SUBSIDIZED INDUSTRIES, MANAGERIAL EFFORT
AND X-INEFFICIENCY

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Abstract

This paper develops a simple model of managerial behavior, and uses it to explore the relationship between subsidy policy, managerial effort, and X-inefficiency. The model helps to clarify several of the arguments previously advanced concerning X-inefficiency costs of protection and industrial concentration. The model is tested using cross-section data from a survey of firms in two subsidized industries in Ghana. Efficiency indices are computed on the basis of a Cobb-Douglas type frontier production function. Variations in relative efficiency are then correlated with several explanatory variables including the presence of subsidy payments to the firm. Subsidized firms in both industries are found to exhibit higher relative levels of X-inefficiency.
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A growing empirical literature has developed concerning the X-inefficiency costs of protection and industrial concentration in developing countries. Balassa (1975) and Bergsman (1974), for example, have argued that protection, by increasing X-inefficiency, generates a major welfare cost which is not captured by traditional costs of protection calculations, and White (1976) has examined the relationship between inappropriate factor intensities which he associates with X-inefficiency and industrial concentration. The common theme which emerges from each of these studies is that public policy can have a major impact on economic performance not only by influencing factor proportions, but also by influencing the intensity with which a non-measurable input, X-efficiency, is employed.

This paper develops a simple model of managerial behavior, and uses it to explore the relationship between subsidy policy, managerial effort, and X-inefficiency. The model helps to clarify several of the arguments previously advanced concerning X-inefficiency costs of protection and industrial concentration.

The model is tested using cross-section data from a survey of firms in two subsidized industries in Ghana. Efficiency indices are computed
on the basis of a Cobb-Douglas type frontier production function. Variations in relative efficiency are then correlated with several explanatory variables including the presence of subsidy payments to the firm. Subsidized firms in both industries are found to exhibit higher relative levels of X-inefficiency.

1. Managerial Effort and X-Inefficiency

A major problem with any empirical test for the presence of X-inefficiency arises from the ambiguity of the concept itself. Leibenstein (1966) does not give a concise definition of X-inefficiency, and, as a result, the concept has been subject to differing interpretations. What emerges from the literature appears to be a consensus that X-inefficiency, if it exists, involves the failure of firms to produce at the outer bound of their production surface, and that this failure is related to the allocation of effort. Leibenstein states:

"...when an input is not used effectively, the difference between actual output and the maximum output attributable to that input is a measure of the degree of X-inefficiency." and argues "that effort, ..., becomes a significant discretionary variable under X-efficiency theory."  

For our analysis of the X-efficiency effects of public policies, we have chosen to focus solely on the effort-leisure decision of managers. Although Leibenstein stresses the interactive nature of effort decisions by all productive agents, labor, management and owners, the dimensions in which managers can act to improve or diminish the efficiency of the firm are substantial. Reductions in managerial effort may take the form of decreased supervision of the production process, inattention to input costs,
reduced application of technical knowledge, or choice of inappropriate techniques. Laborers' effort decisions, particularly in the simple production processes characteristic of many manufacturing industries in the developing countries, generally relate only to the pace of work, and perhaps to the quality of effort. Managers, through intensive supervision, should be able to modify the effort behavior of workers. Indeed, in discussing the role of X-efficiency in economic development Leibenstein argues that "innovative entrepreneurs who have the capacity to start firms or reorganize existing firms, which reduces the level of X-inefficiency, are likely to be the ones to contribute significantly to economic development", and that "managers determine not only their own productivity but also the productivity of all cooperating units in the organization."\(^4\)

Our model focuses on the allocation of effort to the management of an enterprise under several possible structures of the market for managerial services. Each firm is assumed to have an entrepreneur (owner-manager) who maximizes a twice differentiable, strictly concave utility function:

\[
U = U(\pi, N) \tag{1}
\]

where \(\pi\) is the amount of net managerial income (profits) and \(N\) represents the amount of non-labor time (leisure) of the owner-manager.\(^6\)

Output is a function of a well behaved twice differentiable, strictly concave production function of the form:

\[
Q = \gamma(E, I)F(Z) \tag{2}
\]

where \(E\) is the total input of managerial effort supplied to the firm (both
by the owner-manager and hired management), I represents a predetermined
stock of technical information available to the management of the firm,
and \( z \) is a vector of the prices and quantities of other inputs which, for
analytical convenience, we shall assume to be exogenously determined.\(^7\)
Managerial effort and technical information are assumed to augment produc-
tion in a Hicks neutral fashion such that \( \frac{\partial y}{\partial x} > 0; \frac{\partial f}{\partial x}, \frac{\partial f}{\partial x} = 0 \)
and \( \frac{\partial^2 y}{\partial x^2}, \frac{\partial^2 y}{\partial z^2} < 0 \). Thus the level of total managerial effort and
the stock of information possessed by managers determine, for any given
endowment of other inputs the level of \( X \)-efficiency.

Total managerial effort is the sum of effort provided by the
owner manager and the net quantity of management services hired into the
firm, \( M \). Net managerial labor demand is given by:

\[
M = E - T + N
\]

(3)

where \( T \) is the total time available to the entrepreneur. Since \( M \) represents
the net demand for managerial effort it need not be positive. For firms
with sufficiently small endowments of productive factors, effort supplied
by the owner-manager may be sufficient and the firm may sell managerial
services to other enterprises.

A Perfectly Competitive Market in Managerial Services

If the firm is assumed to face an infinitely elastic supply
curve for managerial services the full income constraint for the entrepre-
neur is given by:

\[
F \cdot W_m + P \cdot y(E,z) - E \cdot W_m + A - \pi + N \cdot W_m
\]

(4)
where $w_m$ is the parametrically given managerial wage, $P$ is the price of output, and $A$ is asset income. Substituting from (3) the constraint may be rewritten as the profit function:

$$P \gamma(E,I)F(Z) - M \cdot w_m + A = \pi$$  \hspace{1cm} (5)

The Lagrangean equation for maximization of (1) subject to (5) is thus:

$$V = U(\pi, N) + \lambda[P \gamma(E,I)F(Z) - M \cdot w_m + A - \pi]$$  \hspace{1cm} (6)

Assuming interior solutions for all control variables, the first order conditions for utility maximization are:

$$I_\pi = \lambda = 0$$  \hspace{1cm} (7)

$$I_N = \lambda w_m = 0$$  \hspace{1cm} (8)

$$P \gamma(E)F(Z) - W_m = 0$$  \hspace{1cm} (9)

$$P \gamma(E,I)F(Z) - M \cdot w_m + A - \pi = 0$$  \hspace{1cm} (10)

where $U_\pi = \partial U/\partial \pi$ etc.

The first two conditions imply that the marginal value of the owner-manager's time is equal to the managerial wage rate regardless of whether the work is performed within or outside the firm. Condition (9) is a profit maximizing condition for variable input use, implying that the level of profits in the firm is independent of the manager's consumption preferences since the quantities of $E$ employed will always be those corresponding to profit maximization. Thus in the perfectly competitive model the level of $X$-efficiency is independent of the preference structure of the firm's management.
This contrasts with the X-efficiency models of Corden (1970, 1974), White (1976), and Martin (1978), in which the supply curve of managerial effort from outside the firm is assumed to be completely inelastic. In these models the entrepreneur reaches a "subjective equilibrium" which reflects his tastes and production possibilities.

Total differentiation of equations (7) - (10) yields:

\[
\begin{bmatrix}
U_{\pi} & U_{\pi N} & 0 & -1 \\
U_{N} & U_{NN} & 0 & -W_m \\
0 & 0 & P_Y & 0 \\
-1 & -W_m & 0 & 0
\end{bmatrix}
\begin{bmatrix}
d\pi \\
dN \\
dE \\
dW_m
\end{bmatrix}
= 0
\]

\[
\begin{bmatrix}
0 & 0 & P_Y F d I & - P_Y F d Z - \gamma_d dP \\
-1 & -W_m & 0 & 0
\end{bmatrix}
\begin{bmatrix}
d\lambda \\
-dW_m \\
-P_Y F d I - P_Y F d Z - \gamma_d dP - dA
\end{bmatrix}
\]

We consider first the impact of a direct transfer on the level of managerial effort and X-efficiency. The comparative static results of a lump sum subsidy, which may be represented as an increase in asset income are obtained by solving the relevant equations in (11):

\[
\frac{dE}{dA} = \frac{-D_{43}}{|D|} = 0 
\]

\[
\frac{dN}{dA} = \frac{-D_{42}}{|D|} > 0
\]

where \( |D| \) is the bordered Hessian determinant in (11) and \( D_{ij} \) is the cofactor of row \( i \) and column \( j \). Thus a lump-sum transfer in a perfectly competitive market for managerial inputs has no affect on the total input of managerial services and hence on the level of X-efficiency. The non-labor time of the owner-manager increases but this is precisely compensated
by an increase in net labor demand (an increase in hired managerial effort).

The effect of an increase in the price of output, say in response to an ad valorem tariff or output subsidy is given by:

\[
\frac{dE}{dP} = -\gamma_E F(Z) \frac{D_{33}}{|D|} \frac{D_{43}}{|D|} > 0 \quad (14)
\]

\[
\frac{dN}{dP} = -\gamma_F F(Z) \frac{D_{32}}{|D|} \frac{D_{42}}{|D|} > 0 \quad (15)
\]

An increase in the price of output is therefore compatible with both an increase in total managerial effort and with an increase in the non-labor time of the firm's owner-manager. Total effort increases as a consequence of the subsidy because at the original (pre-subsidy) production point the marginal value product of effort now exceeds the managerial wage. If the wage remains unchanged, the opportunity cost of leisure to the owner-manager is constant, and since leisure is assumed to be a normal good, he reduces his own supply of effort to the firm, compensating for the increase in net labor demand by additional hiring of managerial services.

These conditions are illustrated in Figure 1. The curve OR is the presubsidy managerial profits curve, while the slope of the ray OB measures the parametric managerial wage. The distance OT represents the time constraint on the owner manager. Because of the possibility of trade in managerial services the equilibrium production and consumption points are separate and are represented by A and C respectively.

The firm uses OH of managerial effort, made up of OG of the owner's
effort and GH of hired effort. Now we consider what happens when the firm receives protection. The tariff-distorted profits curve is OR' and the new post-tariff production and consumption points are at D and E where the "terms of trade" line $P_2$ which is parallel to OB, is tangent to both OR' and the indifference curve $I_2$.

This result has several interesting implications. First, protection leads to increased X-efficiency in line with the increase in total managerial effort in the firm. This contrasts with the Corden, Martin and White models where protection increases X-efficiency only if the substitution effect outweighs the income effect. Second, while the level of X-efficiency in the firm increases, this is compatible with a reduction in the owner-manager's effort i.e., he becomes less X-efficient. Finally, with the given parametric wage, further increases in protection which serve to raise managerial profits will result in increased managerial effort and, hence, greater X-efficiency. This is represented by the line QQ which shows the locus of all points of tangency between progressively higher tariff-distorted profit curves and the given managerial wage line.

A Variable Managerial Wage

We now proceed to relax the assumption that the firm can hire (or sell) any quantity of managerial effort at a fixed price. If there are serious informational imperfections in the managerial labor market, the wage rate may become an important recruiting tool and each firm may exercise monopsony power in the market for managerial personnel. The owner-manager thus faces a rising supply price for managerial effort which
represents the average cost (i.e. the wage) of the hired manager. The entrepreneur's optimization problem differs from the standard monopsony model in the following respect. In the latter the monopsonist's decision rule is to equate the marginal cost of hiring extra inputs with their marginal value product. In this model the monopsonist must choose how much of his own effort he supplies to the firm in addition to the optimal degree of discrimination against hired managerial effort.

The full income constraint may be written as:

$$F(Z, I) - w(M)M + A - \tau = 0.$$  \hspace{1cm} (16)

Maximization of (1) subject to (16) yields the following first order conditions for an interior solution:

$$U_\pi - \lambda = 0$$  \hspace{1cm} (17)

$$U_N - \lambda[w(M) + Mw'(M)] = 0$$  \hspace{1cm} (18)

$$F(Z) - \lambda[w(M) + Mw'(M)] = 0$$  \hspace{1cm} (19)

$$F(Z, I) - w(M)M + A - \tau = 0$$  \hspace{1cm} (20)

where \(w'(M) = \frac{\partial w}{\partial M}\). The bracketed term in equations (18) and (19) can be rewritten in the familiar form \(w(1 + 1/\epsilon_H)\), where \(\epsilon_H\) is the elasticity of supply of hired managerial effort.

Thus when the entrepreneur acts as a monopsonist in the market for managerial labor he equates the marginal rate of substitution of leisure for managerial income to the marginal cost of hiring (or the marginal return to providing) additional managerial services external to the enterprise. The
comparative static results arising from a change in asset income and the
price of output are derived from the set of differential equations obtained
by totally differentiating equations (17) - (20):

$$\begin{bmatrix}
U_{\pi} & U_{\pi N} & 0 & -1 & \vdots & d\pi \\
U_{N\pi} & [U_{NN} - U_{\pi} (2w' + w'' \cdot M)] & -U_{\pi} [2w' + w'' \cdot M] & -[w + M \cdot w'] & dN \\
0 & -U_{\pi} [2w' + w'' \cdot M] & U_{\pi} [P_{\gamma E} F(Z) - (2w' + w'' \cdot M)] & 0 & dE \\
1 & -[w + M \cdot w'] & 0 & 0 & d\lambda \\
\end{bmatrix}$$

(21)

The effects of a change in asset income on the effort supplied by
the entrepreneur and on total managerial effort are:

$$\frac{dN}{dA} = \frac{-\phi_{42}}{|\phi|} > 0 \quad (22)$$

$$\frac{dE}{dA} = \frac{-\phi_{43}}{|\phi|} < 0 \quad (23)$$

where $|\phi|$ is the bordered Hessian determinant in (21) and $\phi_{rc}$ is the cofactor
of row r and column c in $\phi$. A rise in asset income incident, say, upon a
lump sum transfer, results in an increase in the amount of non-labor time
consumed by the entrepreneur and in a decline in the total level of effort
supplied to the firm. Unlike the parametric wage case, the increase in
hired managerial services is insufficient to offset fully the reduction in
effort supplied by the owner-manager. Since the change in output is given by:

\[ \frac{\partial y(z, z')}{\partial A} = \frac{\partial y(z, z')}{\partial z} \frac{\partial z}{\partial A} < 0 \]  

output declines for the given vector of measured inputs, indicating a reduction in X-efficiency.

The result is illustrated in Figure 2. The transformation frontier or describes the maximum combinations of profits and leisure which may be produced in the firm. If there is no market in managerial services this also describes the consumption availability locus for the entrepreneur.

The presence of an imperfectly competitive market in managerial services extends the consumption availability locus for the entrepreneur outward as represented by the curve GCR. The consumption possibilities frontier is constructed by the same technique as the familiar "Baldwin Envelope" employed in international trade theory. The maximum combinations of managerial income and leisure that the entrepreneur can obtain from any given input of effort are derived by placing the origin of the offer curve for hired managerial effort at each point along the transformation curve, keeping the axes parallel, and tracing the locus of all points where the slope of the offer curve (the marginal cost of hiring managerial services) is equal to the slope of the transformation frontier (the marginal value product of managerial effort). The envelope thus defined represents the consumption possibilities frontier between income and leisure for an entrepreneur acting as a monopsonist in the market for managerial services. The equilibrium conditions of equations (17) - (20) are simultaneously met at a consumption
FIGURE 2
point such as C where the indifference curve I₁ is tangent to the envelope, and the production point, A, on the transformation curve OR, where the slope of the production possibilities frontier is equal to the slope of the common tangent to the consumption possibilities frontier and the indifference curve. The entrepreneur supplies OB of his own effort to the firm and hires BD additional units of managerial effort at a cost in terms of income forgone of AE. The slope of the line CA measures the average managerial wage.

Consider the case of a lump sum subsidy or a subsidy to a fixed input. Such a transfer shifts the managerial profits curve vertically by the amount OS, leaving its slope at each vertical section unchanged. If leisure is a normal good, the new equilibrium consumption point will lie to the left of C at a point such as C' on indifference curve I₂. The owner manager reduces his supply of effort to the firm. Moreover, the production point shifts to the left to A' as well, reducing the total amount of managerial effort supplied from hired and owner managers. X-inefficiency has increased.

Although the payment of direct subsidies is not a widespread instrument of industrial policy in developing countries, subsidy payments to fixed inputs, at least in the short run, are not uncommon. Government operated loan windows have been opened in many countries to provide investment and operating capital at less than market rates of interest. Where these loans are not explicitly tied to the purchase of new capital stock, they function in the short run as a subsidy to the fixed capital input of the firm. Similarly, exchange control regimes which permit firms to act as direct importers of intermediate inputs provide a subsidy element in the form of the quota rents. In industries characterized by limited substitution possibilities between
imported inputs and other factors of production, these quota rents will act much like a lump sum subsidy payment.

The effect of a tariff or ad valorem subsidy when the market in managerial services is imperfect is ambiguous. The partial derivatives of non-labor time and total managerial effort with respect to the price of output can be written as (25) and (26):

\[
\frac{dN}{dP} = -U_{\pi} \gamma F(Z) \frac{\phi_{32}}{\phi} - \gamma(\xi, \xi) F(Z) \frac{\phi_{42}}{\phi} \quad (25)
\]

\[
\frac{dE}{dP} = -U_{\pi} \gamma F(Z) \frac{\phi_{33}}{\phi} - \gamma(\xi, \xi) F(Z) \frac{\phi_{43}}{\phi} \quad (26)
\]

The first term in (25), representing the substitution effect, is negative for non-labor time of the entrepreneur. The rise in the marginal value product of effort devoted to his firm increases the opportunity cost of leisure time. This is offset to some extent by the income effect represented by the second term in equation (25) which is positive. Similarly, the first term in (26) is positive, the rise in price will increase the demand for total managerial effort at a constant level of real income, but this is offset by the negative income effect reflected in the second term. Thus the sign and magnitude of any X-efficiency effects of subsidies related to the price of output or an ad valorem tariff are ambiguous.

The model is useful in addressing the hypothesized relationship between competition and X-efficiency. Given reasonable competition in both product and capital markets, entrepreneurs cannot sustain higher real incomes (in terms of profits plus leisure) than their counterparts in other sectors of the economy. The higher incomes will attract additional
entrepreneurs resulting in changes in both the asset income of existing enterprises and in the prices of inputs and output. The long run relationship between competition and X-efficiency would depend, therefore, on the magnitude and sign of these income and price effects which are not unambiguously determined. If tastes are not uniform, and the new entrants exhibit greater preferences for income as opposed to leisure one might expect a positive long run relationship between X-efficiency and competition, but the relationship cannot be addressed rigorously on the basis of our model.

2. Measuring X-Inefficiency

Empirical studies reveal that within well defined industries some firms achieve greater levels of output for a given vector of measured inputs than all others. Our analysis suggests that these "best practice" firms will be characterized by the highest levels of managerial effort. Managerial effort, however, has never been measured at an acceptable level of accuracy, and it is, therefore, usually excluded from the production function. Estimated production functions will be biased by the excluded factor, and there will be an unexplained residual due to its omission. It has become customary in studies of the efficiency of production to draw inferences concerning the relative efficiency of firms from the magnitude of the residual between observed output and an efficient production surface.

Two methods have been proposed as a basis for the measurement of relative efficiency. The first consists of estimating an efficient unit isoquant in input space and employing Farrell's (1957) measure of technical efficiency. The alternative approach is to estimate an explicit parametric
frontier production function. The latter method is more easily adapted to industries in which increasing returns to scale may be present and is empirically more tractable than the former, but it involves some sacrifice of generality due to the need to specify an explicit functional form.

In the present context we have chosen to estimate a frontier production function of the Cobb-Douglas type by restricting the observed points in output-input space to lie on or below the frontier. If all firms have equal access to known technology, those observations which lie on the frontier production function obtain the highest observed levels of output for given quantities of the measured inputs. Since the level of managerial effort is an unobserved input the frontier production function represents an approximate total productivity curve for maximum managerial effort, and observations below the frontier lie on total productivity curves for lesser amounts of managerial effort. The distance of an observation from the frontier thus provides an estimate of the intensity of managerial effort, and an index of relative X-efficiency.

The frontier production function is specified as

\[ \ln V_j = \ln \hat{A} + \hat{\beta}_1 \ln L_j + \hat{\beta}_2 \ln K_j - e_j \]

where \( V_j \) is the annual level of output, \( L_j \) is the input of labor services in man hours and \( K_j \) is the input of capital services per year. The residuals, \( e_j \), are constrained to be non-negative.

Choice of an estimation procedure depends crucially on the assumptions made with regard to the distribution of the residuals. If one is willing to make sufficiently strong distributional assumptions several
procedures have been suggested for maximum likelihood estimation of the production function parameters (Richmond, 1974; Schmidt, 1976; and Aigner et al., 1978). The alternative approach, which we have adopted, is to minimize the sum of the residuals subject to the constraint that all observations lie on or below the frontier and non-negativity constraints on the estimated parameters. With this specification the estimation procedure is a simple application of linear programming (Aigner and Chu, 1968; Timmer, 1971; Forsund and Hjalmarssson, 1979b).

A firm's actual output $V_j$, given observed input levels, would be equal to predicted output $\hat{V}_j$ only if the firm operated on the production frontier. Each firm is assigned an efficiency index equal to the ratio of its actual to predicted output, $V_j/\hat{V}_j \leq 1$. The value of the index provides a measure of relative efficiency and, therefore, an index of the intensity of managerial effort and X efficiency.13

However, efficiency indices derived in this manner do not necessarily constitute an unambiguous measure of relative managerial effort. First, the residuals will contain the effects of other omitted inputs. We have explicitly assumed that firms possess equal access to known technology and that they confront the same physical environment. If technical knowledge is firm-specific, there is no basis for measuring X-efficiency relative to a single production frontier. Each firm may be equally efficient with regard to the techniques available to it. Similarly where firms face widely varying physical environments, an index of efficiency constructed from a single cross-section of firms may reflect differences in firm-specific fixed factors, rather than variations in managerial effort and efficiency. Both problems are
empirical, and depend in large measure on the characteristics of the industries under study. We shall argue that information on production techniques is widely available to firms in the two industries analyzed below, that techniques of production are of the same vintage, and that the physical environment confronted by each firm is similar.

Secondly, the residual term captures specification, aggregation, and measurement errors common to any empirical study of the production function. Since our interest centers on the extent to which the residual reflects differing amounts of managerial effort, specification errors and errors in the variables will tend to reduce the accuracy of the index as a measure of $X$-efficiency. To some extent this can be mitigated by allowing a specified proportion of the observations to lie above the frontier and observing the sensitivity of the estimated coefficients to possible outliers. This adjustment is essentially arbitrary, however, and lacks explicit economic or statistical justification.

In addition the programming approach suffers from the defect that it does not generate parameter estimates with known statistical properties.

Thus the efficiency indices derived from the frontier production function should be interpreted with some caution. They provide a measure of relative efficiency, but little is known about the frontier from which they are estimated. Nevertheless, the estimated efficiency indices will be shown below to be correlated with a number of important managerial attributes supporting the hypothesis that differences in the index among firms of similar vintage reflect in large measure variations in the degree of $X$-efficiency.
3. Subsidies and Inefficiency: Some Evidence

The preceding analysis suggests that variations in the efficiency of firms measured relative to a production frontier in observable inputs should arise in part from variations in managerial effort. Subsidies, however, will unambiguously reduce the total quantity of managerial effort supplied to the firm only if they are applied in a lump-sum fashion.

To evaluate the effect of a subsidy policy on the relative efficiency of firms it would be desirable to obtain data in which randomly selected firms were provided with a form of subsidy while otherwise identical firms were not impacted and therefore serve as a control group. A data set consisting of firm level observations from two industries in Ghana, timber extraction and sawn timber manufacturing, appears to fulfill many of the conditions for such a "natural experiment."

During the 1960's the Government of Ghana pursued industrial policies in the timber and wood-processing industries designed to promote Ghanaian ownership and to increase the variety and volume of processed lumber exports. Two organizations, the Timber Marketing Board and the Ghana Timber Cooperatives Union, were created and jointly administered a widely used instrument of subsidy policy, the Ghanaian Producers' Loan Scheme. Loans were financed by the central government and consisted of medium-term finance of both working and investment capital and direct provision of equipment to Ghanaian-owned firms.

Costs of borrowing under the producers' loan scheme equalled approximately 50 percent of costs from other sources. More importantly, because repayment terms were often ambiguous, and due to the limited ability of the Timber Cooperatives Union to enforce repayment, loans were subject to high rates
of default and became de facto grants, providing investment and working capital to Ghanaian firms at zero cost. Default on an initial loan, moreover, did not preclude receipt of supplemental funds, and many of the firms receiving loans had obtained funds and defaulted on repayment on a continuing basis.

In 1972 and 1973 a survey of firms in the logging and sawmilling industries was conducted, during the course of which firms were questioned regarding their sources of finance. Eleven of 28 respondents in the logging industry and 10 of 36 respondents in sawn timber manufacturing indicated that they had obtained loans consisting of both investment and working capital from the Timber Marketing Board during the reference year of the survey. Access to the scheme was based on the ability of the individual firm to obtain favor from the Timber Marketing Board and past performance was not one of the selection criteria employed. The nationality and political influence of the owner and to a lesser extent firm size appear to have been among the relevant criteria for selection. Thus the sample contains firms which received subsidies during the accounting year and a "control" group of similar enterprises which did not.

Data from these two industries were used to estimate relative efficiency at the firm level, and to test for the influence of the subsidy program on measured efficiency. The variables employed in the estimated equations were chosen after some experimentation during which several alternative measures of output, capital and labor were tested. The definition of output is conventional. Value added is expressed in Cedis and is defined as the ex-factory value of output net of inputs external to the firm. Labor inputs were converted to man-hours using data provided on the duration of shifts, overtime, and days worked per year. In order to adjust somewhat for differences in skill-mix between
firms, aggregation across skill categories was accomplished by taking wage
weighted unskilled labor equivalents. Capital stocks at original purchased
value, were adjusted to 1970-71 values by means of a price index reflecting
tariff, foreign price and exchange rate adjustments. The stock variables were
then converted to an annual flow on the basis of an assumed 10 percent rate
of discount and uniform economic lifetimes, and were adjusted for capacity
under-utilization using managers' estimates of the percentage of full one-shift
capacity worked during the accounting year.

Estimates of the production functions are presented in Table 1. Equations (a)
and (b) report the results of fitting the Cobb-Douglas form
using the linear programming technique. These are the frontier production
functions for each industry. Equation (a) presents parameters estimated by
fitting the frontier function to all observations in the sample. In order
to allow for the possibility of errors in the extreme observations, Equation
(b) was generated by removing five percent of the most efficient observations
from the sample of logging and sawmilling firms, and reestimating the produc-
tion function. The estimated parameters remain quite stable after the
exclusion of possible outliers.

Average production functions, estimated by ordinary least squares, are
presented as Equation (c). Statistical comparison of the parameters of the
average function with the frontier is not possible, but examination of the
output elasticities of both estimates is suggestive of the relationship between
"best-practice" and average firms. Frontier firms in both industries achieve
substantially greater productivity of capital than average firms, indicating
that technical efficiency is apparently capital augmenting.17
Table 1--Frontier and Average Production Functions for Two Industries in Ghana*

<table>
<thead>
<tr>
<th>Method</th>
<th>Intercept</th>
<th>Capital</th>
<th>Labor</th>
<th>$R^{-2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logging 1.1a</td>
<td>LP$_{100}$</td>
<td>0.000</td>
<td>0.569</td>
<td>0.509</td>
</tr>
<tr>
<td>1.1b</td>
<td>LP$_{95}$</td>
<td>0.000</td>
<td>0.543</td>
<td>0.528</td>
</tr>
<tr>
<td>1.1c</td>
<td>OLS</td>
<td>-0.506</td>
<td>0.384</td>
<td>0.698</td>
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<tr>
<td></td>
<td></td>
<td>(3.44)</td>
<td>(3.09)</td>
<td>(5.93)</td>
</tr>
<tr>
<td>Sawmilling 1.2a</td>
<td>LP$_{100}$</td>
<td>0.000</td>
<td>0.727</td>
<td>0.408</td>
</tr>
<tr>
<td>1.2b</td>
<td>LP$_{95}$</td>
<td>0.000</td>
<td>0.762</td>
<td>0.383</td>
</tr>
<tr>
<td>1.2c</td>
<td>OLS</td>
<td>-0.654</td>
<td>0.471</td>
<td>0.610</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.82)</td>
<td>(3.47)</td>
<td>(4.44)</td>
</tr>
</tbody>
</table>

*t-values are in parentheses.
The frontier production functions of equations 1a and 2a were used to generate an index of technical efficiency for each firm. The (unweighted) mean index for each industry and data on its range and variability are presented in Table 2. Both industries appear to be relatively efficient. Actual output for the representative firm is more than 70 percent of predicted output on the basis of the frontier production function, but there are substantial variations in the firm-specific indices of technical efficiency.

In Section 1 we demonstrated that in the absence of a perfectly competitive market for managerial services, subsidy payments which take the form of lump-sum transfers should reduce the total quantity of managerial effort supplied to the firm and, hence, reduce the level of X-efficiency. Let us, therefore, propose the following testable hypothesis: within our sample of firms those enterprises receiving loans administered through the Timber Marketing Board or the Timber Cooperatives Union should exhibit lower levels of technical efficiency relative to the industry frontier.

We have noted that those loans were regarded de facto as grants by recipients. Ideally, the clearest test of the hypothesis would be to compare efficiency indices for the same firms before and after the introduction of the subsidy. Such data are unavailable, however, and the proposition will be tested using cross-section data. The maintained hypothesis is that firms receiving loans from the central government will exhibit lower indices of technical efficiency than similar firms not so affected. Because relative efficiency, as we have defined and estimated it, is a function of both managerial effort and the level of managerial competence, variations in the stock of information available to entrepreneurs and in the level of experience of managers
Table 2

The efficiency index for two industries in Ghana

<table>
<thead>
<tr>
<th>Industry</th>
<th>Mean Index</th>
<th>Coefficient of Variation</th>
<th>Minimum Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logging Production</td>
<td>0.707</td>
<td>22.57</td>
<td>0.407</td>
</tr>
<tr>
<td>Sawn Timber Manufacturing</td>
<td>0.710</td>
<td>26.62</td>
<td>0.237</td>
</tr>
</tbody>
</table>
will be reflected in the estimated efficiency indices. To control for these variations several variables were drawn from the record of the sample survey as measures of managerial training and experience.

Table 3 reports the results of the most successful attempts to explain variations in relative efficiency. The dependent variable in each equation is the index of technical efficiency which is bounded above at unity with efficient observations concentrated at the bound. These properties imply that the Tobit estimation procedure would be more appropriate than ordinary least squares, and the results of both estimates are presented in Table 3.

Two variables were introduced into the regressions as proxies for the stock of information available to the firm. First, a dummy variable, DED, with the value of unity was assigned to those firms in which the managers had neither prior industry experience nor formal education in logging and wood processing techniques. Twenty-five percent of the firms in the logging sample and twenty-eight percent of the firms in the sawmilling sample were classified in this category. Use of the single dummy variable is predicated on the assumption that to a great extent education and experience are substitutable in the "production" of technical efficiency. For the two industries under study this seems a reasonable assumption. The production technology in logging and sawn timber manufacturing is relatively simple and industry experience in production should be sufficient to acquaint management personnel with the technical characteristics of the industry. The coefficient of the dummy variable representing lack of prior training or experience is significant and negative in all regressions. Lower levels of managerial training imply lower measured technical efficiency.

Second, because expatriate managers are distributed quite widely among
Table 3: Determinants of Technical Efficiency
OLS and TOBIT Regression Coefficients

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>LOGGING</th>
<th>SAWMILLING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OLS</td>
<td>TOBIT</td>
</tr>
<tr>
<td>SUBS</td>
<td>-.149</td>
<td>-.148</td>
</tr>
<tr>
<td>DED</td>
<td>-.119</td>
<td>-.120</td>
</tr>
<tr>
<td>EXRA</td>
<td>.056</td>
<td>.066</td>
</tr>
<tr>
<td>YEARS</td>
<td>-.026</td>
<td>-.026</td>
</tr>
<tr>
<td>YEARSQ</td>
<td>.001</td>
<td>.001</td>
</tr>
<tr>
<td>CORP</td>
<td>-.047</td>
<td>-.044</td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>.893</td>
<td>.895</td>
</tr>
</tbody>
</table>

R²: .504
F: 5.57
OBS: 28

Asymptotic t-values in parentheses

SUBS: recipient of loan (=1)
DED: absence of formal training or industry experience (=1)
EXRA: percentage of expatriates in management staff
YEARS: registered age of enterprise in years
YEARSQ: years squared
CORP: non owner-managed firm (=1)
the various ownership categories of firms, and because they generally embody higher levels of technical training, the nationality of the management staff may provide an additional proxy for the level of information available to the firm. When the ratio of expatriate managers to total managers, EXRA, is included in the regressions reported in Table 3 its coefficient is positive but not significant. Higher proportions of expatriates in management do not appear to increase the level of technical efficiency. 19

The age of the enterprise, YEARS, was included in the analysis as a test for the presence of learning by doing. The expectation was that the sign of the estimated coefficient would be positive. It is reasonable to expect, however, that there will be decreasing returns to experience beyond some age of the enterprise. In order to incorporate this type of decrease in the effectiveness of experience into our specification we have included the square of the age of the enterprise, YEARSQ, in the estimating equations with the expectation that the sign of its coefficient will be negative.

The results for the sawmilling industry appear to support the learning by doing hypothesis. The coefficients of YEARS are significant and positive, while the coefficients of YEARSQ are significant and negative. The magnitudes of the coefficients imply that a 1 year increase in the age of the enterprise initially increases the efficiency index by approximately .03, but after only 7.5 years further increases in age are completely ineffective.

The results for the logging industry do not conform to prior expectations. The coefficient for age of enterprise is negative and significant while that for the squared term is positive. A straightforward interpretation would suggest that in the logging industry several vintages of "plant" may coexist
embodying different levels of absolute efficiency. Older firms tend to be
dominated by newer ones and, thus, show lower efficiency relative to the single
industry frontier. This is plausible and may account for some of the signifi-
cance of the variable, but the nature of the industry also suggests another
explanation. Firms may extract timber from their most productive concession
areas during the early years of operations. Thus the age of enter-
prise variable may be capturing the effects of declining input quality on
measured efficiency rather than experience.

A final qualification applies to the interpretation of the results
for both industries. Age of establishment data is an imperfect proxy for
experience, particularly in our sample where the age of the firm is determined
from the registration date of the enterprise. Several firms in the sample
had changed registered ownership at least once without major changes in manage-
ment; the variable is therefore, at best, an imperfect indicator of total
managerial experience.

The results strongly support the hypothesis that subsidies reduce the
level of relative technical efficiency of recipient firms. The dichotomous
variable SUBS which takes on a value of one for firms receiving government loans
has a negative and significant coefficient in all regressions. In the sawmilling
industry in particular the presence of subsidy payments to the firm gives rise
to substantial reductions in relative technical efficiency. Subsidized firms
are less X-efficient for given levels of information and managerial competence
than their non-subsidized counterparts.

Our model is framed in terms of an owner-managed enterprise, although
we have argued that it has broader application to corporately managed firms with
similar managerial objectives. The great majority of observations in our sample consisted of owner-managed enterprises - 23 of 28 observations in the logging industry and 29 of 36 observations in sawn timber manufacturing - but as a check on this specification, a dummy variable, CORP, with a value of unity for corporately managed enterprises was introduced into the analysis. Estimates of its coefficient values are not significant, and the relationship between the subsidy variable and the efficiency index is not affected. Within our sample the corporate organization of the enterprise apparently has no impact on relative efficiency.

4. Conclusions

Our model of managerial choice represents a synthesis and extension of a family of "neoclassical" models of X-efficiency. X-efficient behavior at the level of the enterprise was shown to depend not only upon the effort-income preferences of the entrepreneur, as hypothesized in previous studies, but also, in the presence of a market for managerial services, upon the characteristics of that market. Within the context of our model there is only one form of commercial policy which will give rise to unambiguously negative X-efficiency effects, and that is a lump-sum transfer. Even in this case, if the market for managerial services is perfectly competitive, the effort effect of the transfer is zero.

The empirical results appear to support the hypothesis that public subsidies to private enterprise can have an adverse effect on economic performance. Subsidized firms in both industries were found to exhibit significantly lower levels of efficiency measured relative to a frontier production function
in quantifiable inputs. Our analysis suggests that these observed differences in measured efficiency arise from decreases in the supply of an unmeasurable input, managerial effort, to the firm. Public policies designed to alter output and input prices or to promote the development of "desirable" enterprises through direct grants can engender economic costs by allowing managers to indulge their preferences for a quiet life, leading to a reduction in X-efficiency.

Throughout the paper we have focused our attention on the positive effects of subsidy policy on X-efficiency. The welfare costs to the economy of an increase in leisure on the part of managers will only equal the resource cost imposed by the decline in X-efficiency if society attributes zero valuation to the increase in managerial leisure. At the opposite extreme, if the social and private valuation of leisure are equal, the welfare loss associated with a reduction in X-efficiency is zero.²⁰

The results in Section 3 also support the growing body of evidence which suggests that managerial efficiency is an important determinant of economic performance in LDCs. The importance of educational levels as an explanatory variable in the efficiency index regressions would appear to have important implications for the desired pattern of management education and for screening criteria for industrial promotion schemes. The apparent significance of technical education and training in explaining variations in technical efficiency suggests that resources directed toward improved schemes of technical training for managers of existing firms would yield potential gains in terms of reduced costs of production under existing techniques.
Footnotes

1. White uses a model similar in some respects to ours, although he does not allow for the hiring of managerial services from outside the firm, and he makes the implicit assumption that the income effect of a positive price change will outweigh the substitution effect. For further discussion of this point see Martin (1978).


3. The focus on the effort-leisure tradeoff of managers is common to much of the literature on X-efficiency. Martin (1978) has subjected this class of models to a critical review in both partial and general equilibrium.


6. The assumption of an owner-manager is made both on grounds of analytical simplicity and also because such firms are more common in developing countries. However, the basic model can also describe a "managerial" firm where the managers control the firm not the shareholders. Simply assume that the managers possess a utility function which is analogous to (1) above. They can also manage the firm to satisfy their own preference function subject to achieving some minimum profit constraint which keeps the shareholders content and avoids take-over bids.

7. Recent empirical studies have focused attention on the role of technical information in determining the relative technical efficiency of firms. See for example Shapiro and Muller (1977) and Page (1979). The assumption that measurable inputs are predetermined is analytically convenient but can be relaxed without altering the results.

8. One of the second order conditions for maximization of (6) is that the determinant of this system, |D|, be negative.

9. This assumption is not uncommon. See for example Phelps (1970). Alternatively we could assume that managers receive a parametric wage but differ in ability. The entrepreneur thus faces a rising supply price of efficiency units of managerial effort.

10. In order for the Hessian determinant in (21) to satisfy the second order conditions for a maximum we shall require \( \frac{\partial^2 \pi}{\partial M^2} > 0 \) and \( \frac{\partial^2 \pi}{\partial M^4} < 0 \).

11. As drawn the envelope curve implies that net managerial labour demand (M) is always positive as this is the relevant case for our purposes. However, the theoretical model does not rule out values of \( M < 0 \). In that event, the geometric
construction would be exactly symmetric with the standard "Baldwin envelope." Sliding the offer curve around the transformation frontier would first trace out the region of the envelope where M is positive. At one point the envelope curve will be tangent to the transformation curve (i.e., M=0) and, as M becomes negative, the entrepreneur will be selling managerial services to other firms.

12 See for example Farrell (1957), Timmer (1971), Carlsson (1972), Meller (1976), or Forsund and Hjalmarsson (1979 a, b).

13 Forsund and Hjalmarsson (1979a) p. 312, argue for example, "some differences in efficiency were explained by the modernity of equipment while others were explained by more or less skillfull management (degree of X efficiency)." They do not, however, attempt to test the X-efficiency hypothesis.

14 It is common to appeal to errors in variables as justification for the probabilistic frontier approach. See for example Timmer (1971) and the criticisms of the method in Aigner, Lovell, and Schmidt (1977).

15 Discussion of the survey and variable definitions may be found in Page (1979).

16 Use of value added presented some problems in the logging industry where differential resource-based rents are reflected in the unit value of output. These rents, unless the output measure is adjusted accordingly, will become part of measured efficiency. The approach adopted was to standardize value added by taking the product of the firm's volume of physical output and the national average price per cubic foot of timber.

17 The non-neutral relationship between the frontier and average functions may reflect biases in the OLS estimates. Simultaneous equation bias will tend to bias the coefficient of the predetermined variable, capital, downward. Further, it is possible that there is a positive relationship between capital intensity and technical inefficiency. Thus it is possible that management bias in the OLS regression may also act to reduce the estimated output elasticity of capital. On the management bias problem see Timmer (1970). Richmond (1974) has proposed a technique to use the OLS residuals to estimate technical efficiency. Use of the OLS residuals provides an upward biased estimate of the average efficiency level. Relative rankings of firms by each method are highly correlated. Spearman's rank correlation coefficients for the two sets of residuals are .858, and .935, for logging and sawmilling respectively. Both are significant at the .01 level or above.

18 Contrast for example the results in Meller (1976) or Carlsson (1972).

19 There is, however, a strongly collinear relationship between age of the enterprise and EXPAT.

20 See Martin (1978, pp. 281-282) for several arguments that an increase in X-inefficiency may involve welfare costs to society even if the social valuation of additional managerial leisure is non-zero.
References


