Recovering Technologies That Account for Generalized Managerial Preferences: An Application to Banks That Are Not Risk-Neutral

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Abstract Large banks involved in recent mergers often cite scale economies as a principal motive. Yet despite this belief that bigger is more economical, most economic studies find either constant or decreasing returns to scale for large banks. What accounts for the disparity between the beliefs of bank managers and the results of these studies? This paper suggests that the answer may lie with the assumptions underlying estimations of standard cost and profit functions. Typically these estimations assume that banks are risk-neutral -- that they ignore risk in their quest to maximize profits. This paper develops an alternative model which is sufficiently general to allow for active risk management. The resulting empirical estimates indicate large economies of scale that increase with bank size.

We develop a maximization model that allows for (but does not impose) preferences of bank management that are not risk neutral. Our estimated equations are fully consistent with the theoretical model underlying the estimation procedure. The model considers a bank managerial utility function in which profit is one of many elements. Since we do not observe the probabilities that a bank assigns to various sets of outcomes, our model considers how banks

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rank production plans given their choices of the quantity and quality of outputs and inputs. Risk neutrality then implies that a bank's preferences will depend only on profit and that other variables in the utility function have no impact on bank preferences.

Our empirical model strongly rejects the hypothesis that banks are risk-neutral. Preferences over production plans are not invariant with respect to the tax rate on profits or on fixed revenues. Unlike previous studies, we find large increasing returns to scale even for the largest banks. This result is due to our allowance for behavior that is not risk-neutral. When the empirical restrictions implied by risk neutrality are imposed, our estimates of returns to scale are similar to those found in previous studies -- small returns to scale that decline with bank size.

1. **Introduction**

Managers who have participated in recent large bank mergers have often cited scale economies as a principal motive. Despite the apparent belief of some bank managers that bigger is more economical, most economic studies find either constant or decreasing returns to scale for large banks. What accounts for the disparity between the beliefs of bank managers and the results of these studies? This paper suggests that the answer may lie with the assumptions underlying estimations of standard cost and profit functions. Typically these estimations assume that banks are risk-neutral -- that they ignore risk in their quest to maximize profits. This paper develops an alternative model which is sufficiently general to allow for active risk management.

The standard cost and profit functions using modern duality theory usually ignore risk. However, risk and risk management fundamentally shape bank costs and profits. Correctly accounting for behavior toward risk is crucial for uncovering the underlying production technologies in banking.

There are a number of reasons that banks might be concerned about the level of risk inherent in their production plans. If there is value in a bank charter, then bank owners might value production plans that reduce the risk of insolvency even if such a plan reduces earnings. In addition, banks may wish to avoid regulatory actions which punish excessive risk taking by banks. Alternatively, bank managers may be concerned about risk because a significant loss could threaten their jobs. Whatever the motive for managing risk, it is clear that aversion to risk should not be ruled out when estimating bank production decisions.

Appropriately controlling for risk may have profound affects on empirical analysis of bank production. For example, if a larger scale of banking operations improves opportunities for diversification and hedging, this would produce two important effects -- a direct reduction in risk and a consequent reduction in the marginal costs of controlling risk. These are the direct or exogenous effects of greater risk diversification. These exogenous effects of diversification are accompanied by an indirect endogenous effect of diversification -- the bank's choice of risk in response to the reduced price of risk. The optimal amount of risk depends not only on the marginal cost of controlling risk, but also on the additional revenue or return. The net marginal benefit or compensation for risk-taking is the price of risk.

If an increase in the scale of operations diversifies risk and increases the net marginal compensation for risk-taking, then banks may respond by assuming more risk and, hence, incur higher costs. Accurate measurement of scale economies must control for the endogenous component -- the component that is a matter of choice -- while allowing the exogenous component to adjust freely to scale variations. Hence, the cost-saving component of diversification of a loan portfolio is the exogenous reduction in credit risk at a given level of quality of assets and liabilities.

This paper develops a maximization model that allows for (but does not impose) non-neutral risk preferences of bank management. Our estimated equations are fully consistent with the theoretical model underlying the estimation procedure. The model considers a bank managerial utility function in which profit is one of many elements. Since we do not observe the probabilities that a bank assigns to various sets of outcomes, our model considers how banks rank production plans given their choices of the quantity and quality of outputs and inputs. Risk neutrality then implies that a bank's preferences will depend only on profit and that other variables in the utility function have no impact on bank preferences.

Our empirical model strongly rejects the hypothesis that banks are risk-neutral. Preferences over production plans are not invariant with respect to the tax rate on profits or on fixed revenues. Unlike previous studies, we find large increasing returns to scale even for the largest banks. This result is due to our allowance for behavior that is not risk-neutral. When the empirical restrictions implied by risk neutrality are imposed, our estimates of returns to scale are similar to those found in previous studies -- small returns to scale that decline with bank size.

1.1. **Amending the Standard Cost and Profit Functions to Account for Risk**

McAllister and McManus (1993) condition the cost function on financial capital and control for the risk of insolvency by adjusting each bank's level of financial capital so that all banks in their sample have the same probability of insolvency. They find essentially constant returns to scale. If improved diversification reduces return risk, it also reduces the risk of insolvency. Hence, adjusting capital to control for the probability of insolvency may obscure scale economies achieved by improving diversification.

When the standard cost function omits any consideration of risk, it implicitly assumes that managers choose the return-maximizing level of risk for any given vector of outputs or, equivalently, that managers are risk-neutral. Hughes and Mester (1993) recognized that the level of financial capital may not minimize cost if bank managers are not risk-neutral, so they conditioned the bank's cost function on its level of financial capital. This conditional cost function permits the level of financial capital to deviate from the least-cost expansion path. However, given this level, their model assumes that banks choose levels of all other inputs to minimize cost. In measuring scale economies, they control for loan quality, but assume financial capital varies proportionately with the output vector. Not surprisingly, they obtain essentially constant returns to scale for their sample, U.S. banks whose assets surpass $1 billion. The equiproportionate variation in financial capital obscures any economies that might be obtained when better diversification allows banks to reduce their capital-to-asset ratios.

When Hughes and Mester (1995) embed the conditional cost minimization problem into the problem of maximizing managerial utility, where managers choose the utility maximizing level of capital and profit, they obtain a utility-maximizing demand for financial capital that allows for non-risk-neutral preferences or, equivalently, a level of financial capital that does not minimize cost. They also control for loan quality. In measuring scale economies, they no longer need to assume that financial capital varies proportionately with output. In fact, using the same large bank sample, they obtain evidence of substantial economies in capitalization and of relatively large overall economies of scale.

These attempts to account for risk in the measurement of technology raise an important question: Are managers neutral toward risk? There are good reasons to believe that managers may in fact be risk-averse. Risk aversion poses grave difficulties for the standard cost and profit functions. When managers take on higher cost and reduced profit in return for less risk, their production decisions cannot be modeled by assuming that cost is minimized and profit is maximized. The theory of the firm draws important distinctions between the behavior of risk-neutral and risk-averse managers. For example, the risk-averse manager's demand for inputs responds to changes in fixed costs and to changes in marginal tax rates on profits; the risk-neutral manager's demand does not. Equivalently, cost minimization and profit maximization equilibria are not affected by these variables, while the equilibrium of the firm that accepts lower profit and higher cost in return for reduced risk is influenced by them. Hence, by implicitly assuming risk neutrality, the standard cost and profit functions omit variables such as fixed costs and taxes on profits and, in the case of risk-averse behavior, fail to capture important aspects of production.

To incorporate risk into a model of production, one should choose a model that is general enough to allow for non-neutral as well as neutral risk preferences. Additionally, generalized risk preferences should be incorporated within the context of an optimization process rather than as an ad hoc construction. Finally, as noted in the previous subsection, the model should also account for sources of risk, as opposed to the resulting levels of risk.

1.2. Risk-Averse Managerial Preferences

Banking technology is characterized by fundamental information asymmetries between banks and their borrowers and between banks and their creditors and owners. Banks employ credit analysis and loan monitoring to reduce information asymmetries between themselves and their borrowers. In addition, a bank’s information on a borrower’s demand deposits gives it a low-cost source of credit information that historically has not been readily available to other lenders. This “inside” information concerning asset quality may generate another information asymmetry between bank management and those providing external financing, the owners and creditors of the bank. These outsiders have less information than insiders about the inherent risk of the loan portfolio or the resources that banks devote to credit analysis and loan monitoring.

When owners and creditors of firms cannot perfectly monitor the actions of the firms' managers and managers' interests differ, agency problems arise. To protect their firm-specific human capital, or, perhaps, to appease their regulators, bank managers may accept higher cost and reduced profit in return for less risk. For example, to reduce liquidity risk, managers may fund the loan portfolio with more expensive but less volatile funding sources, such as core deposits. To reduce credit risk, managers may allocate extra resources to credit analysis and loan monitoring. To reduce interest rate risk, they may choose less profitable mixes of loans and funding sources to close the duration gap. Because bank owners are able to diversify risk in their own investment portfolios, they would prefer that their banks' managers make risk-neutral decisions. However, the owners' inability to perfectly monitor loan quality and risk management gives managers the opportunity to exercise risk-averse preferences.

Even if managers are risk-neutral, the fundamental informational asymmetry between managers and creditors may lead to phenomena that cannot be captured by the standard cost and profit functions. Since managers are better informed about loan quality and the resources devoted to risk management, they may signal loan quality to uninsured creditors to reduce the risk of a liquidity crisis by “overemploying” certain readily observed inputs, such as financial (equity) capital. Since loan losses are subtracted from financial capital, equity serves as a cushion against insolvency and represents a bank's “bet” on its loan quality. Consequently, the level of financial capital relative to the size of the loan portfolio is a credible signal of asset quality. Well-capitalized banks are more likely to have high quality loans and to allocate more resources to managing risk. If financial capital serves as a signal of risk to less informed, uninsured creditors, its level may not minimize cost or maximize profit.

Risk-neutral managers might also “overemploy” financial capital to protect a valuable charter. The charter value constitutes a bankruptcy cost that is not included in the usual calculation of cost and profit. Hence, even risk-neutral managers might employ more than the cost-minimizing or profit-maximizing level of capital to protect the charter value. “Overemploying” capital to reduce the probability of liquidity crises and of bankruptcy would look like risk aversion.

Regulators may also contribute to the appearance of risk aversion. For example, to protect the payments mechanism, regulators may induce or require bank managers to adopt production plans that reduce risk below cost-minimizing and profit-maximizing levels. Regulatory attention is routinely focused on maintaining “prudent” capital levels.

Thus, there are many plausible theoretical explanations for managers choosing production plans that do not minimize cost or maximize profit. In this paper we do not attempt to uncover evidence for any particular theory. Rather, we formulate a general model of managerial preferences that allows for the possibility for departures from risk neutrality.

1.3. Generalized Managerial Preferences

Managers who minimize cost and maximize profit prefer high profit production plans to low profit ones. The specific output and input mixes of the production plans matter only in terms of their implied profit. On the other hand, managers who accept higher cost and reduced profit in return for other objectives care about the particular composition of the output and input bundles insofar as their composition contributes to achieving the additional objectives. For example, they may care about the implied credit risk and liquidity risk of the bundles. Or they may rank plans by the implied work load and prestige for top management. Or they may rank plans by the incentives regulators provide.

In any of these cases, managerial preferences can be characterized by a utility function defined by the inputs and outputs constituting the production plan and by the profit the production plan implies. The plan's profitability uses price information to aggregate the components of the plan. When managers simply minimize cost and maximize profit, only profit has marginal significance in their utility function. The production plan affects utility only indirectly through its effect on profit. However, when managers take on higher cost and reduced profit in return for other objectives, the particular components of the production plan will influence utility individually as well as through their effect on profit.

A managerial utility function defined over the production plan and profit is sufficiently general to represent a variety of objectives without having to be specific about any objective other than profitability. Similarly, it is sufficiently general that it could reflect the sources of a variety of risks without having to be specific about the nature of those risks.

1.4. Modeling Risky Production

In the sections that follow, we draw on earlier work by Hughes (1989, 1990) on hospitals and education that allows managers to choose production plans that trade profit or net income for other objectives. We specify a generalized managerial utility function, defined over profit and the production plan, to model banking technology and to derive a measure of scale economies that accounts for the risky nature of production. We assume that managers maximize utility with respect to the mix of inputs and profit, subject to the production constraint that the input mix must produce the given output vector. The problem's solution gives the manager's most preferred production plan. To the extent that managers have favored inputs and will increase their levels at the expense of profit, the most preferred production plan will not minimize cost or maximize profit.

The cost function that follows from the utility-maximizing (or most preferred) production plan is sufficiently general to incorporate non-neutrality toward risk, and to account for the sources of risk, without masking the diversification effects of scale on risk. Moreover, the most preferred cost function allows tax rates and fixed charges and revenues to affect production and, thus, accommodates the comparative statics of a firm that is not risk neutral. Although the most preferred cost function allows departures from strict cost minimization, it does not sacrifice desirable duality properties.

We empirically implement the model by adapting the Almost Ideal (AI) Demand System to allow for generalized managerial preferences. From this system we obtain input share equations and a profit (cost) function that, in the case of cost minimization, are identical to the translog cost function and input share equations. The model is estimated using 1989 and 1990 data from 286 U.S. banks with assets of at least $1 billion. The AI Demand System fits the data well. Risk neutrality is conclusively rejected. The estimate of scale economies obtained from the most preferred cost function is larger than that obtained from more conventional cost functions; it increases with bank asset size, suggesting that the diversification economies enjoyed by larger banks allow them to reduce the share of resources used to control risk, which magnifies the diversification economies. These results may provide insights into the economic reasons for the recent wave of mergers among large banks in the United States. When risk neutrality is imposed on the model and sources of risk are deleted, the measure of scale economies is smaller and resembles that generally found in studies employing the standard framework. Our evidence helps to explain why the standard literature (see Berger and Humphrey [1992]) finds cost savings to be a poor rationale for recent mergers.

2. Risky Production and Managerial Preferences

To incorporate risk into the production model, two important principles should be observed. First, the framework for choosing the production plan should allow for non-neutrality toward risk. Second, the basic construction of the model should focus on the sources of risk rather than the levels of risk. To observe these principles, we represent managers' attitudes toward risk by a utility function whose arguments include profit, output levels, and input levels. In its application to banking, the utility function is expanded to include financial (equity) capital as an input in the production plan. In addition, to account for sources of credit risk, output prices and nonperforming loans are included to measure loan quality.

If bank outputs are defined by asset categories such as commercial and industrial loans, consumer loans, commercial real estate loans, and securities, while inputs are labor, physical capital, financial capital, and other types of funding sources, the output vector, by comprising the bank's asset portfolio, reflects some of the sources of the bank's riskiness. In addition to asset composition, another determinant of risk is the quality of the assets and, in particular, of the loan portfolio. An important indication of loan quality is the interest rate charged on loans. In general, the higher the rate relative to the risk-free rate, the greater the credit risk and, thus, the lower the loan quality. Although an increase in the loan rate, given the risk-free rate, may improve the expected return on assets, it also reduces the quality of the loan applicants, since borrowers with better credit ratings will seek lenders offering lower rates. This suggests that the arguments of the bank managers' generalized utility function should include the vector of output levels, output prices, and the risk free interest rate. The risk premia inherent in the output prices are *ex ante* measures of output quality. The level of nonperforming loans, given the output levels, is an *ex post* measure of loan quality.

Credit risk is important to a bank because it affects the bank's risk of insolvency. Financial capital is the cushion that absorbs the impact of loan losses. For a given loan portfolio, the risk of insolvency increases as the level of financial capital decreases and as the amount of nonperforming loans increases. Thus, the generalized utility function should also include financial capital and nonperforming loans. Finally, the risk characteristics of the input mix must also be taken into account. Although production techniques involving the greater use of overnight funding sources might be less costly, such a course might increase liquidity risk. And although a bank might save on costs by doing less intensive credit evaluations and loan monitoring, doing so would mean greater credit risk. Hence, the input mix is included among the arguments of the utility function.

These generalized managerial preferences are represented by the utility function $U(\pi,\mathbf{s})$, where π is real, after-tax accounting profit; s = **(y,**

x, p, r, n, k); **y** is the vector of output levels; **x**, the vector of input levels; **p,** the vector of output prices; r, the risk-free rate of return; n, the level of nonperforming loans; and k, the level of financial capital. Let **w** be the input price vector; w_k, the price of financial capital (rate of return on equity); and m, income from sources other than those accounted for by output. Letting t be the tax rate on profit and $p_\pi (=1)$ be the nominal "price" of a real dollar, the price of a dollar of real, after-tax profit in terms of nominal, before-tax dollars is $p_\pi = \frac{p_\pi}{1-t}$. Nominal, before-tax accounting profit is, thus, defined as

$$p_\pi \pi = \boldsymbol{p}\grave{A}\_\_\_ + \boldsymbol{m} - \boldsymbol{w}\grave{A}\_\_\_ \quad (1)$$

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

$$\begin{aligned} p_\pi \pi &= p_\pi\left[\frac{w_k k}{p} + \pi\right] \\ &= p_\pi\left[\frac{r \bullet g(s) \bullet k}{p} + \pi\right] \end{aligned} \quad (2)$$

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

The utility function U(π,**s**) allows for a variety of managerial objectives and sources of risk without having to be specific about the particular objectives and the particular kinds of risk. In the special case of risk neutrality, cost is minimized and profit is maximized. Given the level of financial (equity) capital, this corresponds to maximizing the rate of return on equity. In this special case, only profit has marginal significance in the utility function. The output levels and input levels affect utility only through their effect on profit. On the other hand, if managers have favored inputs that they prefer to employ more intensively, such as staff or core deposits, say, because larger staffs convey prestige or permit more careful credit evaluation and loan

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[1] The "price", p_π , facilitates stating the homogeneity conditions: a proportional variation in p_π implies the same variation in p_π so homogeneity will be stated in terms of the latter.

monitoring, or because core deposits reduce liquidity risk, then arguments in the utility function other than profit have marginal significance, and managers will accept higher cost (reduced profit) for greater prestige or reduced risk.

3. Organizing Risky Production

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

$$C(\boldsymbol{y},\boldsymbol{w},n,k) = \min_{x} \boldsymbol{w}\cdot\boldsymbol{x} \quad s.t. T(\boldsymbol{x};\boldsymbol{y},n,k) \leq 0$$

minimization problem,

The optimal input levels are determined by the first-order conditions, which

$$\frac{\frac{\delta T}{\delta x_i}}{\frac{\delta T}{\delta x_j}} = \frac{w_i}{w_j}$$

equate marginal rates of substitution and input price ratios:

The standard problem of cost minimization implicitly assumes risk neutrality so that the optimal input mix must be on the boundary of the input requirement set. The boundary is, of course, the isoquant, and the input requirement set is the set of input combinations that can produce the given output vector. Any input combination on the boundary is defined as technically efficient, while the combination that satisfies (4) is termed allocatively efficient.

But managers may prefer input mixes that achieve the risk level they desire or perhaps that confer comfort or prestige. They may prefer to "overemploy" an input to

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[2]Noting that the level of financial capital may not minimize cost if bank managers are not risk neutral, Hughes and Mester (1993) proposed this cost function as a means of controlling for such deviations from the least-cost expansion path; the levels of all inputs other than financial capital are chosen to minimize cost. A technique more general than this conditional cost function is required to account for the possibility that all inputs, not just financial capital, may contribute to production risk.

reduce risk or to achieve another objective. From the managers' viewpoint, these input mixes are preferable to the least costly mixes; they lie either on the frontier of the input requirement set but are allocatively inefficient, or in the interior of the input requirement set and are technically inefficient from the viewpoint of risk neutrality. Thus, the input requirement set defines an infinite number of possible costs. One of the sets implies the globally least cost and would be chosen by someone who wishes to minimize cost and who is completely indifferent to risk. One of these input sets is the managers' *most preferred*, given their preferences that allow for objectives in addition to profit maximization. The interaction, then, of technology and generalized managerial preferences defines a *most preferred cost function*, which subsumes the standard least cost function as a special case.

4. The Most Preferred Cost Function

The most preferred (MP) cost function is derived from the solution to the managers' problem

Error! (5)

$$s.t. \quad \boldsymbol{p} \cdot \boldsymbol{y} + m - \boldsymbol{w} \cdot \boldsymbol{x} - p_\pi \pi = 0 \tag{6}$$

$$T(\boldsymbol{x};\boldsymbol{y},n,k) \leq 0 \tag{7}$$

Letting the price vector be represented by **v = (w, p,** r, p_π), the optimal production plan is defined by the solution **x (y,** n, **v,** m, k) and **(y,** n, **v,** m, k). As functions of the vectors of outputs and input prices, the input demand functions resemble the standard cost-minimizing ones. As functions of prices and income (revenue), they resemble consumers' demand functions. As functions of the tax rate on profit, they resemble neither. The profit equation reflects the optimal trade-off of profit for other objectives and will yield the MP cost function and its characterization in terms of scale and scope economies.

These input demand and profit equations are conditioned on the level of financial capital, allowing us to investigate the effect of capital level on the organization of production. The choice of financial capital will be derived in a second-stage optimization discussed below.

The expansion path defining the solution to (5)., which deviates from the standard

$$\frac{\frac{\delta T}{\delta x_i}}{\frac{\delta T}{\delta x_j}} = \frac{\lambda w_i - \frac{\delta U}{\delta x_i}}{\lambda w_j - \frac{\delta U}{\delta x_j}}$$

one, is given by

That is, the marginal rate of technical substitution equals the ratio of shadow prices. The shadow price is the market price adjusted by the marginal utility of the input (A is the Lagrangian multiplier associated with the constraint [6]). Hence, in the case of a risk-averse manager, if the marginal utility of a risky input is negative, its shadow price will be increased by the element of risk.

Error!

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

There are several notable features of the MP cost function. From (9), it is clear that the cost function is embedded in the utility-maximizing demand for profit. As will be discussed later, measures of technology such as scale and scope economies can be derived from the utility-maximizing profit equation. Second, when outputs and inputs as well as profit affect utility marginally, revenue influences cost. Not only will output-based revenue, $\mathbf{p} \cdot \mathbf{y}$, affect the optimum, so will fixed revenue, m (and fixed cost). Additionally, the tax rate the bank pays on its profit will, in general, influence the optimum. Of course, in the special case of a risk-neutral manager, only profit has marginal significance in the utility function, and revenue and tax rates will not influence cost. Finally, notice that input mixes on the interior of the input requirement sets (isoquants) can be utility-maximizing.

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

5. Deriving the MP Cost Function from the Almost Ideal Demand System

The functional forms for the utility-maximizing input demands and profit equation can be obtained from the AI Demand System. In the special case where only profit has marginal significance in the utility function, these functional forms are identical to the translog cost function and share equations. Our strategy is to adapt the expenditure function of the AI Demand System to represent generalized managerial preferences, to apply Shephard's lemma to obtain the expenditure-minimizing demand system for inputs and profit, and then to substitute the indirect utility function in the demand system to convert it into the utility-maximizing system that is to be estimated.

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

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

Error!

problem:

The solution yields the constant-utility demand functions $\mathbf{x}^u(\mathbf{y}, n, \mathbf{v}, k, U^0)$ and $\pi^u(\mathbf{y}, n, \mathbf{v}, k, U^0)$. Substituting these demand functions into (10), the expenditure function $E(\mathbf{y}, n, \mathbf{v}, k, U^0)$ is obtained. The expenditure-minimization problem (10) is dual to the utility-

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

maximization problem (5) so that E(**y**, n, **v,** k, U^0) = **p**· **y +** m. Additionally, the demand functions obtained from (5) and (10) are identically equal when the indirect utility function, V(**y**, n, **v**, m, k), derived by inverting the expenditure function, is substituted for

Error!

the utility index in the expenditure-minimizing demands:

Adapting the framework of the AI Demand System to accommodate the

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

Error!

generalized managerial preferences yields the expenditure function,

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

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

where

Hence, from (15) the indirect utility function is

$$V(\cdot) = \frac{\ln(\boldsymbol{p}\cdot\boldsymbol{y} + m) - \ln P}{\beta_0\left(\prod_i y_i^{\beta_i}\right)\left(\prod_j w_{isup}\mathrm{v}_j\right)p_\pi^\mu k^\kappa}$$

Applying Shephard's lemma to (15) to obtain the constant-utility input demand equations and profit equation and then substituting the indirect utility function (17) in these equations

$$\begin{aligned}\frac{\partial \ln E}{\partial \ln w_i} = \frac{w_i x_i}{\boldsymbol{p}\cdot\boldsymbol{y} + m} = \frac{\partial \ln P}{\partial \ln w_i} + \mathrm{v}_i[\ln(\boldsymbol{p}\cdot\boldsymbol{y} + m) - \ln P] \\ = \omega_i + \sum_s \omega_{si}\ln w_s + \varphi_{pi}\ln p + \sum_j gammasubji \ln y_j + \omega_{\pi i}\ln p_\pi \\ + \omega_{ir}\ln r + \omega_{in}\ln n + \omega_{ik}\ln k \\ + \mathrm{v}_i[\ln(\boldsymbol{p}\cdot\boldsymbol{y} + m) - \ln P]\end{aligned}$$

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

yields the utility-maximizing choice functions:

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

Symmetry requires $\alpha_{ij} = \alpha_{ji}$ and $\delta_{ij} = \delta_{ji}$ in addition to $\omega_{s\pi} = \omega_{\pi s}$. The first two symmetry conditions must be imposed in the estimation of the share equations, since the constituent coeefficients cannot be separately identified. However, the latter two symmetry conditions involve coefficients of prices that are employed by Shephard's lemma to obtain the share equations. Consequently, they appear in separate share equations and are, thus, identifiable and permit a test of symmetry when the condition is not imposed on the estimation. In summary, symmetry requires that

S(1) $\alpha_{ij} = \alpha_{ji}\ \forall$ i,j S(2) $\delta_{ij} = \delta_{ji}\ \forall$ i,j
S(3) $\omega_{s\pi} = \omega_{\pi s}\ \forall$ s S(4) $\omega_{si} = \omega_{is}\ \forall$ s,i

The input and profit share equations are homogeneous of degree zero in (**w**,**p**,r,p_π,m), which implies the following conditions:

$H(1)\ \Sigma\upsilon_j + \mu = 0$ $H(2)\ \Sigma\alpha_i + \Sigma\omega_j + \eta_\pi + \tau = 1$
$H(3)\ \Sigma_i\ \alpha_{ij} + \Sigma_t\ \varphi_{jt} + \psi_{jr} + \psi_{j\pi} = 0\ \forall\ j$ $H(4)\ \Sigma_i\ \varphi_{it} + \Sigma_s\ \omega_{st} + \omega_{tr} + \omega_{t\pi} = 0\ \forall\ t$
$H(5)\ \tau_{rr} + \Sigma_i\ \psi_{ir} + \Sigma_s\omega_{sr} + \eta_{\pi r} = 0$ $H(6)\ \Sigma_i\ \theta_{ij} + \Sigma_t\ \gamma_{jt} + \gamma_{j\pi} + \gamma_{jr} = 0\ \forall\ j$
$H(7)\ \eta_{\pi\pi} + \Sigma_i\ \psi_{i\pi} + \Sigma_s\omega_{s\pi} + \eta_{\pi r} = 0$ $H(8)\ \Sigma_i\ \psi_{in} + \Sigma_s\ \omega_{sn} + \tau_{rn} + \eta_{\pi n} = 0$
$H(9)\ \Sigma_i\ \psi_{ik} + \Sigma_s\omega_{sk} + \tau_{rk} + \eta_{\pi k} = 0$ $H(10)\ (1/2)\ [\Sigma_i\ \Sigma_j\alpha_{ij} + \Sigma_s\Sigma_t\omega_{st} + \tau_{rr} + \eta_{\pi\pi}] + \Sigma_i(\psi_{i\pi}+\psi_{ir})+\Sigma_i\Sigma_t\varphi_{it}+\Sigma_s(\omega_{sr}+ \omega_{s\pi})+ \eta_{\pi r} = 0$

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

$A(1)\ \Sigma_i\omega_i + \eta_\pi = 1$ $A(2)\ \Sigma_i\omega_{si} + \omega_{s\pi} = 0\ \forall\ s$
$A(3)\ \Sigma_i\varphi_{ji} + \psi_{j\pi} = 0\ \forall\ j$ $A(4)\ \Sigma_i\gamma_{ji} + \gamma_{j\pi} = 0\ \forall\ j$
$A(5)\ \Sigma_i\omega_{\pi i} + \eta_{\pi\pi} = 0$ $A(6)\ \Sigma_i\omega_{ir} + \eta_{\pi r} = 0$
$A(7)\ \Sigma_i\omega_{ik} + \eta_{\pi k} = 0$ $A(8)\ \Sigma_i\omega_{in} + \eta_{\pi n} = 0$
$A(9)\ \Sigma_j\upsilon_j + \mu = 0$ (which is also a homogeneity condition)

6. Managerial Objectives: Profit Maximization?

If banks maximize profits (which is equivalent to maximizing return on equity here, since financial capital is treated as exogenous), a variation in the tax rate and equivalently, in p_π (= $[1\text{-}t]^{-1}$) will not affect the bank's choice of before-tax profit. This implies that

$P(1)\ \eta_\pi = \eta_{\pi\pi} = \psi_{i\pi} = \gamma_{j\pi} = \omega_{s\pi} = \eta_{\pi r} = \eta_{\pi n} = \eta_{\pi k} = 0\ \ \forall\ \ i, j, s$

$$\frac{p_\pi\pi}{\boldsymbol{p}\grave{A}\_\_\_+\boldsymbol{m}} = \mu[\ln(\boldsymbol{p}\grave{A}\_\_\_+\boldsymbol{m}) - lnP]$$

Thus , (19) is simplified to

In addition, the revenue and risk characteristics of production represented by the output price vector will not influence the bank's cost-minimizing production plan so that

$P(2)\ \alpha_i = \alpha_{ij} = \theta_{ij} = \varphi_{is} = \psi_{i\pi} = \psi_{ir} = \psi_{in} = \psi_{ik} = 0\ \ \forall\ \ i, j, s$

Similarly, variations in m have no marginal significance for the optimal input demand **x**. Hence, the numerators, w_ix_i, of the shares (18) are unaffected by a variation in m. Instead, the variation in m solely affects profit so that $\frac{\delta p_\pi\pi}{\delta m} = 1$. Employing these results in differentiating equations (18) and (19) with respect to ln m yields the following parameter values in the case of profit maximization:

P(3)

$$\upsilon_i = \delta\left(\frac{w_i x_i}{\boldsymbol{p\grave{A}\_\_\_+m}}\right)\delta \ln m = -\frac{wSUBix_i}{\boldsymbol{p\grave{A}\_\_\_+m}}$$

Therefore, we can test for profit maximization (and cost minimization) by testing the restrictions (P1), P(2), and P(3).

Error!

$$\mu = \delta\left(\frac{p_\pi \pi}{\boldsymbol{p\grave{A}\_\_\_+m}}\right)\delta \ln m = 1 - \frac{p_\pi \pi}{\boldsymbol{p\grave{A}\_\_\_+m}}$$

Error!

$$C = p\acute{\imath}\_\_\_\_ + m - p_\pi \pi = \frac{\boldsymbol{p\grave{A}\_\_\_ + m}}{\boldsymbol{1 + \ln(p\grave{A}\_\_\_ + m) - \ln P}}$$

Substituting (21) into (18) and (22) into (19) yields,

and using (24), an expression for cost can be constructed,
Substituting (25) into (23) and (24) shows that in the *case of profit maximization*, the share equations are cost shares (and are identical to the translog cost function and corresponding share

$$\frac{w_i x_i}{C} = \frac{\delta \ln P}{\delta \ln w_i}$$

equations for inputs):

7. Deriving the Demand for Financial Capital

Conditioning the MP cost function and input demands on the level of financial capital allows us to investigate how a bank's underlying financial condition affects its production decisions.

$$-\frac{p_\pi \pi}{C} = \ln P - \ln(\boldsymbol{p\grave{A}\_\_\_ + m})$$

However, the more basic decision centers on the level of financial capital itself because, as a cushion against insolvency, this level signals the bank's tolerance for risk. Thus, the utility-maximization framework of (5) must be expanded to include a second stage where the financial capital level is determined.

The utility-maximizing demands for inputs and profit derived from (5) are conditioned on the level of financial capital, k. It id straightforward to add a second stage to the maximization problem to determine the bank's choice of capital. Writing the Lagrangian function for (5) and evaluating it at the first-stage optimum, conditional on k, one obtains the conditional indirect

Error!

utility function:

The demand for financial capital follows from maximizing (28) with respect to k. Using the definition from (2) that then $p_\pi \pi = p_\pi[\frac{r \bullet g(s) \bullet k}{pSUBÀ!\_\_+\pi}]$, and differentiating (28) with respect to k

$$\frac{\partial V(\cdot)}{\partial k} = \frac{\partial U(\cdot)}{\partial k} - \lambda(\bullet)\frac{p_\pi[r \bullet g(s) + rk\frac{\partial g(s)}{\partial k}]}{p_\pi} + \gamma(\bullet)\frac{\delta T(\bullet)}{\delta k} = 0$$

yields the first-order condition:

The solution to (29) is the demand for financial capital, k(**y**,n,**v**,m).

The AI system's conditional indirect utility function (17) implies that this first-order

$$990 \qquad 990\frac{\partial V(\cdot)}{\partial k} = \frac{\partial V(\cdot)}{\partial \ln k}\frac{\partial \ln k}{\partial k}$$

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

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

condition is

Not surprisingly, the demand for financial capital follows readily from the parameters of the conditional system of input demands (18) and profit (19) and, thus, constitutes additional parameter restrictions.

The output vector can be made endogenous in an analogous fashion; however, a simpler system can be derived by eliminating the portion of the two-stage problem that results from conditioning the utility maximization on the output vector. This modified procedure is developed in Hughes, Lang, Mester, and Moon (1993).

In the special case of profit maximization, variations in m should not affect the optimal demand for capital so that another restriction is added to (P3) above:

[3]If the regulatory capital constraint were binding on banks, changes in m would not affect even a

(P3) $\kappa = 0$.

8. Deriving Scale Economies from the MP Cost Function

Scale economies are defined by the inverse of the elasticity of cost with respect to output. Using the definition of the MP cost function (9) and substituting the utility-maximizing demand for financial capital into (9), the degree of scale economies is given by

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

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

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

The final expression in (31) is stated in terms of derivatives of the profit share equation (19).

9. The Data

The AI Demand System is estimated using data on U.S. banks that reported at least \$1 billion in assets as of the last quarter of 1988. The data are taken from the Consolidated Reports of Condition and Income for the fourth quarters of 1989 and 1990. Banks in unit-banking states and special-purpose banks chartered under Delaware's, Financial Center Development Act and Consumer Credit Bank Act are excluded from the sample. A total of 286 banks, ranging in size from \$1.025 billion to \$69.612 billion, are included in the data set. The data are summarized in tables 1 and 2.

We specify five outputs, each measured as the average dollar amount in the fourth quarters of 1989 and 1990: y_1, real estate loans, including commercial as well as noncommercial, y_2, commercial and industrial loans, lease financing receivables, and agricultural loans; y_3, loans to individuals for household, family, and other personal expenditures; y_4, other loans (such as loans

non-risk-neutral bank's demand for capital. But in our sample, and in general, the capital constraint is not binding.

for purchasing and carrying securities, unplanned overdrafts to deposit accounts, loans to nonprofit institutions, and loans to individuals for investment purposes); and y_5, securities, assets in trading accounts, federal funds sold, securities purchased under agreements to resell, and total investment securities.

Financial capital, k, is the average amount of equity capital, loan-loss reserves, and subordinated debt in 1990. In addition to financial capital, five other inputs are incorporated into the model: x_1, labor, whose price, w_1, is measured by salaries and benefits paid in 1990 divided by the average number of employees in 1990; x_2, physical capital, whose price, w_2, is proxied by the ratio of occupancy expense in 1990 to the average dollar value of net bank premises in 1990; x_3, insured deposits, whose price, w_3, is the ratio of interest paid in 1990 on deposits under $100,000, net of service charges received by the bank, to the average amount of interest-bearing deposits net of CDs over$100,000; x_4, other borrowed money, whose price, w_4, is the ratio of the total expense of federal funds purchased, securities sold under agreement to repurchase, obligations to the U.S. Treasury, and other borrowed money in 1990 to the average amount of these funds in 1990; and x_5, uninsured deposits, whose price, w_5, is the ratio of the interest expense in 1990 of deposits greater than $100,000 to the average amount of those deposits.

Although some formulations have assumed that deposits are outputs, Hughes and Mester (1993) derived a test for determining whether deposits are inputs or outputs. Using a data set very similar to the one here, they concluded that *insured and uninsured deposits are inputs*. We treat them as inputs here as well.

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

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

The variable, m, is measured by the amount of noninterest income received in 1990. Revenue is the sum, $\mathbf{p}\cdot\mathbf{y}$ + m, and accounting profit is $\mathbf{p}\cdot\mathbf{y} + m - \mathbf{w}\cdot\mathbf{x}$. The risks of the production plan ($\mathbf{y}$, $\mathbf{x}$, k) are suggested by the risk premia found in the output prices, $\mathbf{p}$, by nonperforming loans, n, and by realized profit. The nature of these risks is dictated by the position the bank has chosen on the risk-return frontier. Note that actual or realized profit may be quite different from the expected profit that motivated the production plan. Hence, rather than measure revenue by actual earnings, we use *potential revenue* as a proxy for expected revenue. *Potential revenue* is the revenue that would be earned if all assets performed (that is, accrued interest). Since $\mathbf{p}$ measures the average interest rates on accruing assets and $\mathbf{y}$ includes all assets, accruing and nonaccruing, the product $\mathbf{p}\cdot\mathbf{y}$ captures *potential interest income*; total potential income is $\mathbf{p}\cdot\mathbf{y}$ + m; and *potential profit* is $\mathbf{p}\cdot\mathbf{y} + m - \mathbf{w}\cdot\mathbf{x}$.

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[4] Hughes and Mester (1993) show that when deposits are inputs (outputs), variable costs (i.e., the cost of all nondeposit inputs) will be decreasing (increasing) in the level of deposits.

Banks pay both federal and state taxes on their income. The federal tax rates are similar for all banks in the data set. Thus, the main variation comes from the state tax component of p,. The state tax rates are obtained for each state from *The Book of the States*, published by the Council of State Governments, and from *Significant Aspects of Fiscal Federalism*, published by the U.S. Advisory Commission on Intergovernmental Relations.

10. Estimation

The system to be estimated consists of the share equations, (18) and (19), given the definition of ln P found in (16), and the first-order condition (30), which defines the level of capitalization. Because a cross-section is employed, there is no variation in the risk-free interest rate, r, so it is dropped from the estimating equations. However, its parameters can be recovered by using the homogeneity conditions.

To reduce the number of parameters to be estimated, the vector of output returns **p**

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

is reduced to its weighted average

$$\begin{aligned}
\ln P = {} & \alpha_0 + \alpha_p \ln p + \sum_i \delta_i \ln y_i + \sum_i \omega_j \ln wsubj + \eta_\pi \ln p_\pi + + ' \ln n + \rho \ln k + \frac{1}{2}\alpha_{pp}(\ln p)^2 \\
& + 1oversm2 \sum_i \sum_j \delta_{ij} \ln y_i \ln y_j + \frac{1}{2}\sum_s \sum_t \omega_{st} \ln w_s \ln w_t + \frac{1}{2}\eta_{\pi\pi}(\ln p_\pi)^2 + \frac{1}{2}'_{nn}(\ln n)^2 \\
& + \frac{1}{2}\rho_{kk}(\ln k)^2 + \sum_j \theta_{pj} \ln p \ln y_j + \sum_s \varphi_{ps} \ln p \ln w_s + \psi_{p\pi} \ln p \ln p_\pi + \psi_{pn} \ln p \ln n \\
& + \psi_{pk} \ln p \ln k + \sum_j \sum_s \gamma_{js} \ln ysubj \ln w_s + \sum_j \gamma_{j\pi} \ln y_j \ln p_\pi + \sum_j \gamma_{jn} \ln y_j \ln n \\
& + \sum_j \gamma_{jk} \ln y_j \ln k + \frac{1}{2}\sum_s \omega_{s\pi} \ln w_s \ln psubpi + \frac{1}{2}\sum_s \omega_{\pi s} \ln p_\pi \ln w_s + \sum_s \omega_{sn} \ln \omega_s \ln n \\
& + \sum_s \omega_{sk} \ln \omega_s \ln k + \eta_{\pi n} \ln p_\pi \ln n + \eta_{\pi k} \ln psubpi \ln k + '_{nk} \ln n \ln k
\end{aligned}$$

The result of these amendments to ln P is the following:

The amended share equations are:

$$420\frac{\partial \ln E}{\partial \ln w_i} = \frac{w_i x_i}{\boldsymbol{p}\cdot\boldsymbol{y} + m} = \frac{\partial \ln P}{\partial \ln w_i} + \text{v}_i[\ln(\boldsymbol{p}\cdot\boldsymbol{y} + m) - \ln P]$$

420 $$= \omega_i + \sum_s \omega_{si} \ln w_s + \varphi_{pi} \ln p + sumfromj \gamma_{ji} \ln y_j + \omega_{\pi i} \ln p_\pi + \omega_{in} \ln n + \omega_{ik} \ln k + \text{v}_i[\ln(\boldsymbol{p}\cdot\boldsymbol{y} + m) - \ln P]$$

$$\rho + \rho_{kk} \ln k + \psi_{pk} \ln p + \sum_j \gamma_{jk} \ln y_j + \sum_s \omega_{sk} \ln \omega_s + \eta_{\pi k} \ln p_\pi k + \upsilon_{nk} \ln n + \kappa[\ln(\boldsymbol{p}\bullet\boldsymbol{y} + m) - \ln P] = 0$$

The first-order condition defining the bank’s optimal capital level is estimated as

The symmetry conditions are given above. Condition (S1) becomes moot once (32) is imposed. We impose (S2) in the estimation, but do not impose (S3) and (S4) so that these conditions can be tested. The homogeneity conditions (amended, since we are

$$\frac{\partial \ln E}{\partial \ln p_\pi} = \frac{p_\pi \pi}{\boldsymbol{p}\cdot\boldsymbol{y} + m} = \frac{\partial \ln P}{\partial \ln p_\pi} + \mu[\ln(boldp\cdot\boldsymbol{y} + m) - \ln P]$$
$$= \eta_\pi + \eta_{\pi\pi} \ln p_\pi + \psi_{p\pi} \ln p + \sum_j \gamma_{j\pi} \ln y_j + \sum_s \omega_{s\pi} \ln w_s + \eta_{\pi n} \ln n + \eta_{\pi k} \ln k + \mu[\ln(\boldsymbol{p}\cdot\boldsymbol{y} + m) - \ln P]$$

using the weighted average of the p_is) are used to recover the coefficients on variables involving the risk-free rate in (15). These homogeneity conditions are (H1), as given above, plus the following:

H(2') $\alpha_p + \Sigma\omega_j + \eta_\pi + \tau = 1$ H(3') $\alpha_{pp} + \Sigma_t\, \varphi_{pt} + \psi_{pr} + \psi_{p\pi} = 0$

H(4') $\varphi_{pt} + \Sigma_s\, \omega_{st} + \omega_{tr} + \omega_{\pi t} = 0\ \forall\ t$ H(5') $\tau_{rr} + \Sigma_i\, \psi_{pr} + \Sigma_s\omega_{sr} + \eta_{\pi r} = 0$

H(6') $\theta_{pj} + \Sigma_t\, \gamma_{jt} + \gamma_{j\pi} + \gamma_{jr} = 0\ \forall\ j$ H(7') $\eta_{\pi\pi} + \psi_{p\pi} + \Sigma_s\omega_{s\pi} + \eta_{\pi r} = 0$

H(8') $\psi_{pn} + \Sigma_s\, \omega_{sn} + \tau_{rn} + \eta_{\pi n} = 0$ H(9') $\psi_{pk} + \Sigma_s\omega_{sk} + \tau_{rk} + \eta_{\pi k} = 0$

H(10') $(½)[\alpha_{pp} + \Sigma_s\Sigma_t\omega_{st} + \tau_{rr} + \eta_{\pi\pi}] + \Sigma_t\varphi_{pt} + \Sigma_s(\omega_{sr} + \omega_{s\pi}) + \psi_{p\pi} + \psi_{pr} + \eta_{\pi r} = 0$

The adding-up conditions are (A1), (A2), (A4), (A5), (A7), (A8), and (A9) as given above, plus the amended condition:

A(3') $\Sigma_i\varphi_{pi} + \psi_{p\pi} = 0\ \forall\ j$ [Note that (A6) is dropped.]

The amended conditions for risk neutrality are then:

P(1') $\eta_\pi = \eta_{\pi\pi} = \psi_{p\pi} = \gamma_{j\pi} = \omega_{s\pi} == \eta_{\pi n} = \eta_{\pi k} = 0 \;\; \forall$ j, s

P(2') $\alpha_p = \alpha_{pp} = \theta_{pj} = \varphi_{ps} = \psi_{p\pi} = \psi_{pn} = \psi_{pk} = \psi_{ik} = 0 \;\; \forall$ j, s

and, omitting the restrictions on υ_j and μ, since testing whether they hold is not feasible,

P(3') $\kappa = 0$

We use nonlinear two-stage least squares to estimate the following system of non-linear simultaneous equations [subject to the parameter restrictions (A1)-(A2), (A3'), (A4)-(A5), (A7)-

$$f_t(y_t, n_t, v_t, m_t \mid \Theta) \equiv \begin{bmatrix} s_{1t} - (r.h.s.\ of\ (34)\ with\ i = 1) \\ s_{2t} - (r.h.s.\ of\ (34)\ with\ i = 2) \\ s_{3t} - (r.h.s.\ of\ (34)\ with\ i = 3) \\ s_{4t} - (r.h.s.\ of\ (34)\ with\ i = 4) \\ s_{\pi t} - (r.h.s.\ of\ (35)) \\ l.h.s.\ of\ (36) \end{bmatrix} = \boldsymbol{u_t}$$

(A9), and (S2)]:

where r.h.s. designates the right hand side of the indicated equation and l.h.s. the left hand side; t is the bank index, ranging from 1 to T; s_{it} is the i-th input's revenue share at the t-th bank, i.e., $s_{it} \equiv \frac{w_{it} x_{it}}{\boldsymbol{p_t}} \bullet \boldsymbol{y_t} + m_t$ for i = 1 ... 5; $s_{\pi t}$ is the profit share at the t-th bank, i.e., $s_{\pi t} \equiv \frac{p_{\pi t} \pi_t}{\boldsymbol{p_t}} \bullet \boldsymbol{y_t} + m_t$; $\mathbf{u_t}$ are i.i.d. over t with the cross-equation covariance matrix **Σ;** and **Θ** is the set of all identifiable parameters excluding those in **Σ.** The standard errors and t-statistics we report are based on the asymptotic covariance matrix of the estimate of **Θ**, which penalizes for not using cross-equation dependence (see Gallant [1977]). The contemporaneously correlated error terms $\mathbf{u_t}$ reflect optimization errors (i.e., errors in utility minimization).

11. The Empirical Findings

The parameter estimates are reported in table 3. To check for model adequacy, we used a Wald test to test the 15 symmetry conditions, (S3) and (S4). The value of the test statistic was 39.70, implying a p-value of 0.05%. Thus, these symmetry conditions are rejected, and the results reported below are based on the estimation in which they are not imposed. (In general, the results are qualitatively similar whether the symmetry conditions are imposed or not.)

There are four striking primary findings. First, risk neutrality, or equivalently, cost minimization is conclusively rejected. Second, the measure of scale economies is larger than that found by most studies, which assume cost minimization. Third, the measure of scale economies increases with bank size, which is consistent with the wave of mergers among large banks. Last, banks with higher capital levels or higher levels of nonperforming loans rely less on volatile funding sources.

11.1. **Risk Neutrality**

We used a Wald test to test the 31 restrictions (PI'), (P2'), and (P3') implied bv risk neutrality or profit maximization. The value of the test statistic was 294.01 with 29 degrees of freedom. Two of the restrictions are redundant because of the adding-up conditions that these parameters satisfy. Thus, the restrictions are strongly rejected, indicating that banks in the sample are not behaving in a risk-neutral manner.

11.2. Scale Economies Measured by Other Studies

The many translog bank cost studies in the literature differ in the following ways: (1) how inputs and outputs are defined and, hence, how cost is constituted, (2) whether financial capital is ignored or included as a conditioning argument or included as an element of cost, and (3) whether an average practice cost function or best practice cost frontier is estimated. All of these differences might be expected to yield a variety of scale estimates, however, the estimates are quite similar. Most studies of large banks (whose assets surpass $1 billion) find either slight scale economies or slight diseconomies, and they usually find that scale economies decrease with bank size.

Treating non-interest-bearing deposits as a quasi-fixed input while characterizing the other inputs and outputs as we do here, Noulas, Ray, and Miller (1990) examine large banks in 1986 and find that scale economies decrease from 1.02 for the smallest banks ($1-3 billion) to 0.97 for the largest banks ($10 billion plus). In a similar study that differs primarily in controlling for the number of branches, Hunter and Timme (1991) find that in 1986 scale economies range from 1.123 for the smallest group ($1-1.5 billion) to 0.950 for the largest group ($25 billion plus). When they omit branches, the measures drop to values very close to those of Noulas, Ray, and Miller: 1.037 for the smallest banks to 0.977 for the largest banks.

Berger and Humphrey (1991) calculate scale economies using a thick frontier and find mild diseconomies, 0.98, for banks with $1-2 billion in assets, decreasing to 0.97 for banks with more

[5] We also computed the test statistic after removing (P3'), the restriction related to m. The value of this test statistic was 52.83 with 28 degrees of freedom. Again, profit maxzation is rejected with a p-value of 0.003077.

[6] To maintain consistency with our measure of scale economies in (31), the discussion below transforms published measures of scale economies so that *values greater than 1 imply scale economies, while values less than one imply diseconomies*.

than $10 billion in assets. When they use a conventional approach, the range drops to 0.96 for the smallest banks and 0.94 for the largest banks.

Two other studies find approximately constant returns to scale overall but much wider ranges in scale economies. Hunter, Timme, and Yang (1990) obtain values ranging from 1.09 for the smallest banks ($1-1.5 billion) to 0.90 for the largest ($25 billion plus) using 1986 data. Excluding interest payments from cost, Evanoff and Israilevich (1991) find measures ranging from 1.11 at $0.72 billion to 0.76 at $30 billion.

McAllister and McManus (1993) apply nonparametric estimation to 1984-90 data and find increasing returns to scale up to $0.5 billion and constant returns from $0.5-10 billion, the largest bank in their sample. Using 1988 data on all banks with more than $1 billion in assets, Pulley and Braunstein (1992) report an average measure ranging from 1.04 to 1.06 depending on the estimation procedure. Evanoff, Israilevich, and Merris (1990) estimate a shadow cost function to account for regulatory distortions from 1972 through 1987 and obtain values of 1.07 for multibank holding companies and 1.10 for one-bank holding companies.

Studies that find scale economies increasing with bank size are rare. Mester (1992) defines outputs to capture the information producing and information processing role of banks and, using 1988 data, finds slight scale economies that increase with bank size. Banks in the smallest group ($1-1.5 billion) exhibit slight economies, 1.0305, and this increases to 1.0426 for banks in the largest group ($5 billion plus). Clark (1996), who examines the period from 1988 through 1991, treats core deposits as outputs and estimates a thick frontier. He finds economies of around 1.05 for the smallest banks (up to $4 billion) and constant returns in all larger size categories (the largest of which is $20 billion plus in assets).

11.3. Scale Economies Measured Without Imposing Risk Neutrality

These studies all assume cost minimization. When sources of risk are included in the structural model of production and when cost minimization is not imposed, scale economies are much larger, as shown in Table 4 and Figure I. These larger economies are more consistent with the explanations given by bank managers for the recent wave of large bank mergers. The measures range from an average of 1.101 in the smallest asset-size quartile, 1.128 in the second quartile, 1.146 in the third, and 1.208 in the fourth. All are strongly significantly different from one. In addition to being larger than those found in previous studies, the measures also increase with bank asset size, contrary to most previous studies.

If incorporating sources of risk and allowing for non-neutrality toward risk has revealed economies previously hidden, imposing neutrality on this model should yield the more commonly

[7] Some of the difference, but not all, is due to our not imposing the symmetry conditions (S3) and (S4). When these conditions are imposed, the scale estimates range from 1.036 in the smallest quartile to 1.120 in the largest. While smaller than the estimates when symmetry is not imposed, they are still on the high side of estimates found in previous studies.

found magnitudes. When we drop financial capital and nonperforming loans and impose the coefficient values implied by risk neutrality, so that the resulting functional form is identical to the standard translog cost function and share equations used in previous studies, we find that the estimated scale measures are all significantly different from one but are considerably smaller and remarkably familiar: ranging from 1.022 for the smallest quartile, 1.029 for the second quartile, 1.035 for the third, and 1.050 for the fourth. These values are surprising only in that they increase in magnitude with asset size.

Since there is no simple difference between the MP cost function and the risk-neutral formulation, it is difficult to determine what leads to the larger scale measures. However, we gain some insight by examining the model of Hughes and Mester (1995) that allows for non-neutrality only in the choice of capital level. They estimate a cost function conditioned on the level of financial capital to allow for the possibility that banks may choose a higher capital level than the cost-minimizing one to reduce their risk of insolvency. The bank's capital choice is derived from utility maximization so that banks can accept higher costs in exchange for greater safety. But this formulation is not as general as the one used here, since it imposes risk neutrality on the choice of inputs other than financial capital. Nevertheless, the estimated demand for financial capital indicates that banks in all four asset-size quartiles are not risk neutral, and the resulting scale economies are in the 1.13 to 1.15 range across the quartiles, much larger than models that impose risk neutrality completely.

11.4. Other Results

Table 4 shows that for banks of all sizes, capital level, k, and volatile funding, x_4, are inversely related. Thus, banks with higher capital are less likely to rely on volatile sources to fund their assets. It appears that banks choosing lower insolvency risk also choose lower liquidity risk. And in all size quartiles except the smallest, the higher a bank's level of nonperforming loans, n, which is an ex post measure of asset quality, the less it relies on volatile funding sources. Because nonperforming loans are likely to be less liquid than other assets, these banks may prefer more stable funding sources. To the extent that the prices of some of the components of volatile funding include a risk premium, this may also be a cost-reducing strategy, since the risk premium is likely to be higher for banks with poor loan quality.

Table 4 also reports that, for the smallest banks, the most preferred level of capital responds positively to the level of nonperforming loans. These banks may be acting to protect their solvency from the *ex post* realization of poor loan quality by increasing their capitalization. Table 4 also indicates that financial capital, k, and the average return on asset, p, are inversely related (although not significantly so). Lower quality assets have an *ex ante* higher return, but this return is a gamble. Our results suggest that the greater the gamble, that is, the higher p is, the lower the amount of financial capital, k, that is bet.

12. Conclusions

When financial intermediation is studied, risk cannot be ignored. Whether managers are risk neutral or risk averse, it is important to control for sources of risk so that the potentially cost-saving effects of scale-related diversification can be identified. But, equally important, allowance must be made for non-neutral risk preferences.

This paper has developed a theoretical model which amends the standard framework to allow for non-neutral risk preferences. While our approach provides a theoretically consistent method for addressing non-neutral risk preferences, our amendments to the standard framework add obvious complexity to the model. However, the importance of incorporating sources of risk and non-neutrality toward risk into models of production can be confirmed only by comparing the empirical adequacy of explanations that incorporate risk with those that abstract from it.

The most preferred cost function we develop in this paper seems to explain important production phenomena in banking that elude approaches using the standard cost function. Most notably, our approach reveals large scale economies, while previous studies that assumed risk neutrality found only small scale economies or constant returns to scale. Our results may be useful in explaining the economics behind the recent wave of mergers among very large banks. Our findings are consistent with the rationale frequently cited by participants in these mergers who argue that significant cost savings can be achieved by enlarging the scale of operations.

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Table 1: Summary Statistics of the Data

variable	sample mean	sample std. dev.	minimum	maximum
y_1†	1490521.75	2739095.05	1038.50	26541000.00
y_2†	1606152.95	3114969.78	15956.00	23962500.00
y_3†	672172.08	1070269.29	8762.50	11781500.00
y_4†	470269.42	1486811	713.00	11868570.50
y_5†	1326574.19	2232463.87	13549.50	20454834.50
p_1‡	0.109	0.017	0.026	0.205
p_2‡	0.107	0.02	0.022	0.187
p_3‡	0.123	0.027	0.028	0.279
p_4‡	0.085	0.065	0.001	0.533
p_5‡	0.088	0.014	0.055	0.174
p‡	0.104	0.011	0.064	0.161
w_1¶	33.092	9.857	18.140	92.178
w_2‡	0.396	0.178	0.116	1.378
w_3‡	0.06	0.009	0.028	0.108
w_4‡	0.087	0.033	0.039	0.350
w_5‡	0.081	0.017	0.027	0.233
$\tilde{p}$‡	1.664	0.112	1.515	1.871
s_1	0.146	0.041	0.043	0.309
s_2	0.05	0.018	0.011	0.141
s_3	0.277	0.095	0.01	0.542
s_4	0.101	0.076	0.004	0.469
s_5	0.314	0.128	0.109	1.208
s_π	0.337	0.071	0.122	0.749
$p_\pi \pi$†	223763.03	360436.38	17125.04	3116164.55
$\mathbf{p.y}$+m†	667979.16	1020863.51	90000.55	8419110.74
n†	157495.47	387914.46	1254.00	3629843.00
k†	561765.95	1069979.99	69516.50	8787000.00
m†	124239.66	277310.33	488.00	2060000.00
total assets†	5865120.40	8037258.81	1025143.00	69611500.00

†in thousands of dollars ‡in dollars per dollar ¶in thousands of dollars per employee

y_1 = real estate loans; y_2 = C & I loans; y_3 = loans to individuals; y_4 = other loans (to purchase accounts; p_i = price of output i; $\tilde{p}$ = weighted average of output prices; w_1 = price of labor; w_2 = (repos, fed funds purchased, etc); w_5 = price of uninsured deposits; p_π = price of real, after tax profit; s_i = share of input i; s_π = profit share; $p_\pi \pi$ = nominal, before-tax accounting profit; **p.y**+m = expected revenue; n = nonperforming loans; k = financial capital; m = noninterest income.

Table 2: Means of the Variables by Asset-Size Quartiles

variable	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
y_1†	357760.68	657490.28	1281000.08	3680519.81
y_2†	249271.21	467700.81	952710.22	4780167.5
y_3†	188318.96	326874.65	639945.94	1538866.02
y_4†	32843.49	80126.14	157397.63	1620612.07
y_5†	325200.96	552054.45	964296.82	3480755.74
p_1‡	0.108	0.111	0.112	0.105
p_2‡	0.115	0.106	0.109	0.098
p_3‡	0.124	0.119	0.125	0.125
p_4‡	0.083	0.095	0.082	0.082
p_5‡	0.086	0.085	0.086	0.093
p‡	0.105	0.103	0.105	0.101
w_1¶	29.372	30.886	33.052	39.09
w_2‡	0.382	0.387	0.393	0.421
w_3‡	0.06	0.06	0.059	0.06
w_4‡	0.08	0.08	0.086	0.102
w_5‡	0.08	0.081	0.084	0.081
$\tilde{p}$‡	1.651	1.662	1.669	1.675
s_1	0.141	0.144	0.144	0.157
s_2	0.047	0.05	0.048	0.053
s_3	0.316	0.309	0.271	0.211
s_4	0.072	0.072	0.107	0.155
s_5	0.289	0.293	0.297	0.376
s_π	0.333	0.337	0.342	0.337
$p_\pi \pi$†	47708.37	84558.38	169048.99	596467.64
p.y+m†	140029.89	249238.77	489462.14	1801597.91
n†	18162.45	49266.1	84958.04	480141.3
k†	106021.51	187606.21	359011.36	1602550.27
m†	18240.58	33365.32	68254.24	379166.96
total assets†	1335138.53	2393107.19	4607230.76	15191623.49

†in thousands of dollars ‡in dollars per dollar ¶in thousands of dollars per employee

y_1 = real estate loans; y_2 = C & I loans; y_3 = loans to individuals; y_4 = other loans (to purchase accounts; p_i = price of output i; $\tilde{p}$ = weighted average of output prices; w_1 = price of labor; w_2 = (repos, fed funds purchased, etc); w_5 = price of uninsured deposits; p_π = price of real, after tax **p.y**+m = expected revenue; n = nonperforming loans; k = financial capital; m = noninterest income.

Table 3: Coefficient Estimates

parameter	estimate	parameter	estimate	parameter	estimate
α_0	101.846 (69.98)	α_p	24.576* (14.92)	δ_1	0.199 (2.00)
δ_2	-0.683 (1.99)	δ_3	-2.199 (1.74)	δ_4	3.045* (1.68)
δ_5	-0.705 (2.00)	ω_1	-2.857* (1.56)	ω_2	-1.235 (0.76)
ω_3	-7.345 (5.23)	ω_4	8.667 (5.32)	ω_5	-1.187 (1.23)
η_π	4.958* (3.00)	υ	-0.342 (1.33)	ρ	-0.979 (0.62)
δ_{11}	0.08 (0.08)	δ_{12}	0.147* (0.08)	δ_{13}	-0.065 (0.04)
δ_{14}	0.006 (0.04)	δ_{15}	-0.024 (0.07)	δ_{22}	0.088 (0.07)
δ_{23}	0.163** (0.08)	δ_{24}	0.001 (0.04)	δ_{25}	-0.117 (0.08)
δ_{33}	0.025 (0.06)	δ_{34}	-0.022 (0.03)	δ_{35}	0.015 (0.05)
δ_{44}	0.045** (0.02)	δ_{45}	0.008 (0.04)	δ_{55}	0.00007 (0.11)
α_{pp}	2.128 (2.93)	ω_{11}	0.131*** (0.04)	ω_{12}	0.040** (0.02)
ω_{13}	0.088 (0.10)	ω_{14}	-0.155 (0.10)	ω_{15}	0.025 (0.03)
ω_{21}	0.022 (0.02)	ω_{22}	0.019** (0.01)	ω_{23}	0.061 (0.05)
ω_{24}	-0.066 (0.05)	ω_{25}	0.019 (0.01)	ω_{31}	0.104 (0.09)
ω_{32}	0.05 (0.05)	ω_{33}	0.786** (0.33)	ω_{34}	-0.523 (0.33)
ω_{35}	-0.021 (0.07)	ω_{41}	-0.179* (0.09)	ω_{42}	0.077* (0.05)
ω_{43}	-0.595* (0.31)	ω_{44}	0.667** (0.32)	ω_{45}	-0.117 (0.08)
ω_{51}	0.018 (0.02)	ω_{52}	0.004 (0.01)	ω_{53}	0.082 (0.08)
ω_{54}	-0.091 (0.08)	ω_{55}	0.074*** (0.03)	υ_{nn}	0.112* (0.07)

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Table 3 continued

parameter	estimate	parameter	estimate	parameter	estimate
ρ_{kk}	0.012** (0.01)	θ_{p1}	-0.524 (0.50)	θ_{p2}	0.019 (0.61)
θ_{p3}	-0.192 (0.36)	θ_{p4}	0.816* (0.46)	θ_{p5}	-0.901 (0.56)
$\psi_{p\pi}$	0.625 (0.51)	φ_{p1}	-0.268 (0.26)	φ_{p2}	-0.127 (0.12)
φ_{p3}	-0.993 (0.93)	φ_{p4}	0.740 (0.95)	φ_{p5}	-0.037 (0.17)
ψ_{pn}	-0.036 (0.44)	ψ_{pk}	-0.065 (0.10)	$\gamma_{1\pi}$	-0.036 (0.08)
$\gamma_{2\pi}$	-0.060 (0.07)	$\gamma_{3\pi}$	-0.015 (0.06)	$\gamma_{4\pi}$	0.051 (0.04)
$\gamma_{5\pi}$	-0.048 (0.08)	γ_{11}	0.009 (0.04)	γ_{12}	0.005 (0.02)
γ_{13}	0.042 (0.14)	γ_{14}	-0.030 (0.15)	γ_{15}	0.009 (0.02)
γ_{21}	0.024 (0.04)	γ_{22}	0.009 (0.02)	γ_{23}	0.114 (0.13)
γ_{24}	-0.119 (0.14)	γ_{25}	0.032 (0.03)	γ_{31}	0.022 (0.03)
γ_{32}	0.009 (0.01)	γ_{33}	0.073 (0.11)	γ_{34}	-0.068 (0.11)
γ_{35}	-0.020 (0.02)	γ_{41}	-0.023 (0.02)	γ_{42}	-0.011 (0.01)
γ_{43}	-0.104 (0.08)	γ_{44}	0.103 (0.08)	γ_{45}	-0.016 (0.02)
γ_{51}	0.018 (0.04)	γ_{52}	0.007 (0.02)	γ_{53}	0.047 (0.15)
γ_{54}	-0.030 (0.15)	γ_{55}	0.006 (0.02)	γ_{1n}	0.077 (0.06)
γ_{2n}	0.003 (0.06)	γ_{3n}	-0.031 (0.04)	γ_{4n}	-0.066* (0.04)
γ_{5n}	0.004 (0.06)	γ_{1k}	0.000 (0.02)	γ_{2k}	0.011 (0.01)
γ_{3k}	0.006 (0.01)	γ_{4k}	-0.009 (0.01)	γ_{5k}	0.007 (0.02)
ω_{1n}	-0.030 (0.03)	ω_{2n}	-0.009 (0.01)	ω_{3n}	-0.083 (0.10)
ω_{4n}	0.090 (0.10)	ω_{5n}	-0.012 (0.02)	$\omega_{1\pi}$	-0.130** -0.060

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Table 3 continued

parameter	estimate	parameter	estimate	parameter	estimate
$\omega_{2\pi}$	-0.055* (0.03)	$\omega_{3\pi}$	0000.395** (0.19)	$\omega_{4\pi}$	0000.302* (0.18)
$\omega_{5\pi}$	-0.087* (0.05)	$\omega_{\pi 1}$	-0.064 (0.07)	$\omega_{\pi 2}$	-0.036 (0.03)
$\omega_{\pi 3}$	-0.474** (0.19)	$\omega_{\pi 4}$	0.368** (0.18)	$\omega_{\pi 5}$	-0.099 (0.08)
$\eta_{\pi n}$	0.045 (0.06)	$\eta_{\pi k}$	-0.009 (0.02)	$\eta_{\pi\pi}$	0.306** (0.14)
ω_{1k}	0.023 (0.01)	ω_{2k}	0.009 (0.01)	ω_{3k}	0.033 (0.04)
ω_{4k}	-0.075** (0.04)	ω_{5k}	0.019 (0.01)	υ_{nk}	-0.010 (0.01)
v_1	-0.034** (0.01)	v_2	-0.015** (0.01)	v_3	0.123*** (0.04)
v_4	0.126*** (0.04)	v_5	-0.019 (0.01)	μ	0.065*** (0.02)
κ	0.013*** (0.005)				

Table 4: Scale Economies and Other Elasticities