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Ten Independence Mall
Philadelphia, Pennsylvania 19106-1574
(215) 574-6428, www.phil.frb.org

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Joseph P. Hughes
Department of Economics
Rutgers University

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Joseph P. Hughes

Department of Economics
Rutgers University
New Brunswick, New Jersey 08903-5055
USA

732-932-7517
(Fax) 732-932-7416
jphughes@rci.rutgers.edu

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ABSTRACT

In perfectly competitive markets, prices aggregate inputs and outputs into a money metric that allows production plans to be ranked by their profitability. When informational asymmetries in competitive markets lead to adverse selection, prices in these markets assume an additional role that conveys information about product quality. In the case of banking production, quality is linked to risk because prices are linked to credit quality.

The problem of efficiency measurement is complicated by the additional role because quality varies with price and price is a decision variable of firms operating in these markets. The effect of these endogenous components of prices on financial performance is illustrated with a production-based model and a market-value model that generate "best-practice" frontiers. Unlike the standard profit function's frontier, these frontiers are not conditioned on prices so that they compare the financial performance of firms with different quality-linked prices. Hence, they identify the most efficient pricing strategies as well as the most efficient production plans.

These two alternative models for measuring efficiency are employed to study the efficiency of highest level bank holding companies in the United States in 1994. The contractural interest rates these banks obtain on their loans and other assets are shown to influence their expected profit, profit risk, market value, and efficiency.

Introduction

The production efficiency of firms is often measured by fitting an upper-envelope profit function or a lower-envelope cost function to firms' price and production data. The envelope function controls for the prices that each firm faces and represents the best observed practice in the sample at these prices. Each firm's inefficiency is gauged by its distance from the best-practice frontier. This distance measures the amount by which a firm's profit could be increased or its cost reduced if its production constituted "best practice." A variety of parametric and nonparametric techniques are available for computing the frontier.[1]

This strategy for measuring efficiency assumes that firms maximize profit given competitively determined prices of inputs and outputs.[2] Conveying information about relative scarcities, these prices aggregate inputs and outputs into a money metric that allows production plans to be ranked by their profitability. The assumption of profit maximization implies that the "best-practice" production plans are, in the ideal, technically efficient, that is to say, they are located on the boundary of the set of inputs required to produce any given set of ouputs. In addition, profit maximization requires that "best-practice" plans be allocatively efficient, which is to say that, out of all technically efficient plans, the allocatively efficient plans maximize profit at their given prices. Various techniques have been used to decompose a firm's overall inefficiency, measured by its distance from the best-practice frontier, into technical and allocative components.[3] In this framework for measuring efficiency, the role of input and output prices is to aggregate production plans into a money metric that permits their ranking by relative efficiency or, equivalently, by their respective distances from the best-practice frontier.

However, when the competitive markets that determine these prices experience the types of informational asymmetries between buyers and sellers that lead to adverse selection, prices take on an additional role in the production process. Not only do they serve as aggregators of inputs and outputs into a money metric, but they also convey information about how markets ameliorate the asymmetry. For example, in financial markets where borrowers

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[1]Berger and Humphrey (1997) and Berger and Mester (1997) provide extensive reviews of this literature in the field of banking.

[2]Given a technology for producing outputs, $\boldsymbol{y}$, with inputs, $\boldsymbol{x}$, represented by the transformation function, $T(\boldsymbol{y},\boldsymbol{x}) \leq 0$, which satisfies certain regularity conditions, and given the output prices, $\boldsymbol{p}$, and input prices, $\boldsymbol{w}$, the profit function, $\pi(\boldsymbol{p},\boldsymbol{w})$, results from maximizing $(\boldsymbol{p}\cdot\boldsymbol{y} - \boldsymbol{w}\cdot\boldsymbol{x})$ with respect to all technically feasible production plans, $\{\boldsymbol{y},\boldsymbol{x}\} \in T(\boldsymbol{y},\boldsymbol{x}) \leq 0$.

[3]See, for example, Berger, Hancock, and Humphrey (1993), Akhavein., Berger, and Humphrey (1997), and Ferrier, Grosskopf, Hayes, and Yaisawarng (1993).

are better informed about their credit risk than lenders and where borrowers are suspected of misrepresenting their riskiness to lenders, prices may not serve the simple role of equilibrating demand and supply.[4] Lenders seeking higher quality credit applicants may charge lower interest rates that result in excess demand for credit. In turn, they ration credit to applicants they perceive to be less risky. Lenders that charge higher interest rates attract riskier applicants on average, since the less risky applicants seek out lenders charging lower rates. Hence, in financial markets prices not only serve to aggregate inputs and outputs into a money metric, they also indicate risk. Lenders that charge higher interest rates expect greater profit but also greater risk.

A. Endogenous, Quality-Indicative Prices

This example illustrates that in competitive markets characterized by these types of informational asymmetries, prices may have an endogenous component that results from the process of ameliorating the informational problems. This endogenous component is linked to the quality of the product. In choosing the quality of their outputs and inputs, producers in these competitive markets are simultaneously establishing the endogenous components of their output and input prices. In financial markets, the contractural interest rates that lenders charge determine the credit quality of their loan applicants and, hence, reflect the lenders' risk-return choices. The link between price and quality also applies to input markets. For example, in labor markets where potential employees are better informed about their productivity than employers, employers who pay higher wage rates will attract more productive applicants than employers offering lower wage rates. Thus, producers operating in competitive output and input markets where prices are linked to quality must solve a more difficult production problem than producers operating in markets having no significant informational asymmetries.

The critical question that the price-quality link poses for efficiency measurement is how to account for the effects on efficiency of choosing the endogenous components of prices. The standard frontier profit and cost functions treat prices *in their entirety* as exogenous.[5] Since they measure "best practice" given the endogenous components of prices, their measures

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[4]See Stiglitz and Weiss (1981).

[5]The standard profit frontier is computed by estimating the profit function, $\pi(\boldsymbol{p},\boldsymbol{w})$, using a composed error term. One component of the error term is two-sided and captures statistical noise while the second component is one-sided and gauges each observation's distance from the noise-corrected frontier. This distance, or lost profit, is interpreted as "inefficiency." See Jondrow, Lovell, Materov, and Schmidt (1982).

of inefficiency do not include inefficiency due to suboptimal choices of quality linked to price. To illustrate this point, consider two lenders with different loan pricing strategies who are each, given their own prices, equally efficient relative to the "best practice" frontier. However, if one of the two loan pricing strategies is more profitable than the other, the profit lost because of one lender's use of a less profitable pricing strategy is not included in the standard profit function's measure of the lender's inefficiency, since the "best-practice" frontier is conditioned on the quality-linked component of price. Capital markets, however, will punish the lender's choice of a suboptimal pricing strategy by reducing the lender's market value.

B. Maximizing Market Value with Quality-Linked, Endogenous Prices

The market value of a firm is the discounted value of its expected cash flows. The discount rate depends on the firm's exposure to systematic risk. Hence, in markets where prices are linked to quality, firms that employ suboptimal pricing strategies diminish their expected cash flows and reduce their market values. When, as is the case in financial markets, the quality-linked component of price is also associated with the risk involved in lenders' cash flows, it influences the market value of the firm through its effect both on expected cash flows and on the discount rate applied to those profits. The link between prices and risk and, hence, between prices and the discount rate applied to expected profit is not taken into account by the standard profit and cost functions and by the efficiency analysis based on their frontier formulations.

The introduction of risk into the analysis requires that feasible production plans and price environments be linked with conditional probability distributions of profit. The standard profit and cost functions assume that firms' managers rank production plans, *given competitively determined prices*, by the first moments of their implied subjective conditional distributions. When risk is introduced into the analysis, higher moments of the distribution can affect the rankings of production plans and, when prices have endogenous components, the ranking of production plans and feasible price schedules. In the absence of agency problems, managers' rankings of production plans and price schedules reflect discounted cash flows or, in other words, their assessment of the effect of feasible plans and prices on their firms' market values. In contrast, the standard profit function ranks production plans, given the prices of inputs and outputs, simply by their expected current-period cash flow.

Since future production plans are not observed, relying on the current period's plan to proxy future cash flows may be the best alternative. However, risk and its effect on the discount rate applied to the cash flows would seem to be essential elements to take into account in measuring efficiency, since they affect the firm's market value. Ignoring risk in measuring efficiency can be justified when a firm's exposure to market-priced risk is independent of its choice of production plan and when all firms in the efficiency comparison group have the same exposure to market-priced risk. However, in many, if not most, production contexts, a firm's choice of production plan influences the degree of systematic and idiosyncratic risk to which it is exposed. Hence, it affects both the firm's expected cash flows and the discount rate applied to those profits. Changes in a firm's production plan that improve its efficiency, measured by the difference between its expected profit and the "best-practice" level of profit, do not necessarily lead to an increase in the firm's market value, since these changes influence the discount rate on cash flows as well as the cash flows. If these changes in production increase market-priced risk so that the discount rate is also increased, their effect on the firm's market value will depend on the relative magnitudes of the increase in profit and in risk and its related discount rate. Thus, reorganizing production to reduce profit inefficiency does not necessarily increase the firm's market value when risk is also increased.

Accounting for the market-priced risk of production in gauging efficiency differences among firms is a general problem not peculiar to the phenomenon of risk-indicative prices. Efficiency measurement can ignore market-priced risk when it is invariant to the firm's production decisions and affects all firms under analysis equally. However, when firms face a schedule of risk-indicative prices, their choices of prices and production plans are likely to generate important differences among them in terms of risk and, to the extent that capital markets price these differences, important differences in market value.

To allow for the possibility that firms operate in markets where informational asymmetries link prices and quality and to allow for the possibility that differences in risk in general and risk associated with the price-quality schedule in particular influence production decisions and market value, two generalizations of the standard frontier profit function used to measure firms' ineffficiency differences are proposed and illustrated in the sections that follow.

C. Generalizing Efficiency Measurement to Account for Quality-Indicative Prices

The first approach, developed by Hughes, Lang, Mester, and Moon (1995,1996) and Hughes and Moon (1995), relies on a managerial utility function that ranks production plans and endogenous price schedules based on managers' beliefs about the likelihood of future economic states of the world and how those states interact with production plans and endogenous prices to generate profit. Hence, their managerial utility function, defined over production plans and endogeous prices, implies a ranking of subjective probability distributions of profit that are conditional on the production plans and price schedules. Managers choose their most preferred plan subject to feasibility conditions. Hughes, Lang, Mester, and Moon (1995,1996) use the Almost Ideal Demand System to obtain functional forms to estimate the utility-maximizing system of share equations that includes a share equation for profit. Their formulation is sufficiently general to allow for rankings of production plans that take into account higher moments of the implied subjective conditional distributions of profit. Hence, the resulting production system that is estimated allows for the possibility that risk influences production decisions.[6]

Hughes and Moon (1995) show that the Almost Ideal Demand System can be employed not just to recover managers' preferences for production plans but also their preferences for expected return and for return risk. Using the estimated system of share equations, they obtain measures of predicted return on equity and return risk for each firm (U.S. commercial banks) in their sample. In turn, using stochastic frontier estimation techniques, they obtain a "best-practice," upper-envelope, risk-return frontier for their sample. They measure a firm's inefficiency at its measured level of risk as the difference between the "best-practice" return and the firm's observed (noise-corrected) return. Hughes and Moon (1995) argue that this measure of inefficiency is priced by capital markets, and they show that, for a sub-sample of publicly traded firms, their measures of expected profit and the profit risk (their transformed measures of the expected return on equity and return risk) explain 96 percent of the variation in the market value of the firms' equity. Their technique of measuring efficiency applies the stochastic frontier estimation not to the profit function, which is conditioned on prices, but to the predicted profit and risk so that the resulting measure of inefficiency takes into account sub-optimal choices of quality-linked prices.

The second generalization of efficiency analysis focuses not on firms' choices of production plans but on their market value and their failure to achieve "best-practice" market value. Developed by Hughes, Lang, Moon, and Pagano (1997), this technique involves

[6]When the parameter restrictions implied by profit maximization are imposed on the system of share equations generated by the Almost Ideal Demand System, they become identical to the standard translog profit function and share equations. Although the Almost Ideal Demand System is based on a translog specification, another flexible functional form can be easily substituted into its structure.

estimating a stochastic frontier or an upper-envelope curve of the market values of firms' assets given the book values of their assets, adjusted to remove goodwill. The adjusted book value of a firm's assets is a proxy for their replacement cost while the market value represents how well the firm has exploited market opportunities and has organized production.[7] The upper envelope of market values defined over adjusted book values gives the highest, or "best-practice," market value for any given book-value investment in assets.[8] A firm's inefficiency is measured by the difference between the frontier market value evaluated at the adjusted book value of the firm's assets and the firm's observed market value. This difference represents the efficiency both of business strategies and of production practices as well as the market advantages the firm might enjoy. The extent to which it is necessary to separate market advantages that the firm has created from those that are purely exogenous to the firm's skill depends on the problem under consideration.

The market-value frontier has the advantage of incorporating the market's assessment of the entire stream of firms' expected cash flows, not just its current-period expected profit. It also incorporates the market's assessment of the relevant discount rate to apply to each firm's expected cash flows. Hence, its evaluation of efficiency fully encompasses the firm's business strategies, pricing policies, and organization of production, as well as the market advantages the firm exploits.

In the sections that follow, these two approaches are described and applied to commercial banking to illustrate the effects of banks' pricing strategies on expected profits, risk, market value, and efficiency measured both by the production model and by the market-value model. Commercial banking, as the examples cited earlier imply, is characterized by informational asymmetries that make prices, that is, interest rates on loans and on uninsured borrowed funds, sensitive to credit quality.

[7]See Demsetz, Saidenberg, and Strahan (1996) for a discussion of using book value adjusted to remove goodwill as a proxy for replacement costs.

[8]The frontier can also be computed using firms' market value of shareholders' equity and their adjusted book values of equity. Using assets rather than equity to measure inefficiency allows for the possibility that there are agency problems that result in a transfer of value from debtholders to equityholders through asset substitution. See Hughes, Lang, Moon, and Pagano (1997) on this point.

II. The Most Preferred Production System

Using a managerial utility function defined over production plans and endogenous prices, Hughes, Lang, Mester, and Moon (1995,1996) derive constrained, utility-maximizing demands for profit and for inputs.[9] These demand functions are conditioned on the level of equity capital, outputs, and endogenous prices. In their estimation of the production system, they add a first-order condition for equity capital. Although the utility-maximizing outputs and endogenous prices can also be obtained, they condition the utility maximization problem on these variables to facilitate its empirical implementation. Conditioning on outputs allows scale economies to be calculated while conditioning on the endogenous components of prices holds these quality characteristics of production constant so that the interpretation of scale economies is not blurred by changes in quality.[10]

If, in its empirical implementation, this alternative framework controls for prices in their entirety, it might seem to offer no advantages over the standard profit function in measuring efficiency when prices are quality-sensitive. Nevertheless, as Hughes and Moon (1995) have adapted it, *it can more easily accommodate quality-sensitive prices than the standard frontier profit and cost functions because it gauges efficiency, not directly from the profit function, which is conditioned on prices, but from a stochastic envelope fitted to performance measures derived as predictions of the profit function.* Hence, their profit function is fitted to firms' data as an average relationship, not as an envelope. These performance measures, each firm's predicted profit and the standard error of its predicted profit, both normalized by equity capital (i.e., its rate of return on equity and the prediction

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[9]This approach draws on earlier work by Hughes (1989, 1990) on hospitals and education that allows managers to choose production plans that trade net income for other objectives.

[10]Hughes, Lang, Mester, and Moon (1995, 1996) contend that banking scale economies measured from the standard cost function fail to control for the effects on cost of scale-related changes in the quality of output. If an increase in scale improves a bank's diversification, it allows the bank to achieve a higher expected return at the same level of risk, since it permits the bank to substitute at the margin better diversfication for costly risk management. The bank may respond to this improved return on risk-taking by taking more risk at the larger scale. If the increased risk-taking is costly, it may mask the scale economies in risk management that are expected from scale-related diversification. In fact, most studies that measure scale economies using the standard approach find essentially constant returns overall and slightly decreasing returns at large banks. Using their alternative framework that controls for output prices as well as other quality characteristics that could vary with scale, Hughes, Lang, Mester, and Moon (1995, 1996) find evidence of large economies of scale that increase with bank size, a result that suggests that the current merger wave is not exhausting potential scale economies.

risk of its return), are conditioned on prices. Hence, they account for the profitability and risk that result from firms' choices of the endogeous components of prices. However, the stochastic upper envelope of predicted return, given prediction risk, is not conditioned on prices. It represents the highest predicted return *over all observed prices* at any given level of risk. It does not, then, control for prices in fitting the frontier.

A. Banking Technology

Banking technology can be characterized in terms of financial intermediation. Banks employ inputs, $\boldsymbol{x}$, which are labor and physical capital, as well as borrowed funds and equity capital, k, to produce outputs, $\boldsymbol{y}$, which are investments in government securities and in information-intensive loans. To allow for the possibility that the prices of inputs and outputs contain an endogenous, quality-sensitive component, their prices can be written in the composite form, $p_i = \bar{p}_i / q_i^y$ where $\bar{p}_i$ is a risk-free rate of interest and quality is gauged by $0 < q_i^y \leq 1$ and $w_j = \bar{w}_j q_j^x$ where $\bar{w}_j$ is a "base" price[11] and the quality premium is $q_j^x \geq 1$. These quality-sensitive components of prices, $\boldsymbol{q} = (\boldsymbol{q}^y, \boldsymbol{q}^x)$, can be interpreted as *ex ante* proxies for quality. The amount of nonperforming assets, n, can be used to gauge *ex post* quality. Banking technology can be represented by the transformation function, $T(\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k) \leq 0$.

These prices, $(\boldsymbol{p},\boldsymbol{w})$, aggregate inputs and outputs into profit:

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

where m denotes noninterest income, p_π is the price of a real dollar of after-tax accounting profit, π, in terms of nominal, before-tax dollars, and $p_\pi = 1/(1-t)$, where t is the marginal tax rate on profit and a real dollar is assumed equal to one nominal dollar. Thus, $p_\pi \pi$ is nominal, before-tax accounting profit, which differs from nominal, before-tax economic profit, $p_\pi \Pi$, by the required return on equity capital, $w_k k$,

$$\begin{aligned} p_\pi \pi &= p_\pi \Pi + w_k k \\ &= \boldsymbol{p} \cdot y + m - \boldsymbol{w} \cdot x . \end{aligned} \tag{2}$$

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[11]Barnett, Hughes, and Moon (1995) employ this formulation to model the salaries of three types of secondary school staff: instructional staff, supporting staff, and administrative staff. They regress salary on factors such as experience, assignments, and training, and they use the constant term to proxy the "base."

B. Managerial Utility

Hughes and Moon (1995) argue that including the production plan and its quality characteristics in the managerial utility function, $U(\pi,\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k)$, rather than expected profit and the standard deviation of profit, leads to a more general specification of managerial preferences since it does not preclude the possibility that higher moments of the distribution of profit could affect preferences. This utility function represents managers' beliefs about the probabilities of future states of the world and about how production plans and quality characteristics, $(\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k)$, interact with those states, s, to yield a realization of profit, $\pi = g(\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k,s)$. If we represent those beliefs about the likelihood of future market conditions by a subjective probability distribution of s, the beliefs about how profit follows from the interaction of states and production plans, summarized in $g(\cdot)$, can be combined with the subjective distribution of s to generate a conditional, subjective probability distribution for realized profit, $f(\pi;\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k)$. Hence, defining utility as a function of the production plan and its quality characteristics is equivalent to defining it as a function of these subjective conditional probability distributions, $f(\cdot)$. Of course, the production plan $(\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k)$ implies an expected profit, $E(\pi;\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k) = \int [f(\pi;\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k)\pi]\, d\pi$ and a level of risk measured by the standard deviation $S(\pi;\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k)$, but the utility function defined over $(\pi,\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k)$ allows higher moments of the distribution to affect the ranking.

C. The Most Preferred Production Plan

The managers' most preferred, feasible production plan maximizes managerial utility:

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

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

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

where $p_i = \bar{p}_i / q_i^y$ and $w_j = \bar{w}_j q_j^x$.

Denoting the price vector by $\boldsymbol{v} \equiv (\bar{\boldsymbol{p}},\bar{\boldsymbol{w}},\boldsymbol{q},p_\pi)$, the solution to (3)-(5) gives the *most preferred production plan:* the utility-maximizing input demands, $\mathbf{x}(\boldsymbol{y},\boldsymbol{q},n,\boldsymbol{v},m,k)$, and the utility-maximizing level of profit, $\pi(\boldsymbol{y},\boldsymbol{q},n,\boldsymbol{v},m,k)$. Since the profit function is conditioned on the level of equity capital, it can be normalized by capital to obtain the most preferred rate of return on equity.

D. Deriving the Most Preferred Production Plan from the Almost Ideal Demand System

Because the organization of production is described in terms of managers' ranking production plans and choosing their most preferred plans, it follows that recovering their preferences and technology from data can be accomplished using the techniques of demand analysis. In particular, Hughes, Lang, Mester, and Moon (1995, 1996) adapt the Almost Ideal Demand System, developed by Deaton and Muellbauer (1980), to accommodate managerial preferences. Rather than express preferences in terms of the utility function, it employs its dual representation, the expenditure function. Formulated to represent managerial preferences, the expenditure function gives the minimum expenditure on the "goods," profit π and inputs $\boldsymbol{x}$, necessary to achieve some minimum level of utility, conditional on the values of ouputs, output quality, and equity capital:

$$\min_{\pi,\boldsymbol{x}} \quad \boldsymbol{w}\cdot\boldsymbol{x} + p_\pi \pi \tag{6}$$

$$s.t. \quad U^0 - U(\pi,\boldsymbol{x};\boldsymbol{y},\boldsymbol{q},n,k) = 0 \tag{7}$$

$$T(\boldsymbol{x};\boldsymbol{y},\boldsymbol{q},n,k) \leq 0 \tag{8}$$

The solution to (6)-(8) gives the constant-utility demand functions. When these demand functions are substituted into (6), the expenditure function $E(\boldsymbol{y},n,\boldsymbol{v},k,U^0)$ is obtained. Since the expenditure minimization problem is the dual of the utility maximization problem (3)-(5), the maximum utility obtained from the expenditure $(\boldsymbol{p}\cdot\boldsymbol{y}+m)$ is U^* while the minimum expenditure required to achieve $U^0 = U^*$ is $(\boldsymbol{p}\cdot\boldsymbol{y}+m)$. Consequently, $E(\boldsymbol{y},n,\boldsymbol{v},k,U^0) = (\boldsymbol{p}\cdot\boldsymbol{y}+m)$.

In adapting the expenditure function to represent managerial preferences and to accommodate the availability of price data for bank holding companies, it is necessary to substitute a weighted average of output prices for the individual prices: $\tilde{p} = \sum_i p_i \, [y_i / \sum_j y_j]$. Hughes, Lang, Mester, and Moon substitute $(\tilde{p}, r)$ *for* $(\boldsymbol{p}, \bar{\boldsymbol{p}})$, where r is a risk-free rate of interest. Their specification of the expenditure function is

$$ln\, \mathrm{E}(\cdot) = ln\, \mathrm{P} + \mathrm{U}\cdot\beta_0 \left(\prod_i \mathrm{y}_i^{\beta_i}\right)\left(\prod_j \mathrm{w}_j^{\nu_j}\right) \mathrm{p}_\pi^{\mu} \mathrm{k}^{\kappa}, \tag{9}$$

where

$$
\begin{aligned}
\ln P \;=\; & \alpha_0 + \alpha_p \ln \tilde{p} + \sum_i \delta_i \ln y_i + \sum_i \omega_j \ln w_j \\
& + \eta_\pi \ln p_\pi + \tau \ln r + \vartheta \ln n + \rho \ln k + \tfrac{1}{2}\alpha_{pp}(\ln \tilde{p})^2 \\
& + \tfrac{1}{2}\sum_i \sum_j \delta_{ij} \ln y_i \ln y_j \\
& + \tfrac{1}{2}\sum_s \sum_t \omega^*_{ij} \ln w_s \ln w_t + \tfrac{1}{2}\eta_{\pi\pi}(\ln p_\pi)^2 \\
& + \tfrac{1}{2}\tau_{rr}(\ln r)^2 + \tfrac{1}{2}\vartheta_{nn}(\ln n)^2 + \tfrac{1}{2}\rho_{kk}(\ln k)^2 \\
& + \sum_j \theta_{pj} \ln \tilde{p} \ln y_j + \sum_s \phi_{ps} \ln \tilde{p} \ln w_s + \psi_{p\pi} \ln \tilde{p} \ln p_\pi \\
& + \psi_{pr} \ln \tilde{p} \ln r + \psi_{pn} \ln \tilde{p} \ln n + \psi_{pk} \ln \tilde{p} \ln k \\
& + \sum_j \sum_s \gamma_{js} \ln y_j \ln w_s + \sum_j \gamma_{j\pi} \ln y_j \ln p_\pi + \sum_j \gamma_{jr} \ln y_j \ln r \\
& + \sum_j \gamma_{jn} \ln y_j \ln n + \sum_j \gamma_{jk} \ln y_j \ln k \\
& + \tfrac{1}{2}\sum_s \omega^*_{s\pi} \ln w_s \ln p_\pi + \tfrac{1}{2}\sum_s \omega^*_{\pi s} \ln p_\pi \ln w_s \\
& + \sum_s \omega_{sr} \ln w_s \ln r + \sum_s \omega_{sn} \ln w_s \ln n + \sum_s \omega_{sk} \ln w_s \ln k \\
& + \eta_{\pi r} \ln p_\pi \ln r + \eta_{\pi n} \ln p_\pi \ln n + \eta_{\pi k} \ln p_\pi \ln k \\
& + \tau_{rn} \ln r \ln n + \tau_{rk} \ln r \ln k + \vartheta_{nk} \ln n \ln k \,.
\end{aligned}
$$

When Shephard's lemma is applied to the expenditure function, the constant-utility demands for inputs and profit are obtained. These demands are readily converted to the utility-maximizing demands, expressed as shares of profit, $p_\pi \pi$, and of inputs, $\boldsymbol{w}\cdot\boldsymbol{x}$ in expenditure, $\boldsymbol{p}\cdot\boldsymbol{y}+m$, by inverting the expenditure function and substituting the resulting indirect utility function,

$$
V(\cdot) \;=\; \frac{\ln(\boldsymbol{p}\cdot\boldsymbol{y} + m) - \ln P}{\beta_0 \left(\prod_i y_i^{\beta_i}\right)\left(\prod_j w_i^{\nu_j}\right) p_\pi^{\mu} k^{\kappa}} \qquad (10)
$$

into the constant-utility demands:

$$\frac{\partial \ln \mathrm{E}}{\partial \ln \mathrm{w_i}} = \frac{\mathrm{w_i x_i}}{\mathbf{p}\cdot\mathbf{y} + \mathrm{m}} = \frac{\partial \ln \mathrm{P}}{\partial \ln \mathrm{w_i}} + \nu_i[\ln(\mathbf{p}\cdot\mathbf{y} + \mathrm{m}) - \ln \mathrm{P}]$$

$$= \omega_i + \sum_s \omega_{si} \ln \mathrm{w_s} + \phi_{pi} \ln \tilde{\mathrm{p}} + \sum_j \gamma_{ji} \ln \mathrm{y_j} + \omega_{\pi i} \ln \mathrm{p}_\pi \tag{11}$$

$$+ \omega_{ir} \ln \mathrm{r} + \omega_{in} \ln \mathrm{n} + \omega_{ik} \ln \mathrm{k}$$

$$+ \nu_i[\ln(\mathbf{p}\cdot\mathbf{y} + \mathrm{m}) - \ln \mathrm{P}]$$

$$\frac{\partial \ln \mathrm{E}}{\partial \ln \mathrm{p}_\pi} = \frac{\mathrm{p}_\pi \pi}{\mathbf{p}\cdot\mathbf{y} + \mathrm{m}} = \frac{\partial \ln \mathrm{P}}{\partial \ln \mathrm{p}_\pi} + \mu[\ln(\mathbf{p}\cdot\mathbf{y} + \mathrm{m}) - \ln \mathrm{P}]$$

$$= \eta_\pi + \eta_{\pi\pi} \ln \mathrm{p}_\pi + \psi_{p\pi} \ln \tilde{\mathrm{p}} + \sum_j \gamma_{j\pi} \ln \mathrm{y_j} + \sum_s \omega_{s\pi} \ln \mathrm{w_s} \tag{12}$$

$$+ \eta_{\pi r} \ln \mathrm{r} + \eta_{\pi n} \ln \mathrm{n} + \eta_{\pi k} \ln \mathrm{k}$$

$$+ \mu[\ln(\mathbf{p}\cdot\mathbf{y} + \mathrm{m}) - \ln \mathrm{P}] . \qquad .$$

Since these share equations are conditioned on equity capital, they can be readily divided on equity capital to obtain a predicted rate of return on equity. However, for such purposes as computing scale economies, it is necessary to add a first-order condition that defines the optimal level of capital. This condition can be derived by adding a second stage to the optimization in (3)-(5). Beginning with the conditional indirect utility function, which can be obtained by evaluating the Lagrangean function for (3)-(5) at the optimum,

$$V(\boldsymbol{y},\boldsymbol{q},n,\boldsymbol{v},m,k) \equiv U(\pi(\cdot),\boldsymbol{x}(\cdot);\boldsymbol{y},\boldsymbol{q},n,\boldsymbol{v},k)$$

$$+ \lambda(\cdot)[\boldsymbol{p}\cdot\boldsymbol{y} + m - \boldsymbol{w}\cdot\boldsymbol{x}(\cdot) - p_\pi \pi(\cdot)] \tag{13}$$

$$+ \gamma(\cdot)[T(x(\cdot);\boldsymbol{y},\boldsymbol{q},n,k)],$$

the first-order condition is obtained by maximizing (13) with respect to equity capital k:

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

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

which gives the condition,

$$\rho + \rho_{kk} ln\, k + \psi_{pk} ln\, \tilde{p} + \sum_j \gamma_{jk} ln\, y_j + \sum_s \omega_{sk} ln\, w_s + \eta_{\pi k} ln\, p_\pi + \tau_{rk} ln\, r$$
$$+ \vartheta_{nk} ln\, n + \kappa [ln(\boldsymbol{p} \cdot \boldsymbol{y} + m) - ln\, P] = 0 . \tag{14}$$

The system of equations estimated consists of the profit share equation (12), the input share equations (11), and the first-order condition (14). Adding-up, homogeneity, and certain symmetry conditions are also imposed on the estimation. See Hughes, Lang, Mester, and Moon (1995, 1996) for details.

Just as the estimation of a consumer demand system recovers consumers' preferences for goods and services from price and expenditure data, the estimation of the Most Preferred Production System recovers managers' preferences for expected profit and production plans from price and revenue data. Consumer demand systems are often estimated using cross-sectional data to minimize the problem of changing tastes. Since managers' preferences are formed from their beliefs about how production plans interact with probable future economic conditions to generate profit and from their beliefs about how probable these future conditions are, the Most Preferred Production System is also estimated using cross-sectional data to minimize the problem of changing beliefs and, hence, changing rankings of production plans and price schedules.

E. Deriving Expected Return and Return Risk

Hughes and Moon (1995) demonstrate that the preferences for expected profit and for production plans that are recovered from estimating the Most Preferred Production Plan can be transformed into preferences for subjective, conditional probability distributions of profit. They employ the fitted profit share equation (12) to obtain a measure of expected profit, $E(p_\pi \pi)$, by multiplying the predicted profit share by $(\boldsymbol{p} \cdot \boldsymbol{y} + m)$. Since the profit share equation is conditioned on equity capital, predicted profit can in turn be divided by equity capital to compute the expected rate of return on equity, $E(p_\pi \pi/k)$. To proxy the risk attached to expected profit and the expected return on equity, Hughes and Moon (1995) use the standard error of the predicted profit share. Since they do not impose homoskedasticity on their estimation, the resulting variance-covariance matrix allows for a nonconstant error variance across all observations in the sample. The error variance will differ as individual bank's production data and choices differ since the predicted profit share depends on $(\boldsymbol{y},\boldsymbol{q},n,\boldsymbol{v},m,k)$.

Hence, the standard error of the predicted profit share captures how prediction risk depends on each observation's particular economic circumstances and production decisions. Multiplying the standard error of the predicted profit share by $(\boldsymbol{p} \cdot \boldsymbol{y} + m)$ gives the standard error of predicted profit, and dividing by equity capital yields the standard error of the predicted rate of return on equity. These standard errors are used as proxies for risk, the second moment of the subjective distributions of profit, conditioned on the production plan and price schedule. Hughes and Moon (1995) argue that this strategy for gauging risk captures market-priced risk. Using 1994 data on highest level bank holding companies[12] in the United States, they demonstrate that these measures of expected profit and profit risk explain 96 percent of the variation in the market value of banks' equity.

F. Measuring Efficiency in Expected Return-Risk Space

Using their measures of each observation's expected return on equity, $E(p_\pi \pi/k)$, and the standard error of the predicted return, $S(p_\pi \pi/k)$, which are functions of $(\boldsymbol{y},\boldsymbol{q},n,\boldsymbol{v},m,k)$, Hughes and Moon estimate a stochastic, upper envelope of predicted return, given its prediction risk:

$$E_i(p_\pi \pi/k) = \Gamma_0 + \Gamma_1 S_i(p_\pi \pi/k) + \Gamma_2 S_i(p_\pi \pi/k)^2 + \epsilon_i . \tag{15}$$

A composite error term, $\epsilon_i = v_i - u_i$, distinguishes inefficiency from statistical noise. The two-sided component, v_i, distributed $N(0,\sigma^2_v)$, accounts for any unmeasured randomness in the data generation process of risk and return while the one-sided component, $u_i > 0$, is distributed half normally, $N(0,\sigma^2_u)$, and gauges inefficiency. Hence, inefficiency is the noise-corrected distance of an observation's expected return from the best-practice return at its measured level of prediction risk.

The log-likelihood function of this best-practice frontier is

$$ln\, L = \frac{N}{2} ln \frac{2}{\pi} - N\, ln\, \sigma - \frac{1}{2\sigma^2}\sum_{i=1}^{N} \epsilon_i^2 + \sum_{i=1}^{N} ln\left[\Phi\left(-\frac{\epsilon_i \lambda}{\sigma}\right)\right] \tag{16}$$

where N is the number of observations and $\Phi(\cdot)$ is the standard normal cumulative distribution

[12]Lower level bank holding companies--that is, holding companies owned by the highest level companies--are not included individually to avoid double counting them. Moreover, their business strategies are likely to depend on the strategy of the highest level company that owns them.

function. The frontier is estimated by maximum-likelihood techniques. The frontier obtained by Hughes, Lang, Mester, and Moon (1996) and by Hughes and Moon (1995) is shown in Figure 1. The empirical example that follows is based on the estimated production system of these two papers.

A bank's inefficiency is measured by the difference between its noise-adjusted expected return and the best-practice frontier value of expected return. This difference is given by □□$_i|\epsilon_i)$ where,

$$E(u_i|\epsilon_i) = \left(\frac{\sigma_u\sigma_v}{\sigma}\right)\left[\frac{\phi\left(\frac{\epsilon_i\lambda}{\sigma}\right)}{\Phi\left(-\frac{\epsilon_i\lambda}{\sigma}\right)} - \frac{\epsilon_i\lambda}{\sigma}\right] \tag{17}$$

denotes the conditional expectation of u_i given ϵ_i.[13] This value represents the bank's return lost to inefficiency or the failure to attain "best practice." When the *return inefficiency* is multiplied by equity capital, it measures *profit inefficiency*, the lost expected profit due to inefficiency.

II. Market Value and the Most Preferred Production System

The measures of return and profit inefficiency obtained from the Most Preferred Production System account for prediction risk but are not directly linked to market value. To demonstrate that these measures of inefficiency are priced by capital markets, Hughes and Moon (1995) estimate the equation, *ln(market value of equity)* = $\alpha_0 + \alpha_1 ln(E(p_\pi\pi/k)) + \alpha_2 ln(S(p_\pi\pi/k)$, and show that it explains 96 percent of the variation in the market value of equity. Hence, given a firm's observed level of prediction risk, an increase in its expected profit (or return) moves it closer to the "best-practice" frontier, reduces its inefficiency, and increases its market value. However, because these measures are not directly linked to market value, they do not anwer the question, "What is the optimal expected return-risk point on the "best-practice" frontier that maximizes a firm's market value?"

A. Market-Value Frontiers

Rather than derive performance measures from a production model, Hughes, Lang, Moon, and Pagano (1997) turn directly to market values and examine differences between market values and replacement costs, proxied by book values. They estimate a "best-practice"

[13]For details of this procedure, see Jondrow, Lovell, Materov, and Schmidt (1982).

market-value frontier given book value and measure *market-value inefficiency* as the difference between a firm's observed market value and the "best-practice" value. They relate market-value inefficiency to production decisions by regressing it on the production plan and variables characterizing the firm's economic environment.[14]

A firm's managers who act in the interests of the firm's shareholders maximize the value of their equity claims. When there are no agency problems, maximizing the market value of the firm's equity is equivalent to maximizing the market value of its assets. In a multi-period setting, the current market value of the i-th firm's assets, $MVA_{i,0}$, is given by

$$
\begin{aligned}
MVA_{i,0} &= MVE_{i,0} + MVL_{i,0} \\
&= \sum_{t=0}^{\infty} \frac{E(CFE_{i,t})}{(1+k_i)^t} + \sum_{t=0}^{\infty} \frac{E(CFD_{i,t})}{(1+r_i)^t}
\end{aligned}
\tag{18}
$$

where $E(CFE_{i,t})$ is the i-th firm's expected cash flow paid to its shareholders at time t while $E(CFD_{i,t})$ is the expected cash flow paid to debtholders at time t. The required return on equity for the i-th firm is k_i and r_i gives the required return on debt. The first term on the right-hand side represents the market value of equity, and the second term, the market value of debt.

Hughes, Lang, Moon, and Pagano (1997) recommend measuring inefficiency using the market value of assets rather than of equity since agency problems that lead to such problems as asset substitution can result in shareholders' expropriating market value from debtholders.[15] In such a case, the gain in the value of the equity may be more than offset by the fall in value of the debt. To capture the inefficiency caused by the agency problems, it is necessary to estimate the frontier on the market value of assets rather than equity.

A firm's market-value inefficiency represents in principle the amount of market value the firm fails to produce, given the replacement cost of its assets. This difference between the

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[14]Hughes, Lang, Moon, and Pagano (1997) find evidence that equity capital serves as a signal of a firm's riskiness. In particular, if we control for asset size, inefficient banks with higher capital-to-asset ratios increase market-value efficiency by *reducing* leverage and increasing asset quality while inefficient banks with lower capital-to-asset ratios increase market-value efficiency by *increasing* leverage and reducing asset quality.

[15]See Jensen and Meckling (1976).

observed market value and the “best-practice” value could be due to inherent market advantages as well as managerial skill. To proxy replacement costs, it is necessary to subtract goodwill from book value since it is a component of market value.[16] The “best-practice” market-value frontier is obtained, following the procedures described in (15)-(17), by estimating the relationship,

$$MVA_i = \Gamma_0 + \Gamma_1 BVA_i + \Gamma_2 (BVA_i)^2 + \varepsilon_i , \tag{19}$$

where BVA_i is the book value of assets adjusted to remove goodwill and, as explained above, $\epsilon_i = \nu_i - u_i$.

B. The Effects of Quality-Indicative Prices on Financial Performance

The market-value frontier (19) and the production-based risk-return frontier (15) are both sufficiently general to incorporate differences in quality-indicative prices into their efficiency measurement since they are not derived from regressors that are prices. In contrast to the standard profit frontier obtained by regressing profit on prices, the market-value frontier is found by regressing market value on replacement cost while the production-based frontier is derived by regressing predicted return on prediction risk. Since each of these frontiers is computed using a different set of regressors, they are not directly comparable. Nevertheless, the importance of accounting for endogenous prices in efficiency measurement can be underscored by asking how endogenous prices affect profitability, risk, market value, and different efficiency metrics, controlling for the other components of the production plan.

To explore the question of how quality-indicative prices affect financial performance, measures of financial performance are borrowed from the estimated market-value frontiers of Hughes, Lang, Moon, and Pagano (1997) and from the estimated production system and risk-return frontier of Hughes, Lang, Mester, and Moon (1996). The production-based measures describe the financial performance of 441 highest-level bank holding companies (BHCs) in the United States in 1994. The market-based measures belong to a subsample of 190 publicly traded BHCs. The full sample ranges in size from $32.5 million to $249.7 billion in consolidated assets while the publicly traded sample spans $159.0 million to $249.7 billion. The data used to estimate the production model are described in the Appendix and summarized in Table 1.

[16]See Demsetz, Saidenberg, and Strahan (1996).

The profit-share equation (12) is used to obtain each BHC's predicted profit, $E(\pi;\mathbf{y},\mathbf{x},\mathbf{q},n,k)$, and its profit risk, $S(\pi;\mathbf{y},\mathbf{x},\mathbf{q},n,k)$, the standard error of its predicted profit. The risk-return frontier derived from these estimates gives each BHC's inefficiency stated in terms of lost expected return on equity (return inefficiency) and in terms of lost (dollars of) expected profit (profit inefficiency). The market-value frontiers are estimated both for the market value of assets relative to the adjusted book value of assets and for the market value of equity relative to the adjusted book value of equity (adjusted to remove goodwill). These two measures of inefficiency give each BHC's lost market value of assets and of equity.

The estimated production model recovers managers' preferences for production plans and for quality-indicative prices from the data and translates them into preferences for expected profit, $E(\pi;\mathbf{y},\mathbf{x},\mathbf{q},n,k)$, and profit risk, $S(\pi;\mathbf{y},\mathbf{x},\mathbf{q},n,k)$.[17] In turn, the market-value equation (18) indicates that expected profit and profit risk play a role in valuing equity and assets. To the extent that the production model's expected profit captures the market's expected current cash flow and proxies the market's expected future cash flows and to the extent that profit risk proxies the market's assessment of the risk that gives the required return on equity, expected profit and profit risk should explain the market value of equity. Thus, each BHC's choice of quality-indicative prices should influence the market values of its equity and its assets and, hence, its market-value efficiency.

To quantify the influence of quality-indicative prices, the following system of equations is estimated using a sample of 190 highest-level BHCs that are publicly traded:

$$\begin{aligned} ln\,(\text{Market value of equity}) &= \alpha_0 + \alpha_1\, ln\,(\text{Expected profit}) + \alpha_2\, ln\,(\text{Profit risk}) \\ ln\,(\text{Expected profit}) &= \beta_0 + \beta'\mathbf{Z} \\ ln\,(\text{Profit risk}) &= \gamma_0 + \gamma'\mathbf{Z}\,. \end{aligned} \tag{20}$$

where $\mathbf{Z} = (\boldsymbol{y,x,q,n,k})$. In addition, four measures of inefficiency--return and profit inefficiency from the production model and asset- and equity-based market-value inefficiency --are regressed on **Z**:

$$ln\,(\text{Inefficiency}) = \eta_0 + \eta \cdot \mathbf{Z}\,. \tag{21}$$

[17]See Section I.B.

The results of these estimations are reported in Table 2.

The data used to estimate market values are obtained from the stock-price database of the Center for Research on Securities Prices and from Standard & Poor's Compustat database. Balance-sheet and income-statement data are taken from the FRY-9 Financial Statements for 1994. The output vector, $\boldsymbol{y}$, in $\mathbf{Z} = (\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k)$ consists of the book-value of assets adjusted to remove goodwill, expressed in log form, and the book value of various balance-sheet and off-balance-sheet products, expressed as ratios of total assets. These specific products are listed in the first column of Table 2. The category "Liquid Assets" comprises cash, balances due, federal funds sold, reverse repurchase agreements, and government securities. "Other Assets" includes assets held in trading accounts and investments in unconsolidated subsidiaries. "Derivatives" is the notional amount of activities in futures, options, and swaps. The capital component, k, in the capital-to-assets ratio is the book value of shareholders' equity. The nonperforming assets component, n, of the nonperforming assets ratio is the sum of accruing and nonaccruing loans, leases, and other assets past due more than 90 days plus gross charge-offs. Including gross charge-offs eliminates any differences among banks in their aggressiveness in charging off past-due assets.

The input vector, $\boldsymbol{x}$, in $\mathbf{Z} = (\boldsymbol{y},\boldsymbol{x},\boldsymbol{q},n,k)$ consists of ratios to total assets of labor (measured by the number of full-time, equivalent employees), physical capital (given by the book value of premises and fixed capital), uninsured domestic deposits, all other domestic deposits, and other borrowed funds (foreign deposits, federal funds purchased, repurchase agreements, commercial paper, subordinated debentures, mandatory convertible securities, trading account liabilities, mortgage indebtedness, and other borrowed funds).

In the context of financial intermediation, the prices of most outputs and of uninsured borrowed funds are likely to reflect credit quality. For the purpose of specifying $\boldsymbol{q}$, the endogenous components of prices, it is assumed that, when banks set the contractural prices on their outputs, they establish the credit quality of their customers. On the other hand, while the prices of uninsured borrowed funds reflect banks' choices of output prices and the resulting credit quality of those outputs, it is assumed that banks do not directly set these input prices. Hence, only output prices are included in $\boldsymbol{q}$. As in Hughes, Lang, Mester, and Moon (1996), the output prices must be measured by an asset-weighted, average contractural price, $\tilde{p} = \sum_i p_i \, [y_i / \sum_j y_j]$, since the data necessary to compute individual contractural prices are not available. The exogenous component of the average price is the risk-free Treasury bill rate, which does not vary across BHCs. Hence, the endogenous component of the average price can be proxied by the weighted average price.

Estimating the relationships in (20) and (21) gives the effects of the endogenous components of output prices on financial performance, which are presented in the second row of Table 2. An increase in the average contractural return on assets of 0.01 increases expected profit by 8.28 percent, but this improvement in profitability entails a 12.056 percent increase in profit risk. The market value of equity increases 5.295 percent. In comparing the effect of the increase in endogenous prices on the four measures of inefficiency, some caution is necessary since the production-based and market-value frontiers are derived from different regressors. Nevertheless, the signs of all four measures of inefficiency indicate that an increase in the contractural return reduces inefficiency; however, only the coefficient on ROE inefficiency, the distance from the production model's risk-return frontier, is statistically significant. If the sample is divided into the more and less efficient halves, a distinct difference in significance levels arises between the two halves. For the more efficient half, the coefficients on the two production-based measures of inefficiency are significantly negative while those on the two market-value measures are insignificantly negative. For the less efficient half, the coefficients on profit inefficiency and on the two market-value measures are all significantly negative while only the coefficient on return inefficiency is insignificantly negative.[18] Thus, banks' choices of endogenous output prices affect their market values, and the market-value measures of inefficiency indicate that these choices also affect their relative market performance compared with their peers of similar size.

By controlling for output prices in their entirety, the standard profit frontier eliminates the influence of these effects on its measure of inefficiency. Moreover, because it abstracts from issues of profit risk, the standard profit frontier's measure of inefficiency may not be a good proxy for the impact on market value of differences in firms' production plans. Although an increase in the average contractural return on assets tends to increase market value by increasing expected profit, it tends to diminish market value by increasing profit risk. In the example at hand, an increase in return of 0.01 results in a statistically significant gain of 13.39 percent in market value through its effect on expected profit while it leads to a statistically significant loss of 8.10 percent in market value through its effect on profit risk.

In addition to the influence of quality-linked prices on financial performance, the effects of the production plan on financial performance deserve comment. First, the composition of assets and liabilities significantly affects expected profit, risk, and market value but does not generally explain efficiency differences among BHCs. A notable exception

[18]The coefficient estimates for the two half-samples are available from the author.

to this generalization is the effect of derivatives activity. Its level adversely affects expected profit and market value and significantly increases all four measures of inefficiency. The poor performance of derivatives products may be due to the Federal Reserve's surprising increase in interest rates in February 1994.

An increase in asset size appears to increase expected profit more than proportionately while it increases profit risk, the market value of equity, and profit inefficiency proportionately. If the book-value of equity increases with the book-value of assets less than proportionately, market-value inefficiency and return inefficiency should be reduced. The coefficients on these measures confirm this hypothesis.

An increase in the capital-to-assets ratio increases expected profit, reduces profit risk, and improves market value; however, the magnitudes are important. An increase of 0.01 in the capital-to-assets ratio increases the market value of equity 0.046, or 4.6 percent. However, for capital-to-asset ratios less than 0.22, the increase in the book value of equity implied by an increase of 0.01 in the capital ratio is greater than 4.6 percent. None of the BHCs in the sample had a capital-to-assets ratio that high. Hence, increases in the capital-to-assets ratio reduce market-value efficiency and return inefficiency. The signs of the coefficients on these measures confirm this interpretation, although the coefficients on the market-value measures are not statistically significant.

III. Conclusions

In perfectly competitive markets, prices aggregate inputs and outputs into a money metric that allows production plans to be ranked by their profitability. When informational asymmetries in competitive markets lead to adverse selection, prices in these markets assume an additional role that conveys information about product quality. In the example of banking production, quality is linked to risk. The problem of efficiency measurement is complicated by the additional role because quality varies with price and price is a decision variable of firms operating in these markets. The effect of these endogenous components of prices on financial performance has been illustrated with a production-based model and a market-value model that generate "best-practice" frontiers. Unlike the standard profit function's frontier, these frontiers are not conditioned on prices so that they compare the financial performance of firms with different quality-linked prices. Hence, they identify the most efficient pricing strategies as well as the most efficient production plans.

Appendix

Data Used to Estimate the Most Preferred Production System

To estimate the system of share equations, (11) and (12), and the first-order condition, (14), Hughes, Lang, Mester, Moon (1996) define the system's variables as follows. They specify five outputs in the vector, $\boldsymbol{y}$: liquid assets, short-term securities, long-term securities, loans and leases net of unearned income, and other assets. Inputs include the level of financial capital, k, and the vector, $\boldsymbol{x}$, consisting of labor, physical capital, insured domestic deposits, uninsured domestic deposits, and other borrowed money. Asset quality is measured by the amount of nonperforming assets, n, which are accruing and nonaccruing loans, leases, and other assets past due over 90 days. Input prices, $\boldsymbol{w}$, are computed by dividing expenditure on each input by its quantity. The contractual price of an output is measured by the ratio of income accruing to the output to the quantity of that output that is accruing interest. Because data are not available to compute individual prices, a weighted average price, $\tilde{p} = \sum_i p_i [y_i / \sum_j y_j]$, is employed. The variable, m, is given by the amount of noninterest income, which is income not due to the components of $\boldsymbol{y}$. These variables are measured as averages over the four quarters of 1994.

The state tax rates are taken from *The Book of the States*, published by the Council of State Governments, and from *Significant Aspects of Fiscal Federalism*, published by the U.S. Advisory Commission on Intergovernmental Relations.

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FIGURE 1. Risk-Return Frontier of U.S. BHCs (1994)

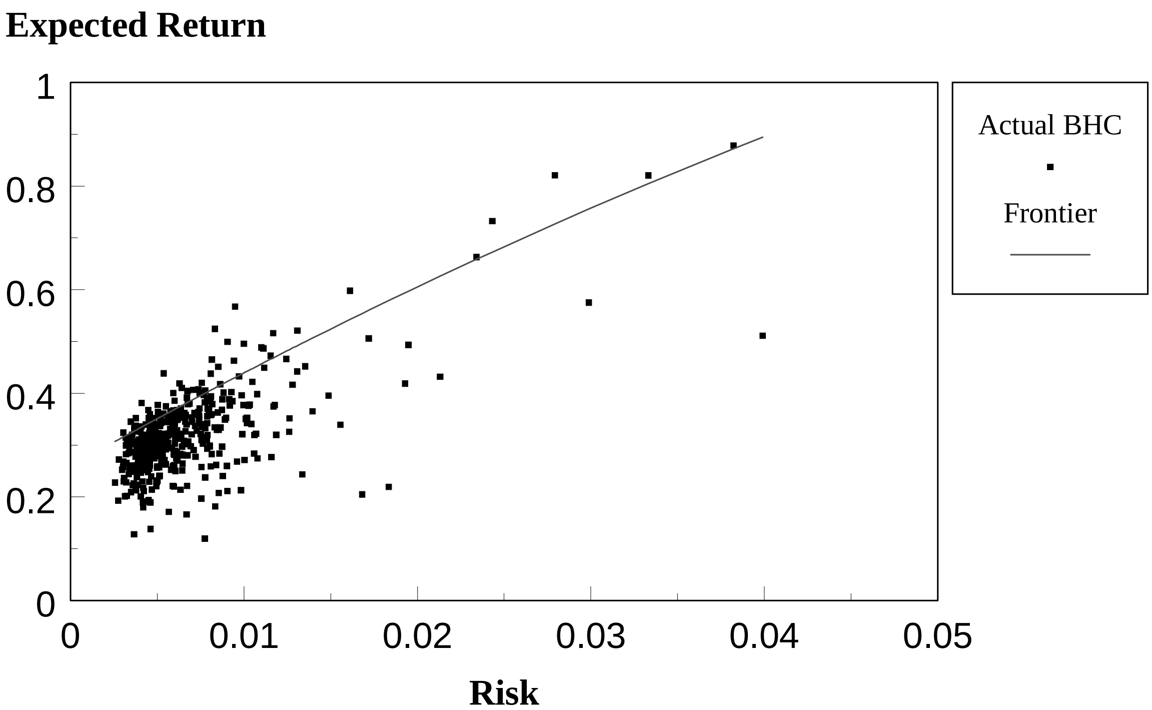

Table 1. Data Summary

	Mean	Std Dev	Minimum	Maximum
Total Assets	12,257,270,210	30,989,407,110	159,002,000	249,745,000,000
Market Value of Assets	12,822,500,000	31,512,800,007	155,108,250	249,287,000,000
Market Value of Equity	1,148,052,392	2,371,303,769	6,321,250	16,287,400,000
Book Value of Equity	946,240,768	2,343,272,632	10,308,000	18,891,000,000
Liquid Assets Ratio*	0.33810	0.10304	0.14593	0.75797
Business Loans Ratio	0.11731	0.071063	0.0069277	0.45039
Agricultural Loans Ratio	0.0074396	0.014537	0.00000	0.12562
Individual Loans Ratio	0.10454	0.060524	0.0011106	0.36190
Real Estate Loans Ratio	0.32004	0.11214	0.0049880	0.64177
Other Loans Rattio	0.020611	0.017929	0.00000	0.12402
Leases Ratio	0.0068320	0.011830	0.00000	0.084528
Other Assets Ratio	0.035612	0.057550	0.010517	0.60479
Equity Capital Ratio	0.084983	0.015936	0.044244	0.13540
Credit Guarantees Ratio	0.21091	0.17009	0.023081	1.27942
Derivatives Ratio	0.32284	0.57121	0.023081	5.46773
Labor Ratio	0.00048880	0.00014879	0.00014976	0.0019616
Physical Capital Ratio	0.016741	0.0056562	0.0028259	0.035027
Uninsured Domestic Deposits	0.057475	0.035292	0.0023887	0.31163
Other Domestic Deposits	0.69690	0.13098	0.085367	0.93471
All Other Borrowed Funds	0.11447	0.12794	0.00039370	0.85313
Average Contractural Return on Assets	0.075487	0.0072123	0.050603	0.12252
Nonperforming Assets Ratio	0.010255	0.010226	0.0016704	0.097385

*All ratios are expressed in terms of total assets.

Table 2. Coefficient Estimates

(Standard Errors are given in parentheses. *Significantly different from zero at the 10% level, ** at the 5% level, and *** at the 1% level. #Tested against 1 and not significantly different, +Tested against 1 and significantly different at the 10% level, ++at the 5% level, and +++at the 1% level.)

Ln(market value) = -0.7840** + 1.6174*** *Ln* (expected profit) - 0.6718*** *Ln* (profit risk) $R^2 = 0.958$
(0.3789) (0.0876) (0.0863)

Dependent Variable	Expected Profit (Log)	Profit Risk (Log)	Market Value of Equity (Log)	ROE Inefficiency	Profit Inefficiency (Log)	Market-Value Asset Inefficiency (Log)	Market Value Equity Inefficiency (Log)
constant	-5.530*** (0.196)	-8.561*** (0.577)	-3.977*** (0.461)	0.193*** (0.056)	-6.025*** (1.057)	10.538*** (0.069)	10.892*** (0.098)
average asset price (return)	8.280*** (1.188)	12.056*** (2.460)	5.295*** (1.916)	-0.525* (0.269)	-3.815 (5.061)	-0.217 (0.332)	-0.349 (0.470)
log(total assets)	1.023***+++ (0.007)	0.974*** # (0.019	1.000*** # (0.018)	-0.006*** (0.002)	0.957*** # (0.031)	-0.006*** (0.002)	-0.008*** (0.003)
capital-to-assets ratio	1.112** # (0.0457)	-4.171** (1.892)	4.554*** (1.106)	0.283* (0.150)	15.729*** (2.821)	0.043 (0.185)	0.153 (0.261)
nonperforming assets ratio	2.500*** (0.517)	11.383*** (1.786)	-3.607*** (1.074)	0.644*** (0.173)	11.646*** (3.265)	-0.178 (0.214)	-0.237 (0.302)
liquid assets ratio	0.815** (0.350)	-0.874 (1.197)	1.906*** (0.716)	0.055 (0.111)	2.726 (2.087)	-0.146 (0.137)	-0.201 (0.193)
business loans ratio	0.972*** (0.343)	-1.195 (1.216)	2.376*** (0.713)	-0.026 (0.108)	1.869 (2.026)	-0.101 (0.133)	-0.131 (0.187)
agricultural loans ratio	0.073 (0.463)	-4.021*** (1.538)	2.820*** (1.100)	0.007 (0.149)	2.736 (2.802)	-0.279 (0.184)	-0.394 (0.259
individual loans ratio	0.799** (0.330)	-2.772** (1.237)	3.155*** (0.812)	-0.081 (0.107)	0.484 (2.018)	-0.153 (0.132)	-0.208 (0.187)
real estate loans ratio	0.789** (0.350)	-1.838 (1.170)	2.511*** (0.736)	-0.022 (0.112)	1.816 (2.111)	-0.141 (0.139)	-0.191 (0.195)
other loans ratio	0.715 (0.495)	-2.448 (1.693)	2.801*** (1.006)	0.160 (0.155)	4.589 (2.922)	-0.123 (0.192)	-0.195 (0.270)
leases and lease financing ratio	2.256*** (0.501)	1.010 (1.725)	3.407*** (1.198)	0.123 (0.180)	5.290 (3.391)	-0.374* (0.223)	-0.478 (0.314)
other assets ratio	1.394*** (0.410)	0.576 (1.319)	1.868** (0.816)	0.050 (0.128)	2.363 (2.419)	-0.301* (0.159)	-0.427* (0.224)
credit guarantees ratio	0.328*** (0.079)	0.749*** (0.151)	0.027 (0.116)	0.009 (0.013)	0.276 (0.252)	0.010 (0.017)	0.020 (0.023)
derivatives ratio	-0.104*** (0.027)	-0.015 (0.078)	-0.158*** (0.046)	0.007*** (0.002)	0.047 (0.038)	0.014*** (0.003)	0.019*** (0.003)
labor ratio	560.571*** (63.795)	927.464*** (201.178)	283.712** (115.084)	-58.298*** (17.580)	-1362.857*** (330.945)	32.225 (21.724)	45.574 (30.600)

Table 2. Coefficient Estimates (Continued)

(Standard Errors are given in parentheses. *Significantly different from zero at the 10% level, ** at the 5% level, and *** at the 1% level. #Tested against 1 and not significantly different, +Tested against 1 and significantly different at the 10% level, ++at the 5% level, and +++at the 1% level.)

Dependent Variable	Expected Profit	Profit Risk	Market Value of Equity	ROE Inefficiency	Profit Inefficiency	Market- Value Asset Inefficiency	M. Value Equity Inefficiency
physical capital ratio	0.488 (1.215)	-11.457*** (3.535)	8.486*** (2.352)	-0.857*** (0.316)	-9.100 (5.944)	-0.31 (0.390)	-0.067 (0.550)
ratio uninsured domestic deposits	-0.022 (0.396	1.843 (1.428)	-1.274 (0.861)	-0.030 (0.127)	-1.685 (2.399)	0.221 (0.157)	0.301 (0.222)
other domestic deposits ratio	0.195 (0.382)	1.954 (1.318)	-1.629** (0.796)	-0.013 (0.120)	-1.254 (2.264)	0.145 (0.149)	0.200 (0.209)
all other borrowed funds ratio	-0.236 (0.375)	2.386* (1.318)	-1.985** (0.800)	0.038 (0.121)	-0.651 (2.273)	0.156 (0.149)	0.210 (0.210)
Adjusted R^2	0.998	0.982	0.958	0.717	0.957	0.409	0.391