	0.1107	154	0.1886	155	0.1804	156	0.10762
157	0.1274	158	0.1380	159	0.1750	160	0.1489	161	0.3330	162	0.12135
163	0.1490	164	0.2041	165	0.1310	166	0.1023	167	0.1822		

1.OBS: Observations.
2. TEI: Technical Inefficiency

APPENDIX H

Scale Economies for Japanese Banks

OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE
1	1.0724	2	1.0051	3	0.6636	4	1.0365	5	1.0780	6	1.1258
7	1.0760	8	1.1284	9	1.0402	10	1.0688	11	0.9525	12	1.0641
13	1.3487	14	1.0249	15	0.9995	16	1.1103	17	1.0119	18	1.0531
19	1.2965	20	1.0692	21	0.9848	22	1.0512	23	1.0111	24	1.0595
25	0.7374	26	1.0492	27	1.0332	28	1.0982	29	1.0010	30	1.0685
31	1.1692	32	1.0391	33	1.2076	34	1.0268	35	0.9781	36	1.0382
37	1.0112	38	1.0491	39	0.9549	40	0.8929	41	0.9505	42	0.7447
43	1.0889	44	0.9975	45	1.0446	46	0.9854	47	1.0159	48	1.2473
49	1.0174	50	1.1507	51	0.9957	52	1.0308	53	1.0052	54	0.9867
55	1.1165	56	1.0163	57	0.9966	58	1.1177	59	1.0723	60	1.0076
61	0.9712	62	0.9512	63	1.0681	64	1.1036	65	1.0305	66	1.0305
67	1.0896	68	0.9737	69	0.9520	70	1.0810	71	1.1550	72	0.9616
73	0.9348	74	0.9871	75	0.9703	76	0.9323	77	1.0929	78	0.9973
79	0.9616	80	0.9715	81	0.9207	82	0.9414	83	0.9772	84	1.0739
85	0.9828	86	1.0379	87	0.9569	88	0.8726	89	0.9764	90	0.9342
91	0.9430	92	1.0044	93	0.9727	94	0.9434	95	0.9586	96	0.9560
97	1.0108	98	0.7632	99	1.1403	100	0.8042	101	0.9402	102	0.9522
103	0.7880	104	0.8065	105	0.8597	106	0.9470	107	0.9159	108	0.8964
109	0.8965	110	0.8831	111	0.8906	112	0.8768	113	0.8761	114	0.8862
115	0.8674	116	0.8414								

1.OBS: Observations.
2. SCE: Scale Economy

APPENDIX I

Technical Inefficiencies for Japanese Banks

OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI
1	0.1789	2	0.2307	3	0.1560	4	0.0252	5	0.1024	6	0.3094
7	0.0884	8	0.1293	9	0.2102	10	0.0955	11	0.2540	12	0.0971
13	0.1417	14	0.2223	15	0.1709	16	0.0256	17	0.1134	18	0.1097
19	0.0273	20	0.0584	21	0.2892	22	0.1104	23	0.0239	24	0.0936
25	0.0184	26	0.1434	27	0.0228	28	0.0894	29	0.1823	30	0.1447
31	0.1777	32	0.1991	33	0.1818	34	0.0573	35	0.2001	36	0.0903
37	0.0353	38	0.1956	39	0.1478	40	0.0983	41	0.1102	42	0.2649
43	0.4136	44	0.2751	45	0.1489	46	0.1450	47	0.0762	48	0.1200
49	0.1848	50	0.2686	51	0.1563	52	0.1245	53	0.0870	54	0.1398
55	0.0224	56	0.1176	57	0.1019	58	0.4502	59	0.1735	60	0.0425
61	0.1671	62	0.1588	63	0.0862	64	0.0219	65	0.2130	66	0.0754
67	0.0098	68	0.1871	69	0.0574	70	0.1920	71	0.2187	72	0.0967
73	0.0089	74	0.2376	75	0.1483	76	0.1601	77	0.2768	78	0.1026
79	0.0417	80	0.1154	81	0.0326	82	0.0155	83	0.1522	84	0.2620
85	0.0700	86	0.0920	87	0.0549	88	1.0834	89	0.0729	90	0.0311
91	0.0246	92	0.1385	93	0.0941	94	0.2296	95	0.0991	96	0.2441
97	0.2653	98	0.3927	99	0.4202	100	0.6672	101	0.2103	102	0.0728
103	0.7186	104	0.4275	105	0.6149	106	0.8249	107	0.6379	108	0.8383
109	0.7964	110	0.7604	111	0.4761	112	0.4262	113	0.2873	114	0.1694
115	0.3606	116	0.0106								

1.OBS: Observations.
2. TEI: Technical Inefficiency

APPENDIX J

Scale Economies for Japanese Banks Operating in U.S.

OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE	OBS	SCE
1	1.7191	2	1.2947	3	1.2048	4	1.2831	5	1.4393	6	1.7009
7	1.1950	8	1.0512	9	1.6777	10	0.9866	11	1.0138	12	1.0223
13	0.9586	14	0.9269	15	0.8826	16	0.8603	17	0.8505		

1.OBS: Observations.
2. SCE: Scale Economy

APPENDIX K

Technical Inefficiencies for Japanese Banks Operating in U.S.

OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI	OBS	TEI
1	0.3421	2	0.0497	3	0.5665	4	0.0649	5	0.8828	6	0.4450
7	0.3081	8	0.0586	9	1.5097	10	0.0871	11	0.3463	12	0.3782
13	0.2489	14	0.7219	15	0.1591	16	0.1432	17	0.1003		

1.OBS: Observations.
2. TEI: Technical Inefficiency

APPENDIX L

Tables and Figures

Author		Scale Elasticity at Sample Mean	Range of Scale Elasticity Measure	Relevant Range for Significant Scale Diseconomies
Benston, Hanweck	U	0.92	0.81-1.12	Above $25 million
and Humphrey (1982)	B	0.91	0.86-1.03	Above $25 million
Berger, Hanweck	U	0.96	0.83-1.15	Above $100 million
and Humphrey (1987)	B	0.98	0.97-1.00	No significant (dis)economies
Cebenoyan (1988)	U	0.93	0.72-1.14	Above $50 million
	B	1.03	0.97-1.07	Economies above $100 million
Gilligan and Smirlock (1984)	U	1.01	0.91-1.02	Above $100 million Economies above $10 million
Gilligan, Smirlock and Marshall (1984)	U	0.97	0.79-1.08	Above $100 million Economies below $25 million
	B	0.98	0.85-1.06	Above $100 million and Economies below $25 million
Kolari and	B	-	0.98-1.01	No significant diseconomies
Zardkoohi (1987)	U	-	1.08-1.13	Economies below $100 million
Ferrier and Lovell (1990)		1.02	1.00-1.03	No significant diseconomies
Lawrence and Shay (1986)		1.01	1.01-1.10	Economies below $100 million
Mahajan et.al. (1996)	M	-	0.82-0.95	Diseconomies for all size levels
	D	-	0.99-1.03	Diseconomies above $0.5 billion

1. U and B represent unit and branch bank subsamples, respectively.
2. M and D represent multinational banks and domestic banks, respectively.

Table 1 : Scale Economies for Small Banks

Author	Range of Scale Economies	Size at Which Economies of Scale are exhausted
Berger and Humphrey (1991)	0.97 - 1.02	$0.3 billion [1]
Clark (1984)	1.04 - 1.05	Non-exhausted through $500 million [2]
Evanoff and Israilevich (1990)	1.02	$5.5 billion
Hunter and Timme (1986)	0.95	$4.2 billion [3]
	1.03	$12.5 billion [4]
Hunter, Timme and Yang (1990)	0.89-1.16	$25.0 billion
Noulas, et al. (1990)	0.89 -1.03	$25.0 billion
Shaffer (1988)	1.06 [5]	Non-exhausted through $140 billion [6]
Shaffer (1984)	1.05	Non-exhausted through $50 billion [6]
Shaffer and David (1991)	1.09	$37.0 billion

1. Branch bank results for the low cost banks
2. Non-exhausted for the entire sample
3. For one bank holding companies
4. For multibank holding companies
5. For a $10 billion bank
6. Non-exhausted for the entire sample

Table 2 : Scale Economies for Large Banks

Author	Approach	Overall Input Inefficiency	Allocative Inefficiency	Pure Technical Inefficiency
Berger and Humphrey (1991) [1]	Parametric (TFA)	23.6	Minimal	
Cebenoyan and Register (1990)	Parametric (EFA)	23.0		
Elyasani and Mehdian (1990b) [2]	Nonparametric (DEA)	22.3	-	22.3
Evanoff and Israilevich (1990) [3]	Parametric (EFA)	22.0	1.0	21.0
Ferrier and Lovell (1990)	Parametric (EFA)	26.4	17.4	8.9
Aly, et al. (1990) [4]	Nonparametric (DEA)	36.0	13.0	23.0
Rangan, et al. (1988)	Nonparametric (DEA)	31.0	3.0	28.0
Elyasiani and Mehdian (1990a)	Nonparametric (EFA)			11.7
Ferrier and Lovell (1990)	Nonparametric (DEA)	21.6	5.2	16.4
Gold and Sherman (1985)	Nonparametric (DEA)			27.9
Mahajan, et al. (1996) [5]	Parametric (TFA)	25.0-28.0		

1. For branch banks.
2. For the 1987-90 period.
3. For the 1972-87 period.
4. Scale inefficiency was also calculated to be 3.1 percent.
5. For the domestic banks.

Table 3 : Input X-Inefficiency in Banking

	Mean	Standard Deviation	Minimum Value	Maximum Value
A. Domestic Banks				
Assets	1,225,057	1,806,491	300,505	22,918,040
Loans	767,297	1,145,239	36,291	11,401,150
Deposits	946,649	1,394,459	1,083	17,975,860
Costs	77,667	108,445	11,430	1,155,081
Labor	501	710	5	6,634
Capital	18,797	29,148	21	297,004
B. Multinational Banks				
Assets	24,302,854	40,030,923	343,557	283,056,000
Loans	14,205,630	23,415,807	12,507	175,639,000
Deposits	9,042,998	16,833,933	65,563	141,934,000
Costs	883,438	2,036,990	5,656	21,132,000
Labor	4,353	7,492	46	62,055
Capital	384,531	800,958	978	6,384,000

1. Assets, Loans, Deposits, Costs and Capital are in thousand dollars
2. Data Sources: Call and Income Report (1994).

Table 4 : Summary Statistics for U.S. Sample Banks for 1994

	Mean	Standard Deviation	Minimum Value	Maximum Value
A. Japanese Banks				
Assets	64,540,480	117,207,050	3,035,878	513,465,790
Loans	40,775,614	73,826,080	2,009,121	350,321,360
Deposits	48,432,853	86,010,358	2,569,446	388,494,280
Costs	3,424,503	6,828,591	127,452	30,812,918
Labor	3,453	3,665	510	21,600
Capital	514,215	717,685	30,114	3,666,442
B. Japanese Banks Operating in the U.S.				
Assets	1,999,817	2,479,470	61,673	7,309,394
Loans	1,369,321	1,843,519	1,241	5,452,636
Deposits	1,404,056	1,980,526	9,537	6,338,156
Costs	121,512	150,972	4,985	455,528
Labor	368	693	12	2,686
Capital	12,210	29,235	203	121,828

1. Assets, Loans, Deposits, Costs and Capital are in thousand dollars
2. Data Sources: Kaisha Nenkan, and Call and Income Report (1994).

Table 5 : Summary Statistics for Japanese Sample Banks for 1994

Parameter	Parameter Estimate	Parameter	Parameter Estimate
α *	6.2008	β_8 *	-0.0910
	(0.0519)		(0.0308)
β_1 *	-0.4630	β_9	0.0152
	(0.0761)		(0.0226)
β_2 *	0.6218	β_{10} *	-0.0779
	(0.1029)		(0.0309)
β_3	0.1648	β_{11}	0.0168
	(0.0972)		(0.0125)
β_4 *	0.7566	β_{12} *	-0.0525
	(0.1762)		(0.0136)
β_5 *	0.1705	β_{13} *	-0.0442
	(0.011)		(0.0189)
β_6 *	-0.1169	β_{14} *	0.0343
	(0.0101)		(0.0154)
β_7 *	0.1251	λ *	1.6821
	(0.0150)		(0.01385)
		σ^2 *	0.085765
			(0.004722)

1. Standard errors in parentheses.
2.* : Significantly different from zero at the 5 % level, two-tailed test.
3. α and βs are parameters in :

$$
\begin{aligned}
\ln C = {} & \alpha + \beta_1 \ln y_1 + \beta_2 \ln y_2 + \beta_3(\ln w_2 - \ln w_1) + \beta_4(\ln w_3 - \ln w_1) + \\
& \beta_5(\tfrac{1}{2}\ln y_1 \ln y_1) + \beta_6(\ln y_1 \ln y_2) + \beta_7(\tfrac{1}{2}\ln y_2 \ln y_2) + \\
& \beta_8[\tfrac{1}{2}(\ln w_1 \ln w_2 + \ln w_2 \ln w_1 - \ln w_1 \ln w_1 - \ln w_2 \ln w_2)] + \\
& \beta_9[\tfrac{1}{2}(\ln w_2 \ln w_3 + \ln w_3 \ln w_2 - \ln w_2 \ln w_2 - \ln w_3 \ln w_3)] + \\
& \beta_{10}[\tfrac{1}{2}(\ln w_1 \ln w_3 + \ln w_3 \ln w_1 - \ln w_1 \ln w_1 - \ln w_3 \ln w_3)] + \\
& \beta_{11}(\ln y_1 \ln w_2 - \ln y_1 \ln w_1) + \beta_{12}(\ln y_1 \ln w_3 - \ln y_1 \ln w_1) + \\
& \beta_{13}(\ln y_2 \ln w_1 - \ln y_2 \ln w_2) + \beta_{14}(\ln y_2 \ln w_3 - \ln y_2 \ln w_2) + u_i + v_i
\end{aligned}
$$

Table 6 : Translog Stochastic Cost Frontier Parameter Estimates for U.S. Domestic Banks

Parameter	Parameter Estimate	Parameter	Parameter Estimate
α *	9.5128 (0.0967)	β_8	-0.0134 (0.0525)
β_1 *	0.5163 (0.0744)	β_9	-0.0022 (0.0383)
β_2 *	-0.4721 (0.0727)	β_{10}	-0.0479 (0.0468)
β_3 *	0.6698 (0.0926)	β_{11} *	0.1205 (0.0464)
β_4 *	0.8429 (0.0905)	β_{12}	-0.0503 (0.0580)
β_5 *	0.5096 (0.1587)	β_{13} *	-0.1427 (0.0674)
β_6 *	-0.4620 (0.1265)	β_{14}	0.0124 (0.0499)
β_7 *	0.4492 (0.0987)	λ *	0.7331 (0.0962)
		σ^2 *	0.1147 (0.0414)

1. Standard errors in parentheses.
2.* : Significantly different from zero at the 5 % level, two-tailed test.
3. α and βs are parameters in :

$$
\begin{aligned}
\ln C = {} & \alpha + \beta_1 \ln y_1 + \beta_2 \ln y_2 + \beta_3(\ln w_2 - \ln w_1) + \beta_4(\ln w_3 - \ln w_1) + \\
& \beta_5(\tfrac{1}{2}\ln y_1 \ln y_1) + \beta_6(\ln y_1 \ln y_2) + \beta_7(\tfrac{1}{2}\ln y_2 \ln y_2) + \\
& \beta_8[\tfrac{1}{2}(\ln w_1 \ln w_2 + \ln w_2 \ln w_1 - \ln w_1 \ln w_1 - \ln w_2 \ln w_2)] + \\
& \beta_9[\tfrac{1}{2}(\ln w_2 \ln w_3 + \ln w_3 \ln w_2 - \ln w_2 \ln w_2 - \ln w_3 \ln w_3)] + \\
& \beta_{10}[\tfrac{1}{2}(\ln w_1 \ln w_3 + \ln w_3 \ln w_1 - \ln w_1 \ln w_1 - \ln w_3 \ln w_3)] + \\
& \beta_{11}(\ln y_1 \ln w_2 - \ln y_1 \ln w_1) + \beta_{12}(\ln y_1 \ln w_3 - \ln y_1 \ln w_1) + \\
& \beta_{13}(\ln y_2 \ln w_1 - \ln y_2 \ln w_2) + \beta_{14}(\ln y_2 \ln w_3 - \ln y_2 \ln w_2) + u_i + v_i
\end{aligned}
$$

Table 7 : Translog Stochastic Cost Frontier Parameter Estimates for U.S. Multinational Banks

Parameter	Parameter Estimate	Parameter	Parameter Estimate
α	-0.2529	β_8 *	0.0817
	(1.3783)		(0.0381)
β_1 *	-3.4004	β_9	-0.0214
	(0.5684)		(0.0158)
β_2 *	3.0637	β_{10}	-0.0184
	(0.2846)		(0.0280)
β_3	0.2736	β_{11} *	0.3606
	(0.2011)		(0.1112)
β_4	-0.4441	β_{12}	0.2193
	(0.2900)		(0.1297)
β_5 *	1.3802	β_{13} *	0.3995
	(0.3786)		(0.0451)
β_6 *	-1.6699	β_{14}	-0.1146
	(0.4114)		(0.1297)
β_7 *	2.0144	λ *	22.2591
	(0.4535)		(1.3738)
		σ^2 *	0.0801
			(0.0042)

1. Standard errors in parentheses.
2.* : Significantly different from zero at the 5 % level, two-tailed test.
3. α and βs are parameters in :

$$\begin{aligned}\ln C = {} & \alpha + \beta_1 \ln y_1 + \beta_2 \ln y_2 + \beta_3(\ln w_2 - \ln w_1) + \beta_4(\ln w_3 - \ln w_1) + \\ & \beta_5(\tfrac{1}{2}\ln y_1 \ln y_1) + \beta_6(\ln y_1 \ln y_2) + \beta_7(\tfrac{1}{2}\ln y_2 \ln y_2) + \\ & \beta_8[\tfrac{1}{2}(\ln w_1 \ln w_2 + \ln w_2 \ln w_1 - \ln w_1 \ln w_1 - \ln w_2 \ln w_2)] + \\ & \beta_9[\tfrac{1}{2}(\ln w_2 \ln w_3 + \ln w_3 \ln w_2 - \ln w_2 \ln w_2 - \ln w_3 \ln w_3)] + \\ & \beta_{10}[\tfrac{1}{2}(\ln w_1 \ln w_3 + \ln w_3 \ln w_1 - \ln w_1 \ln w_1 - \ln w_3 \ln w_3)] + \\ & \beta_{11}(\ln y_1 \ln w_2 - \ln y_1 \ln w_1) + \beta_{12}(\ln y_1 \ln w_3 - \ln y_1 \ln w_1) + \\ & \beta_{13}(\ln y_2 \ln w_1 - \ln y_2 \ln w_2) + \beta_{14}(\ln y_2 \ln w_3 - \ln y_2 \ln w_2) + u_i + v_i\end{aligned}$$

Table 8 : Translog Stochastic Cost Frontier Parameter Estimates for Japanese Banks

Asset Size	Banks	Scale Economies	Standard Errors
A. Domestic Banks			
Overall Sample	744	1.0386*	0.0003321
300 - 700	410	1.0744*	0.0006259
700 - 1,000	106	1.0274*	0.0023112
1,000 - 3,000	165	0.9988	0.0014399
3,000 - 5,000	37	0.9423*	0.0061215
5,000 -	26	0.9098*	0.0083731
B. Multinational Banks			
Overall Sample	167	1.0015	0.000914
300 - 700	12	1.1120*	0.013942
700 - 1,000	6	1.1086*	0.027834
1,000 - 3,000	20	1.0665*	0.007999
3,000 - 5,000	8	1.0142	0.019145
5,000 -	121	0.9736*	0.001237

1. Assets are in million dollars.

2. * indicates that scale estimates are significantly different from one at the 5% level, two-tailed test.

Table 9 : Scale Economies for U.S. Banks by Asset Size

Asset Size	Banks	Scale Economies	Standard Errors
A. Japanese Banks			
Overall Sample	116	0.9982	0.0011859
3,000 - 40,000	84	1.0286 *	0.0017303
40,000 - 500,000	28	0.9254*	0.0043748
500,000 -	4	0.8678*	0.0280310
B. Japanese Banks Operating in the U.S.			
Overall Sample	17	1.1805	0.3327500

1. Assets are in million dollars.
2. * indicates that scale estimates are significantly different from one at the 5% level, two-tailed test.

Table 10 : Scale Economies for Japanese Banks by Asset Size

A. Domestic Banks

Mean $u_i = (2/\pi)^{1/2}\sigma_u$	0.20085
$V(u_i) = \left(\frac{\pi-2}{\pi}\right)\sigma_u^2$	0.02303
Average $\hat{M}(u_i \mid \varepsilon_i)$	0.14401
Average $\hat{E}(u_i \mid \varepsilon_i)$	0.19491
Min $\hat{E}(u_i \mid \varepsilon_i)$	0.02411
Median $\hat{E}(u_i \mid \varepsilon_i)$	0.16520
Max $\hat{E}(u_i \mid \varepsilon_i)$	1.18520

B. Multinational Banks

Mean $u_i = (2/\pi)^{1/2}\sigma_u$	0.15976
$V(u_i) = \left(\frac{\pi-2}{\pi}\right)\sigma_u^2$	0.05564
Average $\hat{M}(u_i \mid \varepsilon_i)$	0.15637
Average $\hat{E}(u_i \mid \varepsilon_i)$	0.15917
Min $\hat{E}(u_i \mid \varepsilon_i)$	0.04180
Median $\hat{E}(u_i \mid \varepsilon_i)$	0.14728
Max $\hat{E}(u_i \mid \varepsilon_i)$	0.46917

Table 11 : Technical Inefficiency Measures for U.S. Banks

A. Japanese Banks	
Mean $u_i = (2/\pi)^{1/2}\sigma_u$	0.2225
$V(u_i) = \left(\frac{\pi-2}{\pi}\right)\sigma_u^2$	0.0290
Average $\hat{M}(u_i \mid \varepsilon_i)$	0.2006
Average $\hat{E}(u_i \mid \varepsilon_i)$	0.2010
Min $\hat{E}(u_i \mid \varepsilon_i)$	0.0089
Median $\hat{E}(u_i \mid \varepsilon_i)$	0.1464
Max $\hat{E}(u_i \mid \varepsilon_i)$	1.0834
B. Japanese Banks Operating in U.S.	
Average $\hat{M}(u_i \mid \varepsilon_i)$	0.3080
Average $\hat{E}(u_i \mid \varepsilon_i)$	0.3773
Min $\hat{E}(u_i \mid \varepsilon_i)$	0.0497
Median $\hat{E}(u_i \mid \varepsilon_i)$	0.3080
Max $\hat{E}(u_i \mid \varepsilon_i)$	1.5094

Table 12 : Technical Inefficiency Measures for Japanese Banks

Asset Size	Banks	Technical Inefficiency
A. Domestic Banks		
Overall Sample	744	0.19491
300 - 700	410	0.17900
700 - 1,000	106	0.20164
1,000 - 3,000	165	0.22919
3,000 - 5,000	37	0.21478
5,000 -	26	0.17249
B. Multinational Banks		
Overall Sample	167	0.15917
300 - 700	12	0.18372
700 - 1,000	6	0.15235
1,000 - 3,000	20	0.13799
3,000 - 5,000	8	0.15874
5,000 -	121	0.16060

1. Assets are in million dollars.

Table 13 : Technical Inefficiency Measures for U.S. Banks by Asset Size

Asset Size	Banks	Technical Inefficiency
A. Japanese Banks		
Overall Sample	116	0.20109
3,000 - 40,000	84	0.13944
40,000 - 500,000	28	0.38518
500,000 -	4	0.20705
B. Japanese Banks Operating in U.S.		
Overall Sample	17	0.37725

1. Assets are in million dollars.

Table 14 : Technical Inefficiency Measures for Japanese Banks by Asset Size

Rank	Bank	Assets [1]
1	Dai-ichi Bank (Japan)	460,427
2	Fuji Bank (Japan)	458,675
3	Sumitomo Bank (Japan)	452,812
4	Sanwa Bank (Japan)	449,770
5	Sakura Bank (Japan)	441,735
6	Mtitsubishi Bank (Japan)	428,014
7	Norinchukin Bank (Japan)	371,278
8	Credit Lyonnals, Paris (France)	350,812
9	Industrial Bank of Japan (Japan)	339,137
10	Deuche Bank (Germany)	305,923
11	Credit Agricole Mutuel (France)	298,210
12	Mitsubishi Trust & Banking Corp. (Japan)	292,546
13	Banque Nationale de Paris (France)	283,823
14	Long-Term Credit Bank of Japan (Japan)	274,035
15	Tokai Bank (Japan)	272,930
16	Sumitomo Trust & Banking Co. (Japan)	268,998
17	Mitsui Trust & Banking Co. (Japan)	257,224
18	Societe Generale, Paris (France)	256,981
19	ABN-AMRO Bank,N.V. (Netherlands)	252,709
20	Asahi Bank (Japan)	249,167
21	Barclays Bank Pic. (United Kingdom)	225,765
22	Bank of Tokyo (Japan)	222,864
23	National Westminster Bank (U.K.)	216,829
24	Daiwa Bank (Japan)	212,229
25	Yasuda Trust & Banking Co. (Japan)	201,329

1. Millions of dollars
Source : American Banker, 1993.

Table 15 : The World's Top 25 Banks Ranked By Asset Size - 1992

Bank	Total Assets [1]
Mitsubishi Bank (Japan)	46,449
Bank of Tokyo (Japan)	44,969
Industrial Bank of Japan (Japan)	32,319
Abn Amro Holding, N.V., (Netherland)	31,452
Sanwa Bank (Japan)	31,211
Fuji Bank (Japan)	31,157
Dai-ichi Kangyo Bank (Japan)	30,169
Sumitomo Bank (Japan)	28,946
National Westminister Bank (United Kingdom.)	28,001
Bank of Montreal (Canada)	22,878
Hongkong & Shanghai Bank(Hong Kong)	20,541
Swiss Bank Corp.(Switzerland)	18,511
Sakura Bank (Japan)	18,192
Societe Generale (France)	18,026
Bank of Nova Scotia (Canada)	17,189
Banque Nationale de Paris (France)	15,005
Credit Lyonnals, Paris (France)	14,869
Lont-Term Credit Bank of Japan (Japan)	14,399
Barclays Pic (United Kingdom)	13,703
Union Bank of Switzerland (Switzerland)	13,662
Tokai Bank (Japan)	13,073
Yasuda Trust & Banking Co. (Japan)	12,836
Daiwa Bank (Japan)	11,902
Mitui Trust & Banking Co. (Japan)	11,043
Mitsubishi Trust & Banking Corp. (Japan)	10,874
Total	**551,376**
Total Assets of FDIC-Insured Banks-1992	**3,506 billion**

1. *Millions of dollars*
Source: American Banker, 1993.

Table 16 : Top 25 Foreign Banks Operating in The United States - 1992

	U.S	Japan	Germany	U.K.	Canada
Insurance:					
Brokerage	N*	N	Y	Y	N
Underwriting	N	N	Y*	Y*	N
Equities:					
Brokerage	Y	N	Y	Y	Y*
Underwriting	N	N	Y	Y*	Y*
Investment	N	Y	Y	Y*	Y
Other Underwriting:					
Government Debt	Y	N	Y	Y*	Y
Private Debt	N	N	Y	Y*	Y*
Mutual Funds:					
Brokerage	N	N	Y	Y	Y
Management	N	N	Y	Y	Y*
Real Estate :					
Brokerage	N*	N	Y	Y	N
Investment	N	N	Y	Y	Y
Other Brokerage :					
Government Debt	Y	Y	Y	Y	Y
Private Debt	Y	Y	Y	Y	Y

1. Y: Yes, Y* : Yes but not directly by the bank.

2.N: No, N* : No, with exceptions.

Source: H.J. Johnson, The New Global Banker, 1994.

Table 17 : Bank Powers : A Cross-Country Comparison

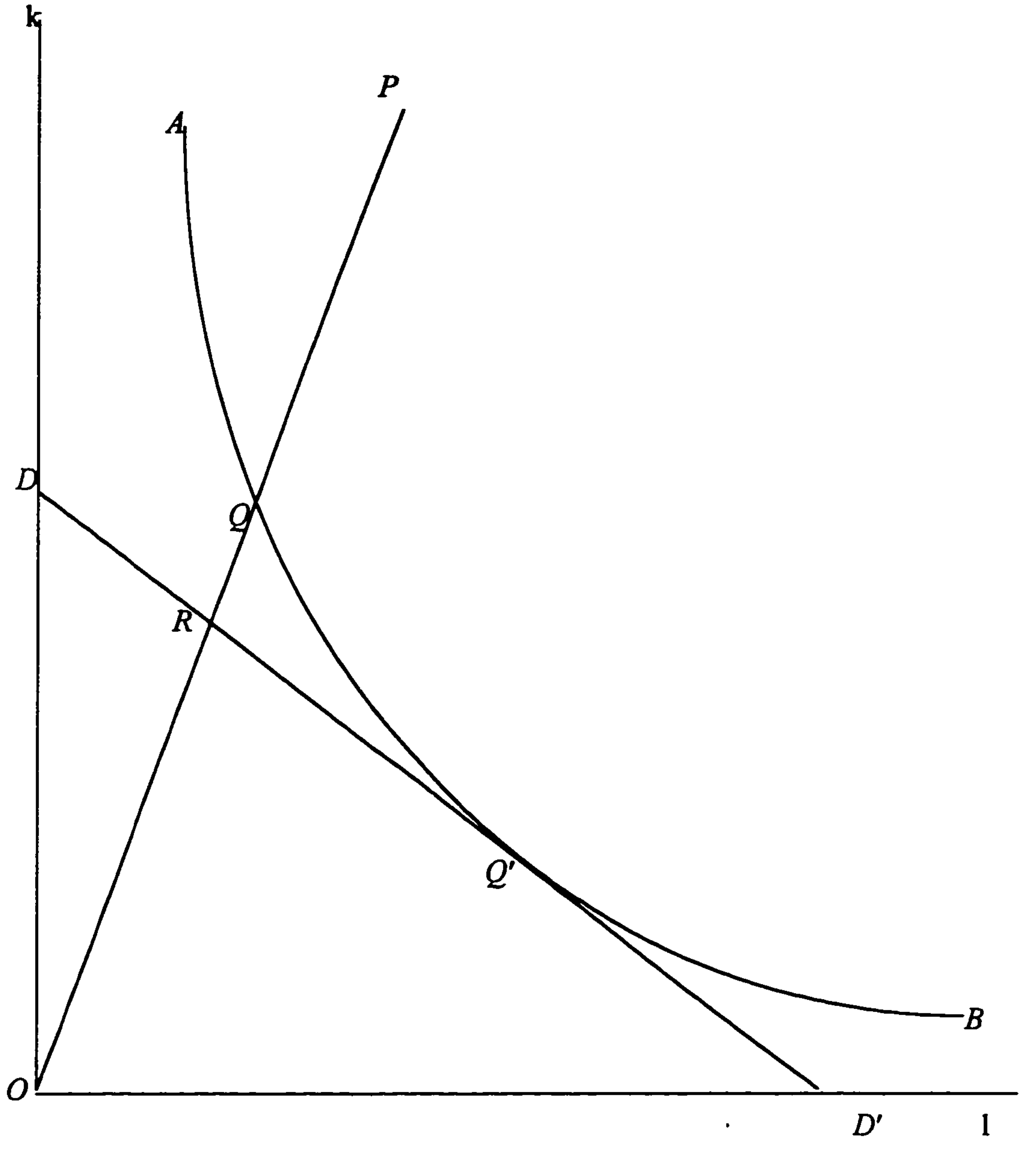

Figure 1 : Pure Technical and Allocative Inefficiency

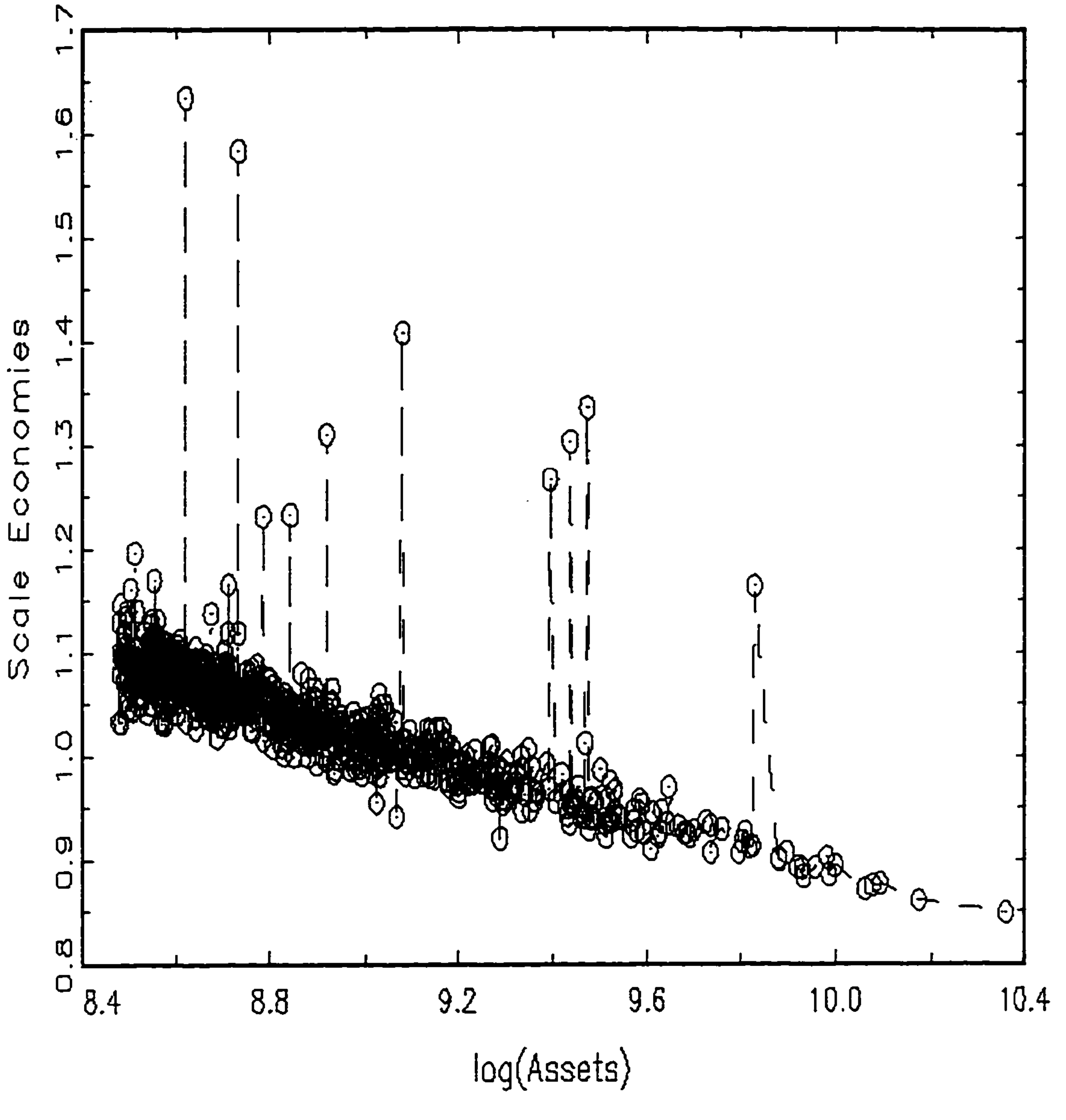

Figure 2 : Scale Economies of U.S. Domestic Banks

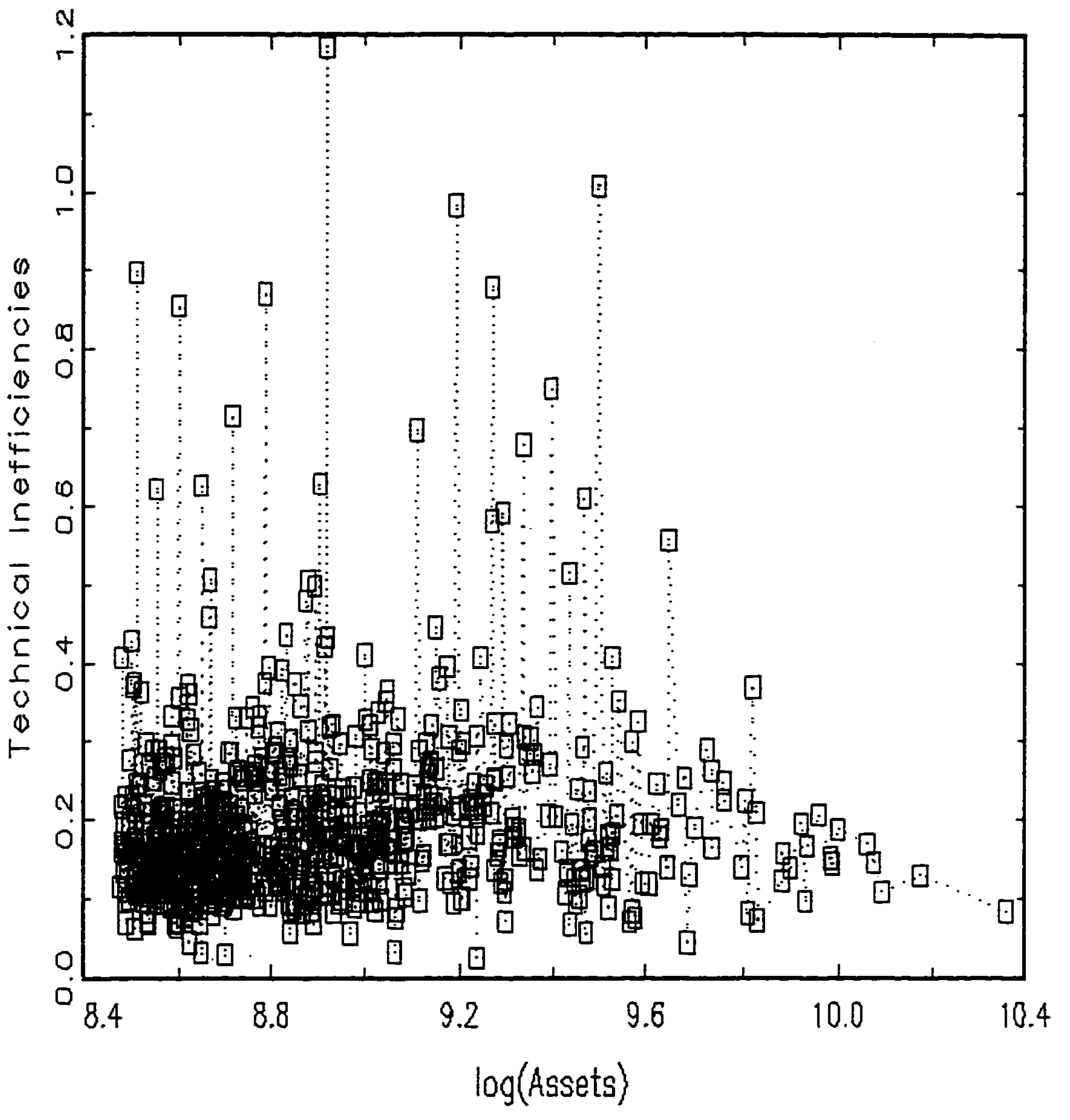

Figure 3 : Technical Inefficiencies of U.S. Domestic Banks

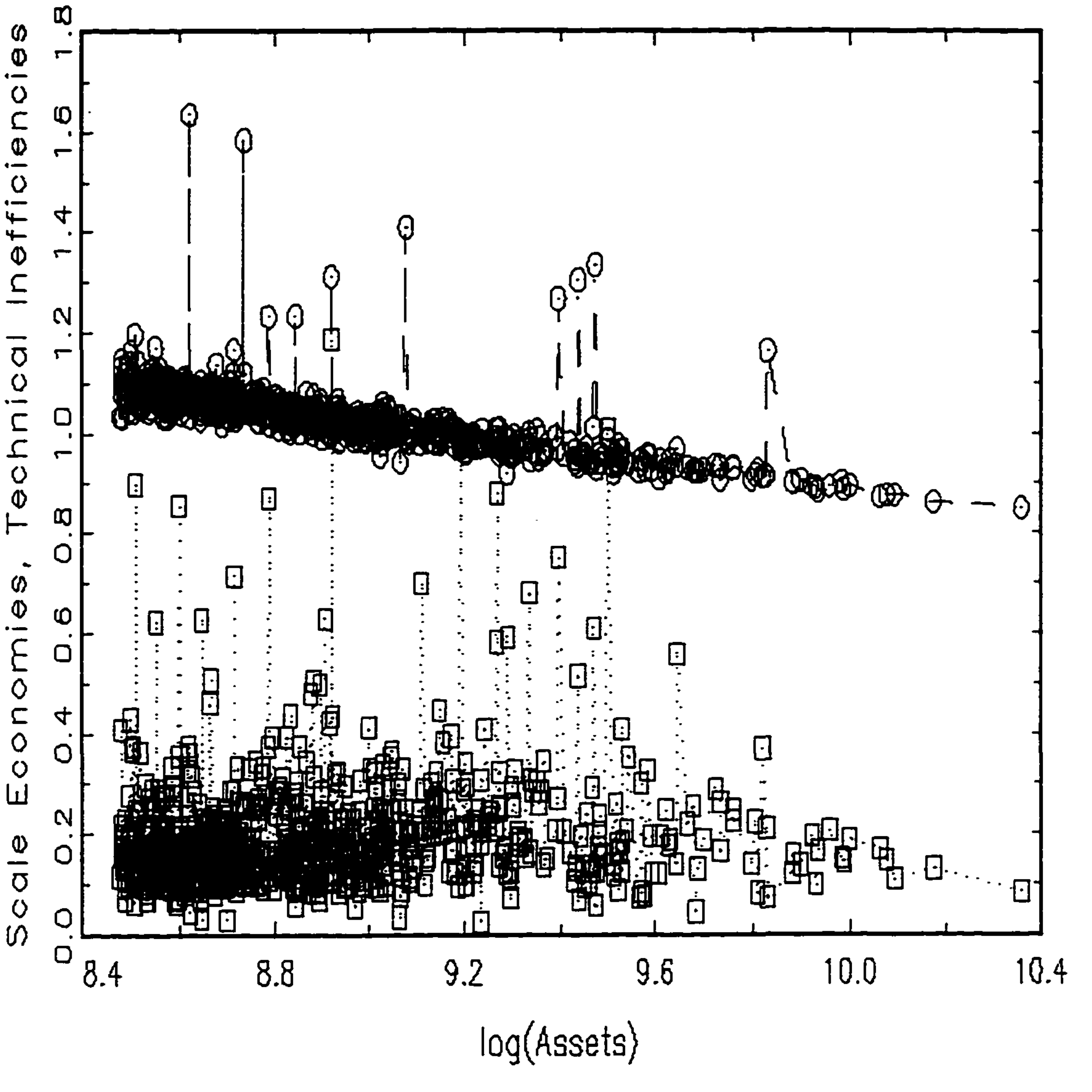

Figure 4 : The Relationship between Scale Economies and Technical Inefficiencies of U.S. Domestic Banks

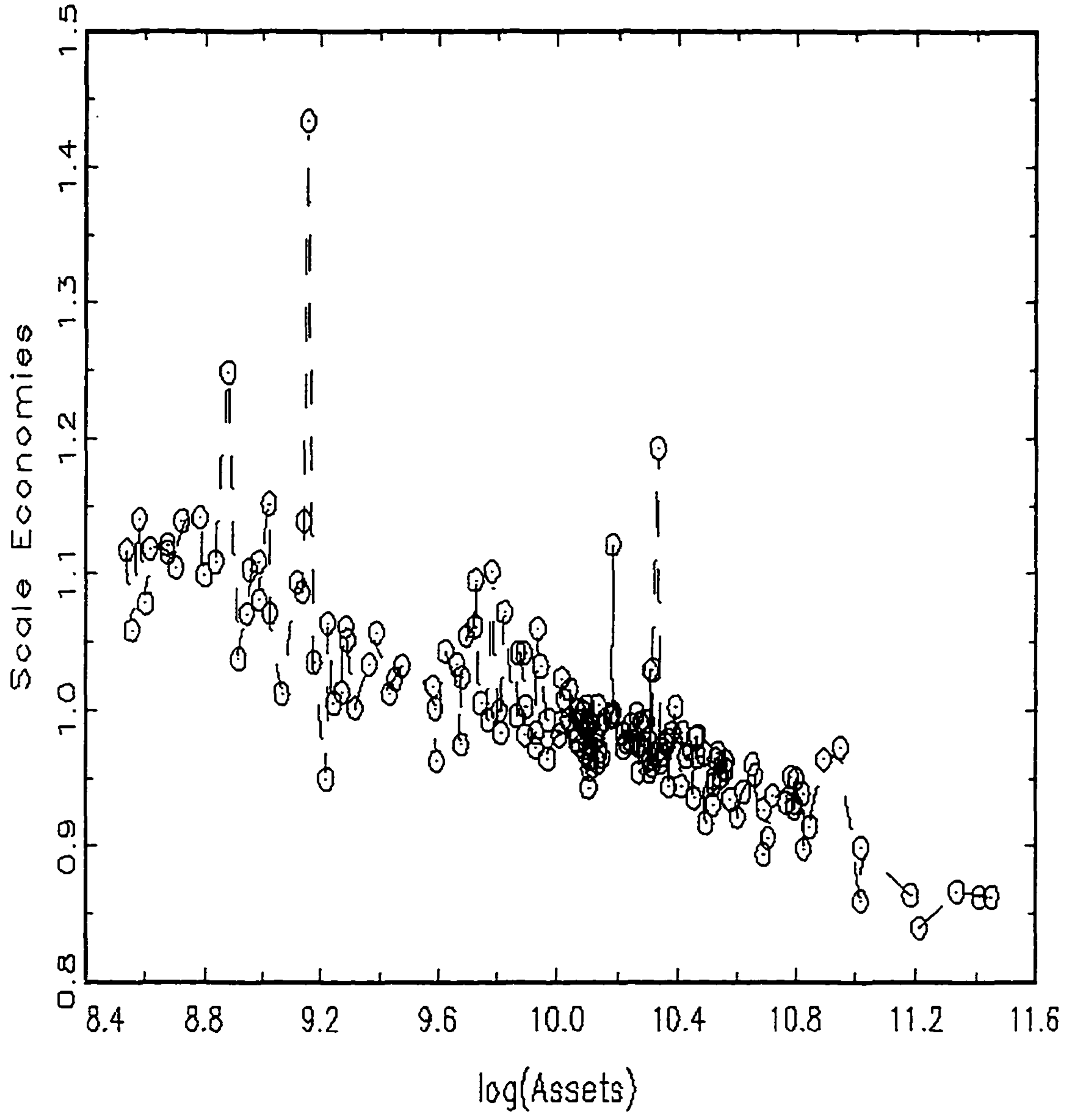

Figure 5 : Scale Economies of U.S. Multinational Banks

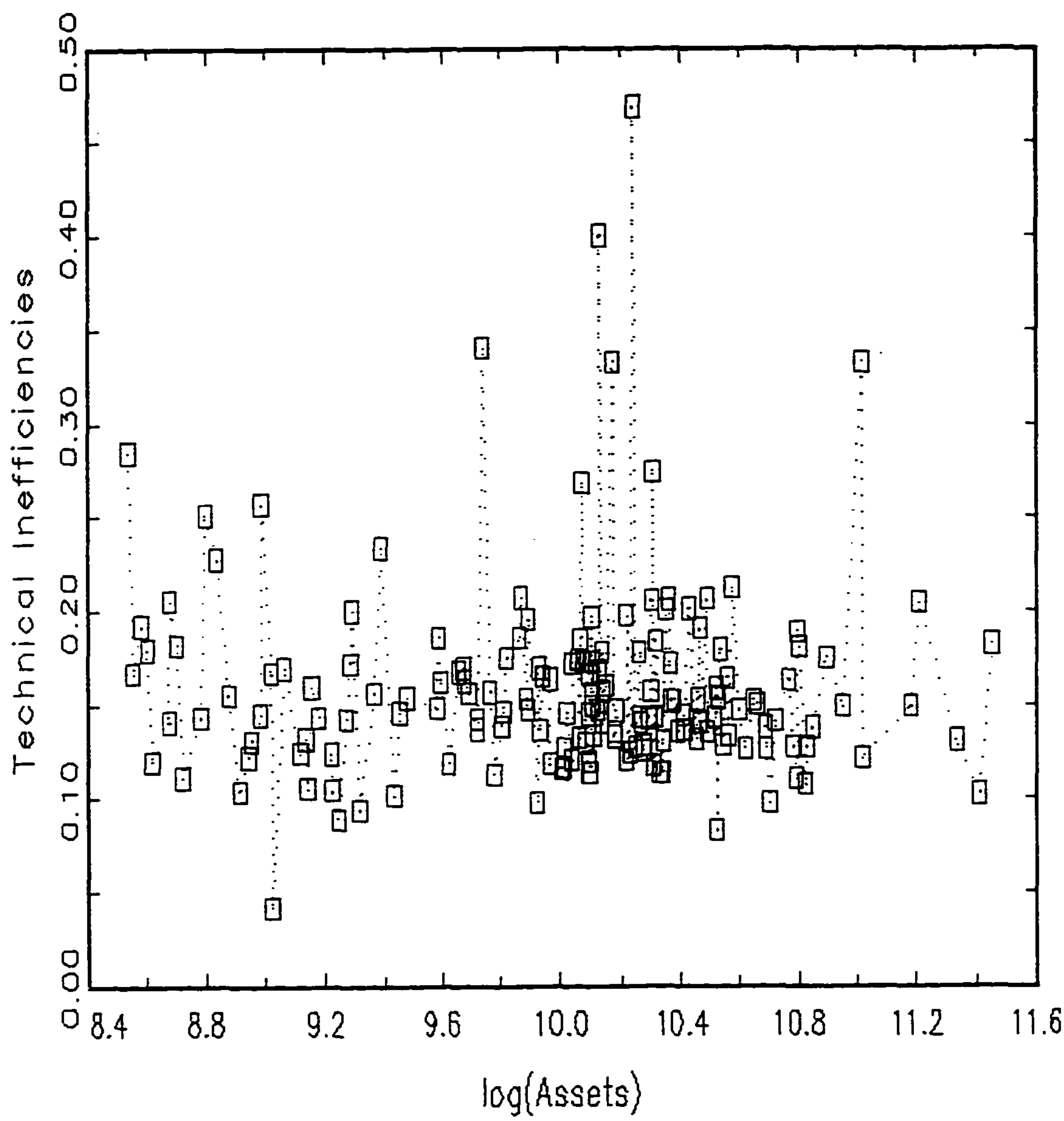

Figure 6 : Technical Inefficiencies of U.S. Multinational Banks

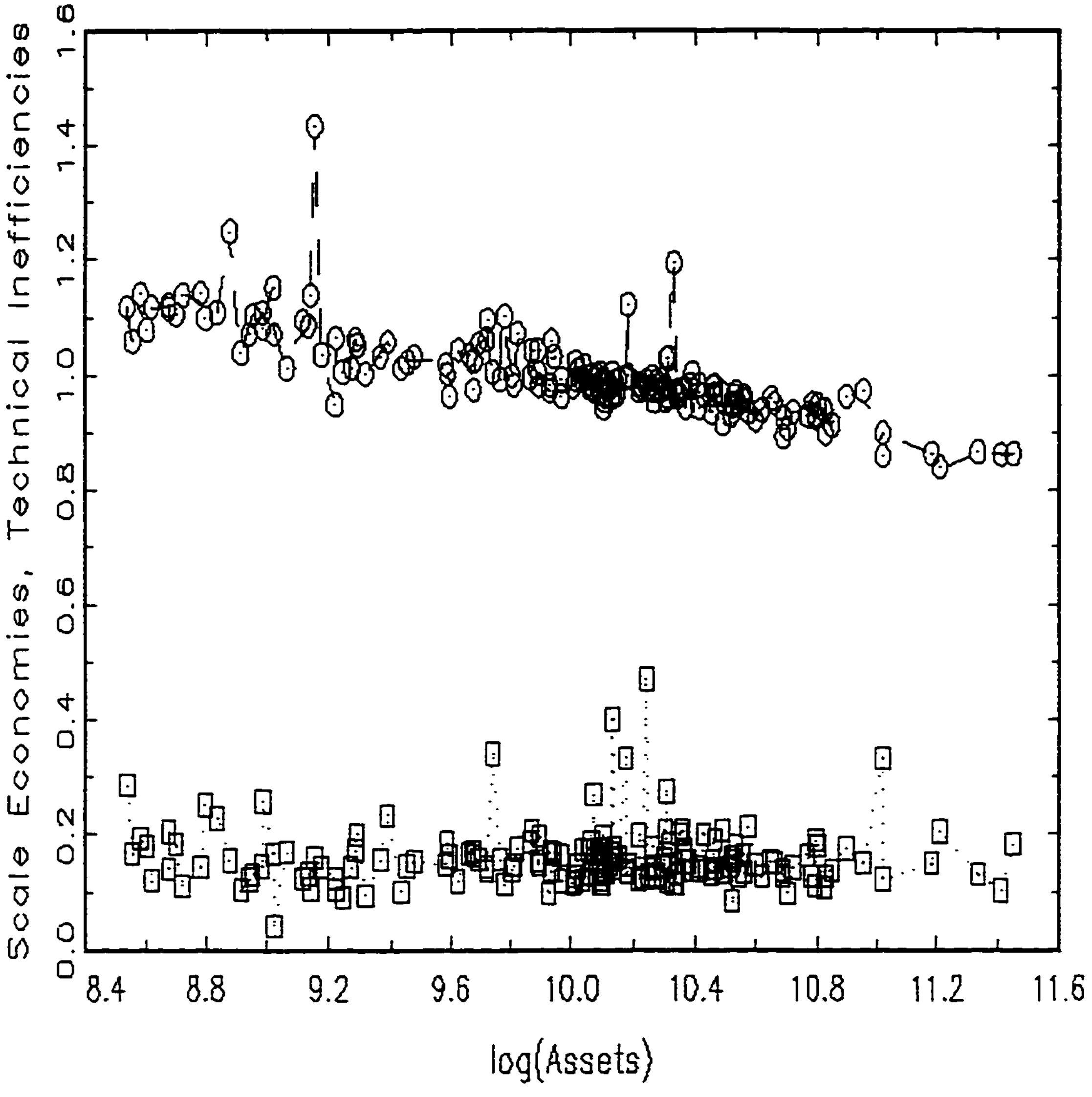

Figure 7 : The Relationship between Scale Economies and Technical Inefficiencies of U.S. Multinational Banks

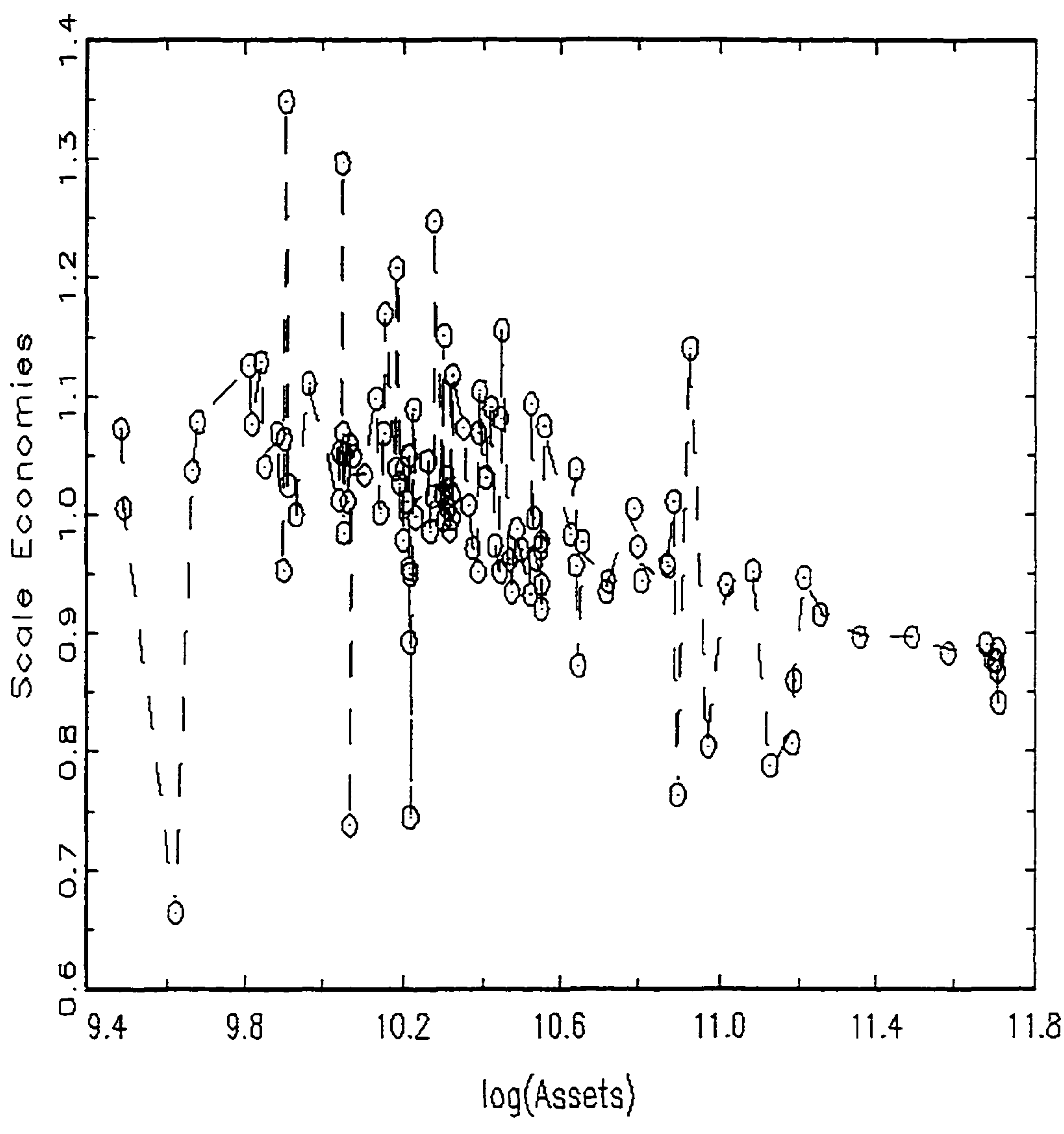

Figure 8 : Scale Economies of Japanese Banks

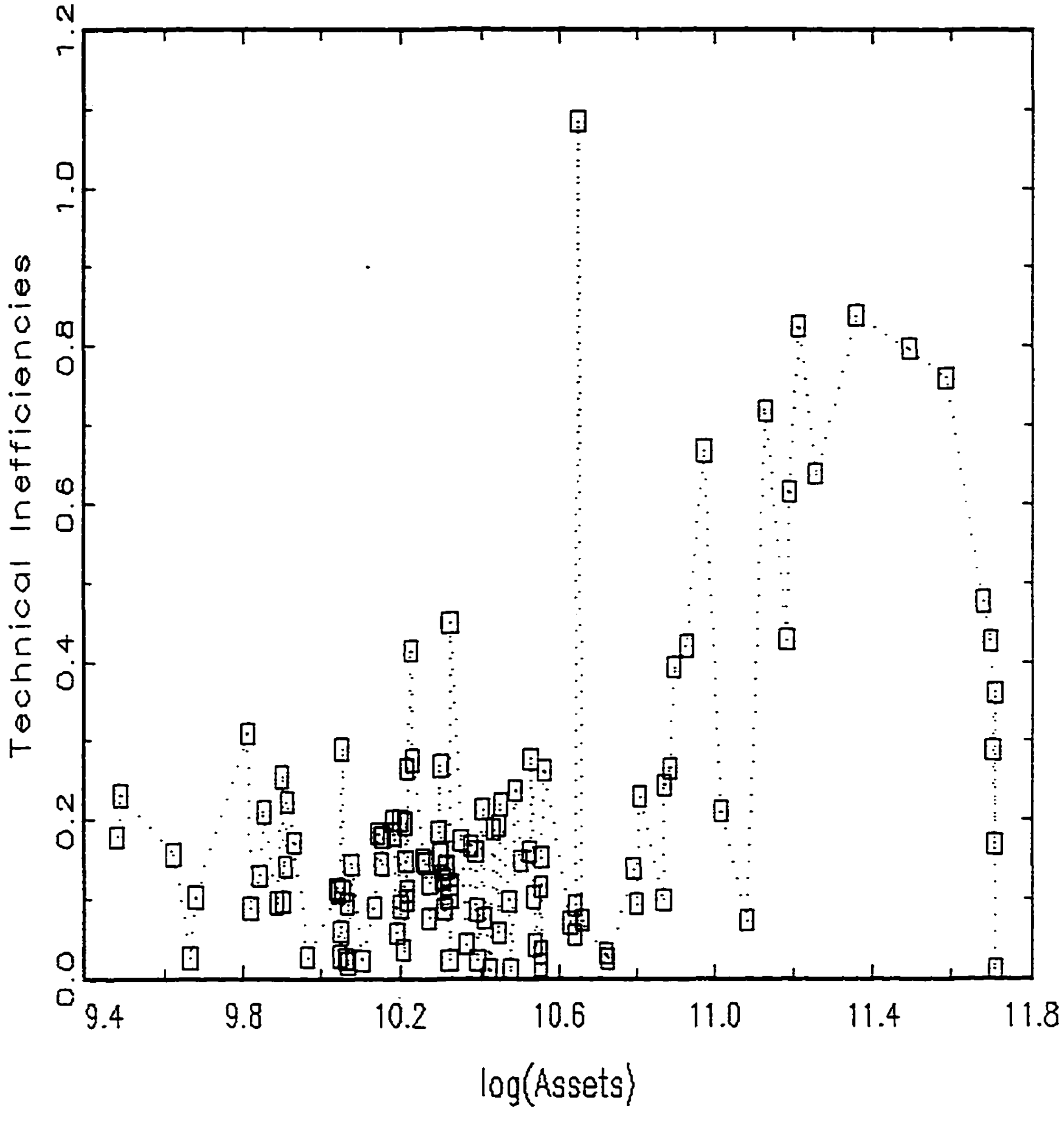

Figure 9 : Technical Inefficiencies of Japanese Banks

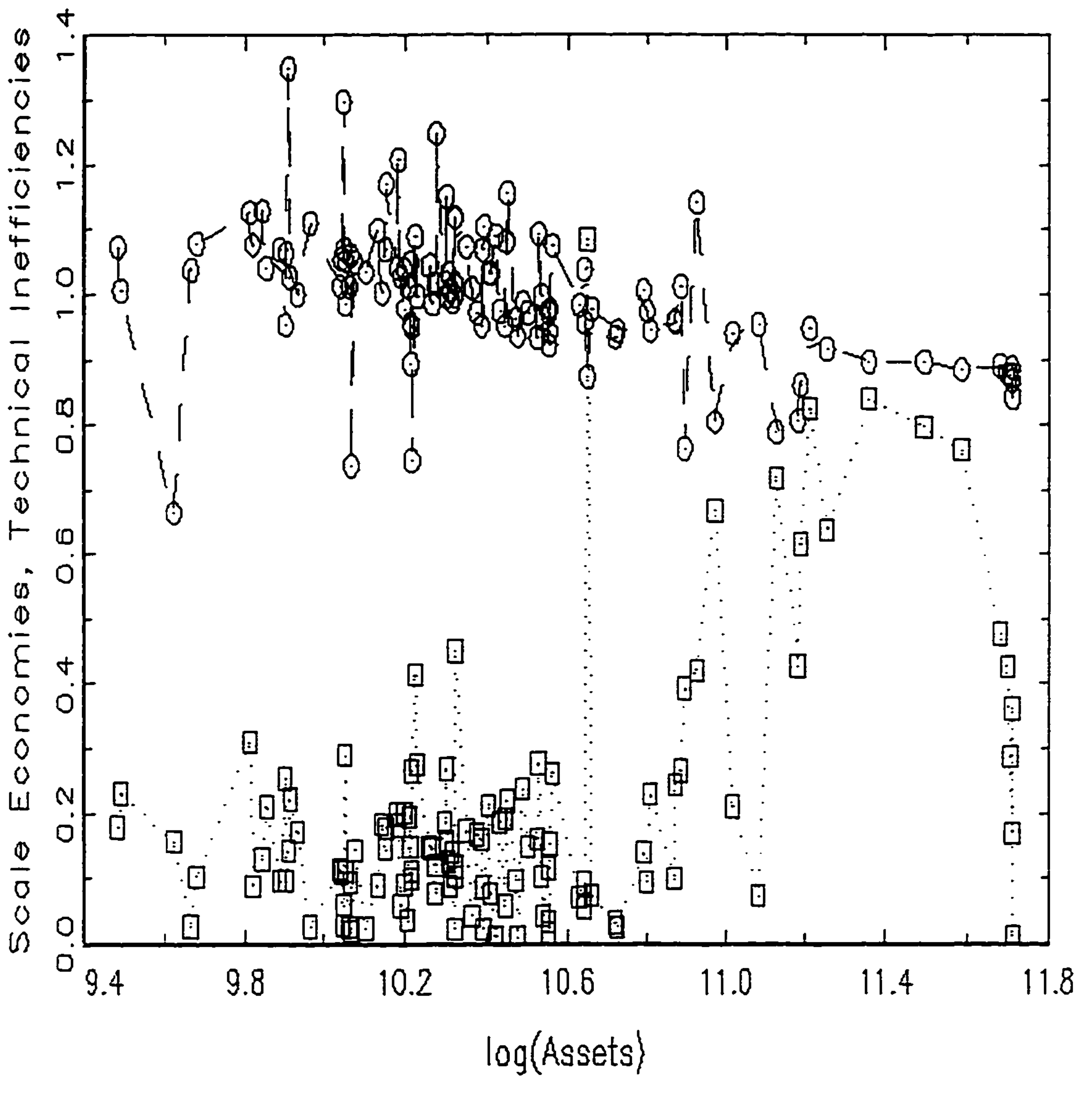

Figure 10 : The Relationship between Scale Economies and Technical Inefficiencies of Japanese Banks

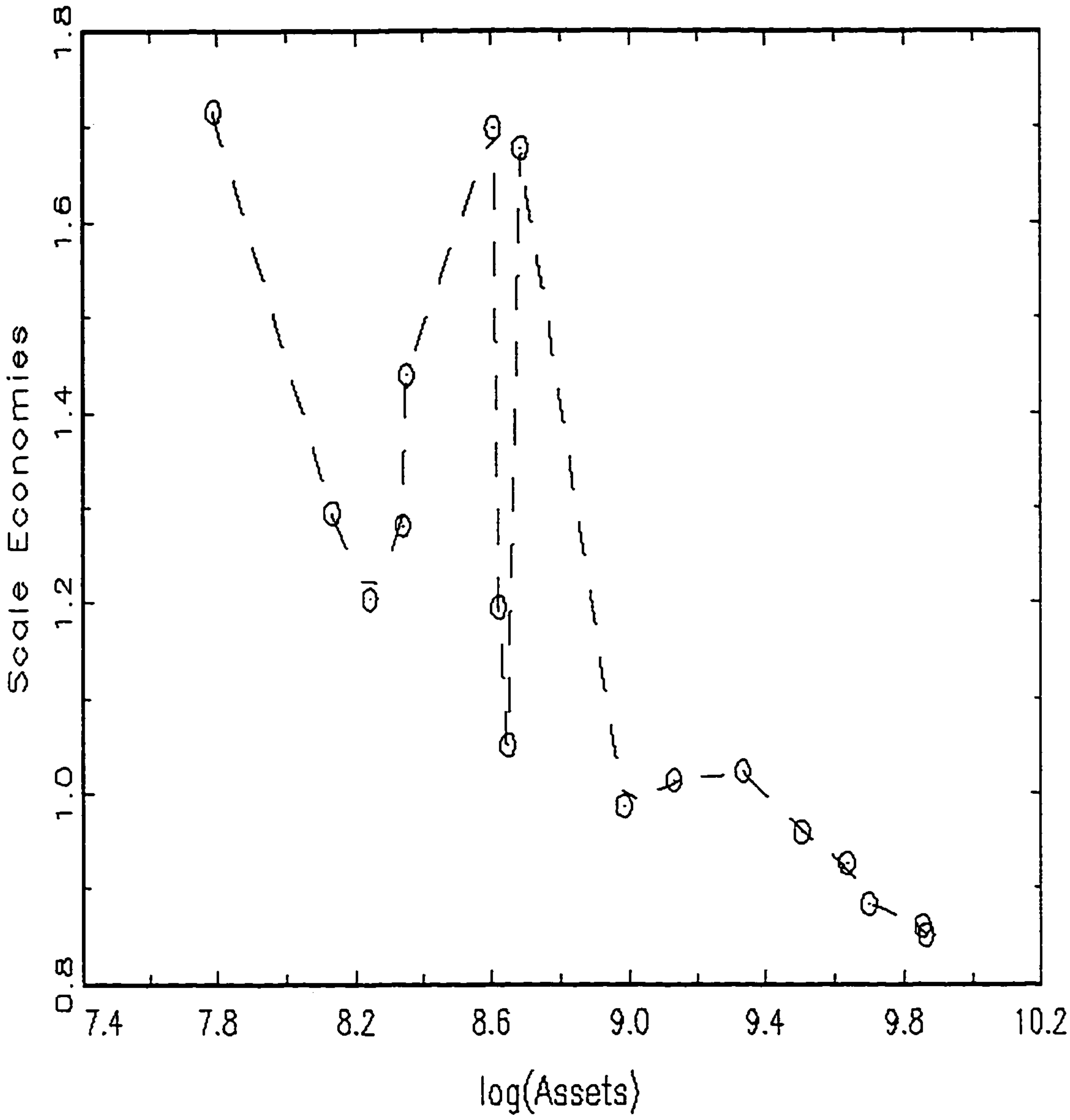

Figure 11 : Scale Economies of Japanese Banks Operating in U.S.

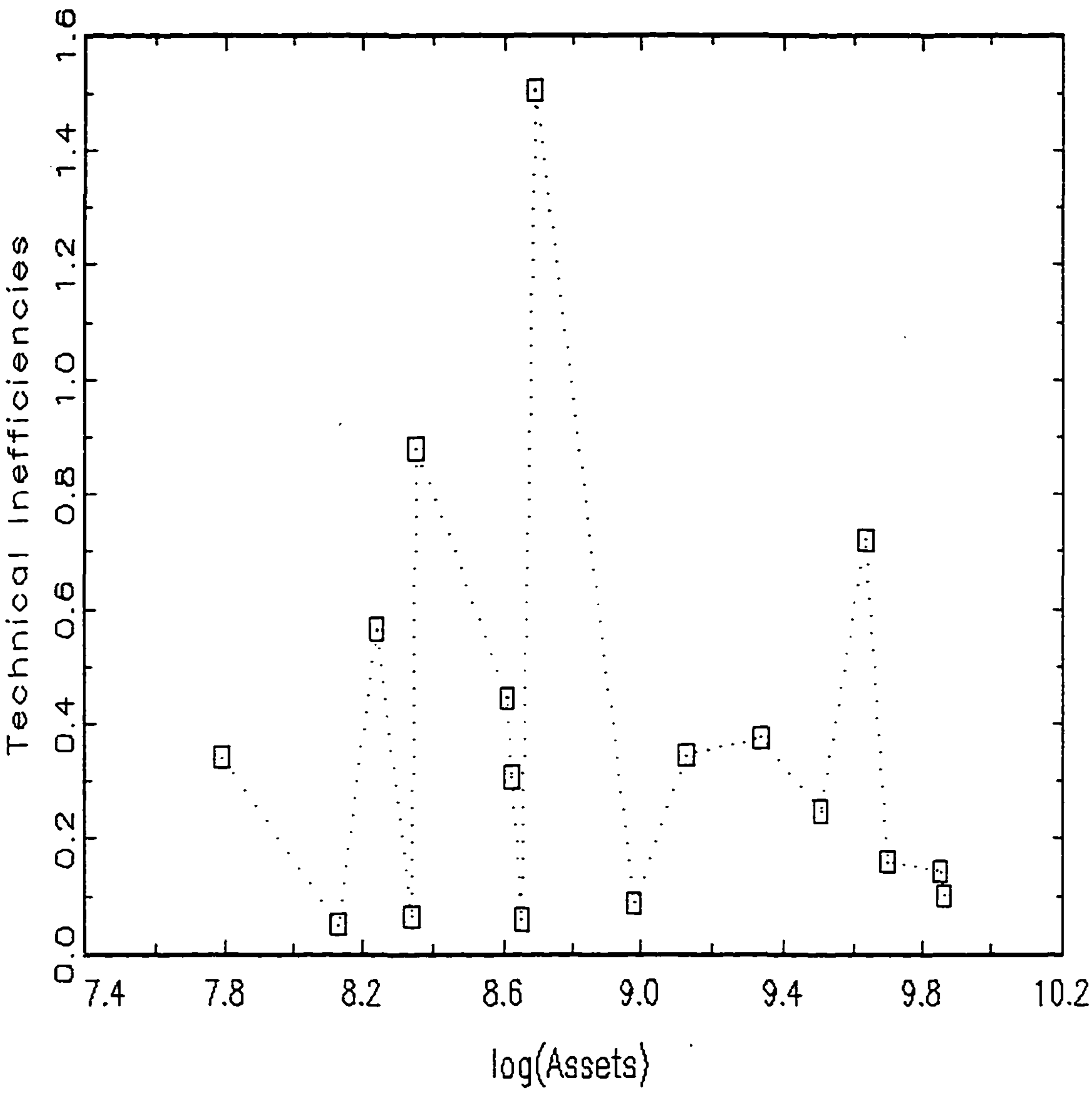

Figure 12 : Technical Inefficiencies of Japanese Banks Operating in U.S.

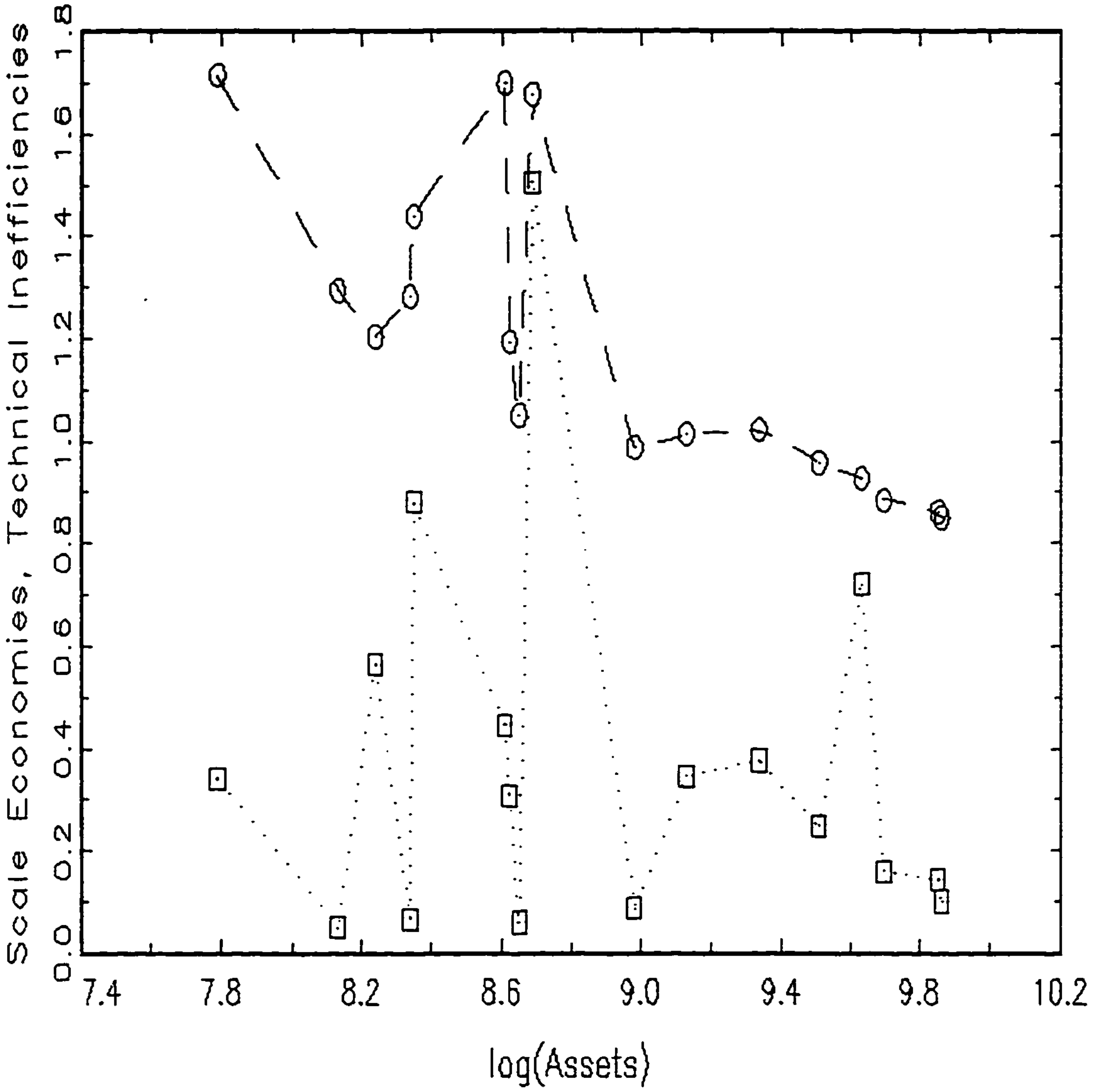

Figure 13 : The Relationship between Scale Economies and Technical Inefficiencies of Japanese Banks Operating in U.S.