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Measures of capacity realisation and productivity growth for Bangladesh food processing industries

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Key to symbols used in tables

n.a.	Not applicable
..	Not available
-	Zero
.	Insignificant

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Abstract

This paper evaluates the performance of firms in the Bangladesh food processing industries in terms of their productive capacity realisation and total factor growth. Using the random coefficient frontier production function is used for this purpose, the total factor productivity growth is decomposed into a change in productive capacity realisation and technical progress. Empirical results show that there is some technological progress in a number of the food processing industries, however, the overall poor performance of this sector is due to the low capacity realisation of many individual firms, even after the implementation of economic reforms. The results also show that output growth in recent years was mainly due to input growth.

measures of capacity realisation and productivity growth for Bangladesh food processing industries

The productivity improvement of firms is the key to sustained economic growth. The growth of the food processing sector is particularly important to Bangladesh as this is one of the important industries in terms of its contribution to total manufacturing production and employment. For example, it is second only to textiles in terms of the value of output and employment, accounting for 25 per cent of total industrial output and 16 per cent of total manufacturing employment in 1990/91 (BBS 1995). Empirical studies (Little et al. 1970; Steel 1972; Bautista et al. 1981; Rahman 1983) in Bangladesh and elsewhere show that manufacturing firms worked with a high degree of unrealised productive capacity due to the excessive controls of the protective regimes in the 1960s and 1970s. It is expected that recent liberalisation programs will encourage firms to eliminate excess capacity and improve productivity growth. The extent of capacity realisation of firms and the productivity performance of key industries such as food processing, however, have hardly been studied in Bangladesh. The absence of quantitative research on capacity realisation and productivity growth is surprising, since as a poor resource-based economy, Bangladesh can no longer afford to hold unrealised capacity and recent reforms have put an emphasis on productivity gains rather than, as in past, the injection of new inputs into the production process. This study attempts to estimate capacity realisation indexes and decompose the total factor productivity growth into the change in capacity realisation and technical progress, using firm-level data from Bangladesh food processing industries.

While productive capacity realisation is defined as the ability and willingness of any production unit to produce the maximum possible output from a given supply of inputs and production technology, total factor productivity growth, on the other hand, measures the output growth that is not accounted for by the growth of inputs. Actually, total factor productivity growth stems from the combined results of technical progress and changes in productive capacity realisation.[1] Technical progress comes from innovation and the diffusion of new technology. The extent of technical progress is measured by how much the firm's potential frontier shifts overtime. A change in capacity realisation, on the other hand, shows the movement of the firm's actual output to its maximum possible output or frontier output, given the technology. Traditional measures, however, do not distinguish between these two components of total factor productivity growth, rather total factor productivity growth is often used synonymously with technological progress (Nishimizu and Page 1982).

Failure to take account of changes in capacity realisation in measuring total factor productivity growth produces biased estimates. Although it is argued that measuring changes in total factor productivity is an appropriate way to gauge the impact of reform on firms' performance, biased estimates of total factor productivity lead to incorrect conclusions. The aim of this paper is to suggest a model for estimating productive capacity realisation and its relationship to total factor productivity growth. This method can be used without knowing the details of economic reform measures; the combined effect of all reforms is represented in the model by random variables which are ultimately captured by the varying coefficients of the production frontier.

The paper is organised as follows. The second section summarises the literature and is followed by an outline of the theoretical arguments and analytical framework followed in this paper. The model specification and estimation procedures are given in the fourth section, which is followed by a discussion of the sources of output growth and the decomposition of total factor productivity growth. Data and empirical estimations are given next and policy implications are explained.

Review of earlier works

There have been few empirical studies undertaken in Bangladesh to measure firms' performance indicators such as capacity realisation, technical efficiency or total factor productivity growth. Ahmad (1973) estimated capacity realisation indices for the jute industries using the traditional time-based approach. He found substantial unrealised productive capacity in the jute manufacturing industries. Following the same methodology, Afroz and Roy (1976) found that the jute, sugar and ship building industries realised about 70 per cent, 58 per cent and 59 per cent respectively of their productive capacities during 1975. Using the shift measure approach, Islam (1978) also found substantial unrealised productive capacity in Bangladesh manufacturing. All these studies are now outdated.

One recent study, Rahman 1994, estimated capacity realisation for the whole manufacturing sector using the trend-through-peaks method. He found that the capacity realisation index varied from 83 per cent to 100 per cent over the period 1972/73 to 1988/89. His findings are, however, upward biased since the trend-through-peaks method underestimates potential output. The Bangladesh Fourth Five Year Plan (1991-95) reported sectoral capacity realisation indexes for manufacturing industries. Capacity realisation across sectors ranged from 60 per cent to 80 per cent. The Bangladesh-Canada Agriculture Sector Team (1991) estimated a capacity realisation index using firm-level data from the food processing sector and found that capacity realised varies from 16 per cent to 56 per cent across firms. Another study of the food processing sector conducted by the International Labour Organisation (ILO) (1991) found that 70 per cent of enterprises realised less than 50 per cent of their productive capacity; another 20 per cent realised 51 per cent to 60 per cent and only 10 per cent realised 61 per cent to 80 per cent of their production capacity.

Very few studies have examined the impact of economic reforms on the performance of the manufacturing sector. Using a deterministic frontier production function, Krishna and Sahota (1991) computed technical efficiency and productivity growth for 30 industries covering the period 1974/75 to 1985/86. Their findings are striking—most of their sample firms were producing at less than 50 per cent of their productive efficiency. They also found that 15 out of 30 industries experienced no significant improvement (that is, technical efficiency and total factor productivity growth stagnated) in technical efficiency and total factor productivity growth, while five of their sample industries experienced an acceleration in total factor productivity. The remaining 15 industries suffered deceleration in total factor productivity during the sample period.

Using the conventional growth accounting approach to firm level data Sahota et al. (1991) measured total factor productivity in a number of manufacturing industries covering the period 1974/75 to 1985/86. They found that total factor productivity declined in most of the enterprises during the sample period and no systematic evidence of positive impact of economic reforms on total factor productivity growth. The Harvard Institute of International Development (HIID) and Employment and Small Scale Enterprise Policy Planning (ESEPP) project of the Bangladesh Planning Commission (1988; 1990a) calculated total factor productivity indices for a large number of industries, both at the firm level and four digit industry levels for the period 1975/76 to 1983/84. The overall results show that only about 35 per cent of manufacturing firms experienced a positive cumulative total factor productivity growth over the entire sample period.

The findings of the HIID/ESEPP study are summarised in Table 1, showing the percentage of industries experiencing positive annual and cumulated total factor productivity growth in the consumer, capital and intermediate goods industries. The capital goods sector performed well in terms of total factor productivity growth (Table 1). While 50 per cent of industries in this sector had positive total factor productivity growth in 1975/76, this figure increased to 53 per cent in 1981/82. Over the sample period, 56 per cent of industries in this sector enjoyed cumulated positive total factor productivity growth. The performance of industries in the other two sectors deteriorated over the years. About 30 per cent of consumer and intermediate goods industries experienced cumulative positive total factor productivity growth. Overall, only 35 per cent of industries in the manufacturing sector enjoyed cumulative positive total factor productivity growth. While it is argued that the most protected industries enjoy the highest total factor productivity growth, the evidence, shows that only 31 per cent of consumer goods industries—receiving highest protection in Bangladesh—experienced positive total factor productivity growth. Various studies within the HIID/ESEPP project have investigated the relationship between economic policy reforms (in terms of incentive structures) and manufacturing value added growth and total factor productivity growth (HIID/ESEPP 1990b; 1990c). However, these studies reported no significant relationship.

Table 1 **Annual and cumulated total factor productivity growth in selected manufacturing sectors, 1975/76–1983/84**

				Capital goods	
	No. of inds.	38	27	14	79
1975/76	total factor productivity +ve	18	14	7	39
	Percentage	47	52	50	49
	No. of inds.	47	39	15	101
1981/82	total factor productivity +ve	17	15	8	40
	Percentage	36	38	53	40
1975/76-	No. of inds.	48	43	16	107
1983/84	total factor productivity +ve	15	13	9	37
	Percentage	31	30	56	35

Source: The Harvard Institute of International Development and Employment and Small Scale Enterprise Policy Planning Project of the Bangladesh Planning Commission (1988; 1990a).

Although these studies contributed much to the understanding of Bangladesh food manufacturing, their results suffered from the several shortcomings. First, most earlier studies adopted traditional approaches to capacity measurement which were not based on well defined economic theories. Therefore, their results were incomplete and led to ambiguous conclusions. Second, these studies were done using highly aggregated data and therefore, ignored firm-specific characteristics which are important from the productivity point of view.

Third, the few studies which have estimated total factor productivity growth have not distinguished between the two components of total factor productivity growth. Technical progress measures the impact of new technology through shifting the production function. Under normal economic conditions, it should be non-negative. Improvements in capacity realisation or technical efficiency, on the other hand, measure firms' abilities to improve production with the given inputs and existing technology. So, it is not possible to conclude from the earlier studies whether changes in total factor productivity were caused by technological progress or improvements in firm-specific capacity realisation.

Fourth, the results of those studies which used the deterministic approach to measure technical efficiency and total factor productivity growth are sensitive to the outliers. These results are, therefore, unreliable due to errors in measurement and modelling. Finally, in most of these studies total factor productivity indices were measured on the assumption that all firms were producing at full productive capacity or productive efficiency, which is not realistic.

In the light of the above limitations of the earlier studies, an appropriate and more reliable measure of productive capacity realisation and total factor productivity growth is required to analyse firms' performance, particularly how they responded to policy changes.

Theoretical arguments and analytical framework

In recent years, productive capacity realisation measures have been estimated by conventional approaches. The econometric approach of measuring of productive capacity realisation has been used increasingly in the last decade (Kim and Kwon 1977; Harris and Taylor 1985; Nelson 1989a, 1989b; Berndt and Morrison 1981; Morrison 1985, 1988; Berndt and Hesse 1986; Segerson and Squares 1990, 1993, 1995). Though these measures either follow the neoclassical theory of the cost function or production function in empirical research, they are usually estimated by allowing the functions to pass through the mean of the data set which provides average output and not the theoretically determined maximum possible output or the minimum cost. So the indexes of productive capacity realisation are either overestimated or underestimated for some of the observations.

There are three further potential limitations of the cost function approach. First, cost functions presume continuous adjustments of the factor mix to minimise cost (Tybout and Westbrook 1995). For various reasons, such as institutional barriers, the adjustment of factor mix may be delayed. So using the cost function to measure productive capacity realisation indices may not give accurate results. Second, cost functions require output and factor price data; simultaneity between output and the error term is a problem with cost functions (Tybout and Westbrook 1995). Similarly, measurement error in factor prices or output can bias the cost function estimates. Third, data on cost and factor prices may not be available for developing economies, or, even if available, may be distorted. So, reliable estimates of productive capacity realisation indices can not be expected using a distorted cost function.

Fare, Grosskopf and Kokkelenberg (1989) developed a method of measuring plant capacity realisation based on Farrell's (1957) measure of output-based technical efficiency by following a nonparametric linear programming approach. However, measurement errors in output cannot be taken into account in the programming approach. This limitation can be serious when using secondary data from developing economies where the method of data collection may not be very accurate.[2]

The framework used in this paper is also based on Farrell's work, but applies the random coefficient frontier production function approach. Our analysis is consistent with the definition of capacity and realisation. Capacity is measured here from observed inputs and output; based on the best practice performance of all firms in the sample. This analysis is also helpful to gauge the performance of firms operating under different production environments.

Defining capacity realisation

In neoclassical economics, a production function shows the maximum output that can be obtained from a given input set. The input/output relation can be written as

$$y_i^* = f(x_i) \qquad (1)$$

where y_i^* is the maximum possible output that can be obtained from the utilisation of the input set x_i. However, the maximum possible output may vary among firms and over time for a firm. Therefore, the maximum possible of the ith firm can be redefined as

$$y_i^* = f(x_i)\exp^{(v_i)} \qquad (2)$$

where v_i is a stochastic error term which is expected to captures 'noises' beyond the firm's control such as luck, weather condition, and unperfected variation in machine or labour performance that cause the firm's output to vary around some mean level. It is assumed that v_i is normally distributed with mean zero and variance σ^2 (i.e. $v_i \sim N(0, \sigma^2)$). Estimation of equation (2) by the ordinary least squares (OLS) method provides only the average output not the maximum output. Further, the above relation (2) is true only if the firm is producing by realising its full productive capacity, that is, the firm is producing on its frontier. In reality this is not true. Besides prices, a firm's behaviour is also influenced by non-price and organisational factors such as government policies and institutional factors. For these reasons, a firm may not realise 100 per cent productive capacity. For example, in Bangladesh, complex bureaucratic procedures, excessive controls, 'soft-budget' constraints, lack of information about modern techniques of production and slow and arbitrary government decisions about state-owned enterprises could all cause firms to operate below their frontiers. It is very difficult to model the influence of each one of these factors separately on firms' output. Nevertheless, one can incorporate the combined effects of all of the non-price and institutional factors on firms' output by modifying equation (2) in the following way.

$$y_i = f(x_i)\exp^{(v_i - u_i)} \qquad (3)$$

where y_i is the realised output from the input level x_i and u_i is a non-negative random variable, which represents the combined effects of all non-price and institutional factors. Known as the stochastic production frontier model in the literature, it was independently introduced by Aigner, Lovell and Schmidt (1977), Meeusen and van den Broeck (1977) and Battese and Corra (1977) to estimate firm-level productive efficiency.

The specification of the above model implies that firms could produce potential output if and only if u_i equals zero which means that reform policies are fully successful in improving firms' productive capacity realisation. As firms cannot produce more than a theoretically possible level of output, the above model is consistent with economic theory, unlike the conventional OLS production function approach. The greater the value of u_i, the further the firm is from its production frontier. If the reform measures are successful, firms will be able to realise more of their productive capacities.

So, the firm-specific capacity realisation can be defined as

$$\text{PCR} = (\exp^{-u}i) = \frac{y_i \ (given\ u_i \geq o)}{y_i^* \ (given\ u_i = o)} \qquad (4)$$

where PCR is firm-specific productive capacity realisation, y_i is the realised output and y_i^* is the potential output evaluated at the input level x_i.

Random coefficient model and capacity realisation

Though the above stochastic frontier production function approach is an improvement over the traditional production function, the following arguments can be levelled against it.

The stochastic frontier production function approach implicitly assumes that the production frontier shifts in such a way that the marginal rate of technical substitution at any input combination remains unchanged. This is referred to as neutral shift of production function in the literature. In practice, this is not true. Although firms may use the same levels of inputs with a given technology, the method of application of inputs may vary across firms. To elaborate, equal amounts of labour and capital in a particular production process may yield different levels of output from different firms due to variations in technical progress, labour efficiency and managerial ability.

Similarly, there is no reason to believe that the recent economic reforms would influence each firm’s production behaviour equally. So different levels of output are obtained by different production agents, despite using the same set of inputs. In other words, firms’ maximum output varies regardless of input levels. Hence, the conventional varying intercept, but fixed slope production frontier, may not be appropriate for measuring a firm’s performance, particularly in measuring firm-specific capacity realisation, (Kalirajan and Obwona 1994; Salim and Kalirajan 1995). Rather, one should allow the slope coefficients to vary in the production function to take into account the different output responses to input.

In the current frontier production function literature, especially with cross-section data, it has been necessary to arbitrarily impose a particular distribution for the firm-specific performance related error term u_i. Schmidt (1985:291) notes that ‘the only serious intrinsic problem with stochastic frontiers is that the separation of noise and inefficiency ultimately hinges on strong (and arbitrary) distributional assumptions’. This has been restrictive, although there are numerous statistical tests to validate such distributions. However, there is no economic reasoning or theoretical justification for assuming a particular distribution of the error term.

Lucas (1981) provides further justification for not using the conventional frontier production function model. In his study of econometric policy evaluation, he argued that

> The standard stable parameter view of econometric theory and quantitative policy evaluation appears not to match several important characteristics of econometric practice. For example, fixed coefficient econometric models may not be consistent with the dynamic theory of optimising behaviour (of firms); that is, changes in

economic or policy variables will result in a new environment that may, in turn, lead to new optimal decisions and new economic structures (Lucas 1981:109–10).

Drawing heavily on the discussion of Hildreth and Houck (1968), Kalirajan and Obwona (1994), and Salim and Kalirajan (1995), this study adopts the following varying coefficient frontier production approach

$$y_i = \alpha_i \prod_{j=1}^{k} x_{ij}^{\beta_{ij}} \qquad (5)$$

$$i = 1, 2, 3, \ldots n$$

where y_i and x_{ij} are the ith firm's output and the jth input respectively. It can be seen from equation 5 that the output response coefficients with respect to different inputs vary across firms (implying variation in input application), and so do the intercept terms (implying heterogeneity across firms). However, it is important to note that the capacity realisation related error is captured by the random coefficients α and βs, and that the 'white noise' term cannot be distinguished from the random error of the varying intercept term (Hildreth and Houck 1968). Now, the productive capacity realisation indices, which are estimated using the above model, can be interpreted as more consistent with firms' behaviour and economic theory.

Model specification and estimation procedures

Assuming Cobb-Douglas technology, the random coefficient frontier production function as explained in Kalirajan and Shand (1994b), can be written as

$$\ln y_i = \beta_{1i} + \sum_{j=1}^{K} \beta_{ij} \ln x_{ij} \qquad (6)$$

$$i = 1, 2, 3, \text{-----------} n \qquad \text{and } j = 1, 2, 3, \text{-----------} n$$

where y refers to output and x to inputs. The above model requires $nK + n$ coefficients to be estimated with the help of only n observations. Since intercepts and slope coefficients vary across firms, we can write

$$\beta_{ij} = \bar{\beta}_j + u_{ij}$$

$$\beta_{1i} = \bar{\beta}_1 + v_i \qquad (7)$$

where $\bar{\beta}_j$ is the mean response coefficient of output with respect to the jth input and u_{ij} and v_i are random disturbance terms which satisfy all the classical assumptions. In addition to the classical assumptions the following assumptions are made

$$E(\beta_{ij}) = \bar{\beta}_j \qquad \mathrm{Var}(\beta_{ij}) = \sigma_j^2 > 0$$

$$\text{and} \quad \mathrm{Cov}(\beta_{ij}, \beta_{im}) = 0 \qquad j \neq m$$

These imply that the random coefficients β_{ij} are independently and identically distributed with fixed mean β_j and variance σ_j^2.

Combining equations (6) and (7) one can write

$$\ln y_i = \bar{\beta}_1 + \sum_{j=1}^{K}(\bar{\beta}_j + u_{ij})\ln x_{ij} + v_i \qquad (8)$$

In matrix format, equation 8 can be written as

$$Y = X\beta + D_x u + v$$

where Y is a (nX1) vector, X is a (nXK) matrix stacked x_i', Dx is a (nXnK) diagonal matrix of the x_i', u is a (nKX1) vector of u_i and v is a (nX1) vector. It can easily be verified that disturbance terms v_i and u_{ij} have zero means and also $E(v_i u_{ij}) = 0$ for all i and j , $E(v_i^2) = \sigma_i^2$, $E(v_i v_j) = 0$ for $i \neq j$, $E(u_i u_j') = \Gamma_u$, a diagonal matrix for i = j and $E(u_i u_j') = 0$ for $i \neq j$.

Given these assumptions, the composite disturbance vector,

$$w = D_x u + v$$

will have a mean vector of zero and covariance matrix

$$\Delta = x_i' \Gamma_u x_i + \sigma_i^2 .$$

It may be noted that the Hildreth-Houck random coefficient model belongs to the class of heteroscedastic error models where error variances are proportional to the squares of a set of exogenous variables X. So the random coefficient regression model reduces to a model with fixed coefficients, but with heteroscedastic variances. This heteroscedasticity will remain, even if $\sigma_j^2 = \sigma^2$ for all j values so long as the square of the explanatory variables is present. So, the ordinary least squares (OLS) method yields unbiased but inefficient estimates of mean response coefficients.

Since, the elements of Γ_u are not known, they have to be estimated. Hildreth and Houck (1968) suggests several methods of estimating the elements of Γ. In this study, we used Aitken's generalised least squares (GLS) to estimate βs by following the arrangements of Swamy (1970).[3]

The assumptions underlying equation 8 are as follows.

i) The maximum possible output stems from two sources. One, the efficient use of each input contributes individually to the potential output, and can be measured by the magnitude of the varying random slope coefficients (β coefficients). Two, when all the inputs are used efficiently, then it may produce a combined contribution over and above the individual contributions. This latter 'lump sum' contribution, if any, can be measured by the varying random intercept term (α coefficient).

ii) The highest magnitude of each response coefficient and the intercept term from the production coefficients of equation 8 constitute the production coefficients of the frontier function showing the maximum possible output.

To elaborate, let $\beta_1^*, \beta_2^*, \beta_3^*, \ldots \beta_K^*$ be the estimates of the parameters of the frontier production function yielding the potential output. The frontier coefficients (β^*) are chosen in such a way to reflect the condition that represents the production responses of following the 'best practice' techniques. These are obtained from among the individual response coefficients which vary across observations as

$$\beta_j^* = \max\left\{\beta_{ij}\right\} \qquad i = 1, 2\text{----------}n \qquad (9)$$

When the response coefficients are selected by using equation 9, then the potential output for the ith firm can be worked out as

$$\ln y_i^* = b^* + \sum_j b^* \ln x_{ij} \qquad (10)$$

where x_{ij} refer to actual levels of inputs used by the ith firm. Subsequently, a measure of productive capacity realisation can be defined as follows

$$\text{PCR} = \frac{realised\,Output}{potential\,Output}$$

$$= \frac{y_i}{\exp(\ln y_i^*)} \qquad (11)$$

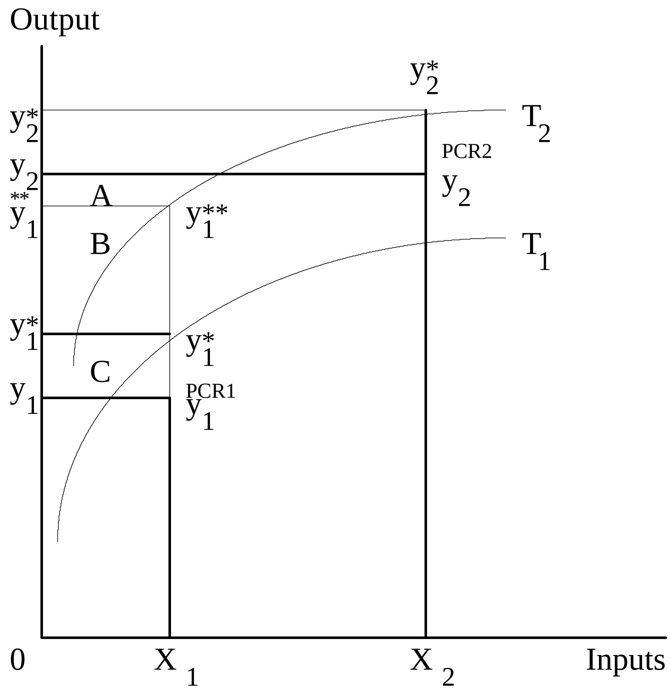
The productive capacity realisation varies between 0 and 1. Thus, the varying coefficient regression model provides a realistic approach for estimating productive capacity realisation over a large number of firms using only cross-section data.

Decomposition of total factor productivity growth

In the conventional approach to measuring sources of output growth, the contribution of total factor productivity is estimated as the residual, after accounting for the growth of inputs. It is usually interpreted as the contribution of technical progress. Computationally, the total factor productivity growth rate is measured as the difference between the growth rates of total output and total inputs. This conventional procedure of total factor productivity measurement implicitly assumes that firms always utilise their full potential of technology, that is, a firm’s production always takes place on the frontier. This assumption is unrealistic, because, due to various non-price and institutional factors; firms could be producing somewhere below the frontier. So, in this case, technological progress is not the only source of output growth. Under these circumstances, a substantial increase in total factor productivity can still be realised, by improving the application of the given technology.

The decomposition of total output growth into input growth, improvement in capacity realisation and technical progress is illustrated in Figure 1. Here a typical firm faces two production frontiers, the efficient production technologies, as characterised by Farrell (1957), for two periods, T_1 and T_2 respectively. At period 1, if the firm is producing with full productive capacity, its realised output will be y_1^*. However, because of various constraints, the firm may be producing at somewhere less than full capacity, which means that the realised output is y_1. So, there is a gap between realised and maximum possible outputs; PCR measures this gap by the vertical distance between y_1 and y_1^*. Now, suppose, there is technical progress, due to the improved quality of human and physical capital induced by policy changes, so a firm’s potential frontier shifts to T_2 in period 2. If the given firm keeps up with the technical progress, more output is produced from the same level of input. So, the firm’s output will be y_1^{**} from X_1 input as shown in the figure. Technical progress is measured by the distance between two frontiers (T_2-T_1) evaluated at x_1.

Figure 1 **Sources of output growth**



Now the firm is generally induced to increase its levels of input in period 2. Its maximum possible output is y_2^* for new levels of input X_2, and its realised output is y_2. Again, the gap is measured by PCR, the vertical distance between y_2 and y_2^*. So, the improvement in capacity realisation between the two periods is measured by the difference between PCR_1 and PCR_2. The traditional source of output growth, output growth due to input growth between the two periods, can be measured by the distance between y_2^* and y_1^{**} along the frontier 2. Referring to Figure 1, the total output growth can be decomposed into three components: input growth, changes in capacity realisation and technical progress.

In accordance with the figure the decomposition can be shown as follows

$$(y_2 - y_1) = A + B + C$$

$$= (y_2 - y_1^{**}) + (y_1^{**} - y_1^{*}) + (y_1^{*} - y_1)$$

$$= (y_2^{*} - y_2^{*}) + (y_2 - y_1^{**}) + (y_1^{**} - y_1^{*}) + (y_1^{*} - y_1)$$

$$= -(y_2^{*} - y_2) + (y_2^{*} - y_1^{**}) + (y_1^{**} - y_1^{*}) + (y_1^{*} - y_1)$$

$$= \{(y_1^{*} - y_1) - (y_2^{*} - y_2)\} + (y_1^{**} - y_1^{*}) + (y_2^{*} - y_1^{**})$$

$$= \quad (PCR_1 - PCR_2) + TP + \Delta y_x \qquad (12)$$

where

y_2-y_1 = output growth

PCR_1 -PCR_2 = change in capacity realisation

TP = technical progress

Δy_x = output growth due to input growth

Equation 12 is used in this study to estimate the above three sources of output growth. The first component (PCR_1 -PCR_2) captures the change in capacity realisation implying the movement of firms towards or away from the frontier, that is, the firm's ability to 'catch up'. The second factor (TP) represents the shift of production frontier at each firm's input mix, what is known as technical progress. The last factor of accounts for the contribution of input growth to output, which refers to a movement along its frontier.

Data and empirical results

Data

The data for the present study have been taken from the Census of Manufacturing Industries (CMI) conducted yearly by the Bangladesh Bureau of Statistics (BBS). The CMI covers all manufacturing establishments in Bangladesh with 10 or more employees. For this study, firm-level data on Bangladesh food processing industries, covering the period 1981 to 1991, were used. Firms which had equal or greater value added than their sale proceeds, and firms with negative or zero value added, were all removed from the data set.

Value added, and two inputs, labour and capital, were considered for estimating the production frontier. Both production and non-production workers were included in the analysis. Capital input was constructed following the 'perpetual inventory' approach.

Estimation of capacity realisation

Several functional forms, such as Cobb-Douglas, CES, and Translog, can be assumed for the production process to evaluate industrial performance in Bangladesh. However, the reliability of the estimates of capacity realisation indices hinges crucially on the specification of the model. The Cobb-Douglas functional form has been extensively used in stochastic frontier production function analysis. Census data are unlikely support more elaborate functional forms (Griliches and Ringstad 1971) and the Cobb-Douglas functional form affords maximum flexibility in dealing with data imperfections (Tybout 1990). Narasimham et al. (1988) demonstrated that the Cobb-Douglas production function is less restrictive when all of the coefficients are allowed to vary. Moreover, the Cobb-Douglas functional form has been acknowledged by researchers to fit the Bangladesh manufacturing data reasonably well (see, for example, Krishna and Sahota 1991).

At the outset, the functional specification, and the assumption of random coefficients, were tested. Ramsey's RESET test and Brausch-Pagan's LM test do not reject the Cobb-Douglas form and the random coefficients model respectively. Therefore, the following Cobb-Douglas production function was used to estimate the firm-specific productive capacity realisation

$$\ln y_i = \ln \alpha_i + \sum_{k=1}^{2} b_k \ln X_{ki} \qquad (13)$$

$$i = 1, 2, 3, \ldots\ldots 93 \qquad \text{and } k = 1, 2$$

where y refers to value added and the X's are capital and labour respectively.

The iterated GLS estimates of the actual response coefficients, mean response coefficients of inputs and frontier production coefficients are given in Table 2.

Table 2 **Range of actual response and mean response coefficients of inputs and the frontier coefficients of the production function**

Years	Input	Range of * actual response coefficients*	Mean response coefficients	Coefficients of frontier production
	Constant	0.7227-0.8447	0.8377 (0.0828)	0.8447
1981	Capital	0.5974-0.6359	0.5746 (0.0189)	0.6359
	Labour	0.4418-0.4774	0.4224 (0.0243)	0.4774
	Constant	0.8273-0.8851	0.8804 (0.0876)	0.8851
1987	Capital	0.6284-0.6635	0.6311 (0.0190)	0.6635
	Labour	0.3369-0.4003	0.3555 (0.0241)	0.4003
	Constant	0.5069-0.5815	0.5768 (0.0507)	0.5815
1991	Capital	0.7364-0.7580	0.7464 (0.0111)	0.7580
	Labour	0.1542-0.2526	0.1589 (0.0145)	0.2526

Note: Calculated from the Census of Manufacturing Industries (CMI), BBS, for 1981–91 period. However, estimates are presented here for three years (1981, 1987 and 1991) to compare the pre-reform, transition period and after reform periods. Figures in parentheses are standard errors.
*The current computer program does not give the standard errors of the actual response coefficients. Kalirajan and Obwona (1995) recently developed a model that gives the standard errors of the actual response coefficients.

All the mean response coefficients are significant at the 5 per cent level (Table 2). The signs and magnitudes of these variables are in conformity with theoretical expectations. Variations among the actual response coefficients show that there are variations in the methods of application of inputs across the sample firms. In other words, the contributions of inputs to output differ from firm to firm.

The estimates of frontier coefficients presented in the last column of Table 2 indicate the maximum possible contribution of inputs to output, when firms are operating on their frontiers, following the best practice techniques. Moreover, these estimates are obtained by relaxing the conventional assumption of neutral shift of the frontier production function.

Using equation 10, firms' maximum possible outputs are obtained to estimate the firm-specific capacity realisation indexes. Industry-wide results are shown in Appendix Table A1.

There are wide variations in capacity realisation across firms in food manufacturing industries. The edible oil industry is performing well, realising on average 78 per cent of its productive capacity in 1981; this figure increased to 82 per cent in 1991. The hydrogenated vegetable oils industry is second to the edible oil industry in realising its productive capacity. Although the average realisation rate decreased to 81 per cent in 1991, from 91 per cent in 1981, these figures are greater than those for other industries. It may be concluded that firms in these industries are producing close to their production frontiers. Firms in the other three industries, dairy products, grain milling, and tea and coffee blending, are doing reasonably well, realising above 60 per cent of their productive capacity. On average, capacity realisation sharply increased in the fish and sea food industry, by registering from a low 47 per cent in 1981 to 78 per cent in 1991. The reason for this sharp rise may be attributed to the outward orientation of this industry. All firms in this sector are 100 per cent export oriented. The remaining industries have performed poorly. Of these the sugar industry is the worst. This may be because all sugar factories belong to the public sector, and it is generally believed that managers of public enterprises are reluctant to utilise the full capacity for various organisational factors; or because the seasonality involved in running sugar factories prevents them achieving full capacity realisation.

The results also show that mean realisation rates of almost all industries stagnated in the mid-1980s, and improved upward, though not significantly in the 1990s. It appears that substantial unrealised productive capacity exists in Bangladesh food processing enterprises. There is room for additional improvements in increasing output by realising these unrealised capacities.

In terms of average rate of capacity realisation, hydrogenated vegetable oil was the most efficient with a 91 per cent mean and a 100 per cent for the most efficient firm in 1981. This was followed by edible oil, realising a mean of about 78 per cent, tea and coffee blending at 67 per cent, and grain milling at about 62 per cent productive capacity in the same year. Fish and seafood, rice milling, bakery products, sugar factories and tea and coffee processing were relatively inefficient with mean PCR levels below the industry's average of about 51 per cent. Industries within the food processing industry group achieved almost similar rates of average capacity realisation in the transition period (1987). The mean rate did increase dramatically in the fish and sea food sector, perhaps due to its export-oriented nature and to the sharp increase in foreign demand for processed fish products in this period.

In the post-reform period, the edible oil industry became the most efficient with the highest mean capacity realisation of about 82 per cent. It may be argued that firms in this industry were producing close to their production frontiers as the minimum PCR was 61 per cent. The hydrogenated vegetable oil, fish and seafood and dairy products showed a similar performance. Other industries achieved moderate rates of capacity realisation, but bakery products, sugar products and tea and coffee processing performed poorly by realising PCR below the industry's mean of 58 per cent.

Changes in mean capacity realisation rates in the food processing industry over the three periods suggest that enterprises in different sectors within the industry gained only moderate increases in efficiency in the post-reform period. The average rate of capacity realisation for this industry increased by only 7 per cent, from 51 per cent in 1981 to 58 per cent in 1991. Substantial unrealised productive capacity clearly exists in most types of enterprises in the food processing industry. The lowest rate of capacity realisation increased by only 2 percentage points, indicating that many enterprises within the industry still produce far away from their frontier, realising productive capacity around the marginal rate. On average, capacity realisation increased most sharply in the fish and seafood industry by 31 per cent from a low mean of 47 per cent in 1981 to 78 per cent in 1991. The reason for this sharp rise may be attributed to the outward orientation of this industry and the need for competitions. All firms in this sector are 100 percent export-oriented. The remaining industries showed little or no improvement and still performed poorly in post-reform 1991. Of these, sugar industry was the worst. This may be because: i) all sugar factories belong to the public sector; and it is generally believed that managers of public enterprises are reluctant to utilise full capacity for various organisational reasons, (ii) long gestation period and the seasonality of sugar factories which prevents them from achieving full capacity realisation.

These results for the food processing industry group do not conform with those of the earlier studies. A pioneering study of the food processing sector by a Bangladesh-Canada Agriculture Sector Team (B-C AST) (1991) using conventional methodology with firm-level data for 1987, found mean capacity realisation rates of 52 per cent for bakery products, 34 per cent for fish and seafood, 16 per cent for rice milling, 43 per cent for hydrogenated vegetables oil, and 56 per cent for sugar factories. A study conducted by the International Labour Organisation (ILO) (1991) using factory level survey data for 1989, found that 70 per cent of its sample enterprises operated at less than 50 per cent of their production capacity, another 20 per cent operated at 51–60 per cent capacity, and only 10 per cent of the sample enterprises realised 61–80 per cent of their production capacity. It also found many reasons, including management inefficiency, inadequate supply of raw materials, low labour productivity and political instability for low rates of capacity realisation.

Using the traditional shift measure by Bhattacharya (1994) found a high average rate of 71 per cent of capacity realisation in the food processing industry in 1992. The findings of the earlier studies do not conform with those of this study for the following reasons:

(i) Both studies used different data sets and covered different time periods.

(ii) Both studies used traditional approaches to estimate productive capacity realisation indices, the limitations of which are discussed in the literature.

(iii) Both studies followed deterministic approaches and therefore estimates of the productive capacity realisation could not be separated from the white noise.

(iv) Both studies failed to take into account of the differences in individual input responses while estimating productive capacity realisation indexes.

Nevertheless, the overall conclusions of these studies are consistent with the this study.

Applying equation (12), the detailed estimates of sources of output growth for ten sectors of the food processing industry group for the periods 1981–87 and 1987–91 are presented in Table 3.

There were considerable variations of performance among the sectors within this industry group. Dairy products, fish and sea foods, and tea and coffee processing and blending were well-performing sectors, in terms of output and total factor productivity growth, in both periods. Fish and sea foods experienced the highest rate of growth, of about 5.5 per cent and 4.7 per cent per annum during 1981–87 and 1987–91 periods respectively. This sector is typically composed of small units with little capital. Abundant natural resources supported the growth of this sector. As mentioned earlier, the production of this sector is geared mainly towards export markets and the opening up of the economy during the 1980s further stimulated growth. As a result, this sector obtained the highest total factor productivity growth, of 3 per cent per annum during the 1981–87 and about 2.5 per cent per annum during 1987–91. Finally, this is the only sector where total factor productivity was growing faster than input growth during both periods.

Sugar factories are the so called large-scale industries within this industry group and in the manufacturing sector as well. All the enterprises in this sector are publicly owned and run by the Bangladesh Sugar and Food Industries Corporation (BSFIC). Since these enterprises enjoyed a seller's market (i.e. no competitors), managers or producers were reluctant to improve productivity. Consequently, sugar factories were the worst performers with total factor productivity growth of only 0.12 per cent per annum during the period

1981–87 and a negative rate of 0.91 per cent per annum during 1987–91. Other industries that experienced declining total factor productivity growth were edible oils, grain milling, rice milling and bakery products.

Table 3 **Annual average growth rates of food processing industries by sources 1981–91 (in percentage)**

Industries	No. of frims	1981–87 Output growth	1981–87 TFP growth	1981–87 Input growth	1987–91 Output growth	1987–91 TFP growth	1987–91 Input growth
Dairy products (3112)	4	3.300	1.374	1.926	4.701	1.357	3.004
Fish and sea foods (3114)	5	5.480	3.027	2.453	4.695	2.573	2.122
Hydrogenated veg. oils (3115)	3	2.822	1.073	1.750	3.858	1.084	2.774
Edible oils (3116)	5	2.767	0.688	2.079	0.698	-0.358	1.056
Grain milling (3118)	5	2.485	0.841	1.643	0.783	-0.951	1.734
Rice milling (3119)	5	3.873	1.382	2.491	2.096	0.397	1.698
Bakery products (3122)	6	2.802	1.127	1.675	2.990	0.658	2.332
Sugar factories (3123)	9	2.719	0.127	2.592	2.776	-0.911	3.687
Tea and coffee processing (3126)	49	3.227	1.096	2.131	3.897	1.407	2.489
Tea and coffee blending (3127)	2	4.194	1.618	2.576	4.768	1.689	2.917

Source: Calculated from CMI data (Master Tape, Current Production).
Note: Numbers in the parentheses are industrial codes using from the 'Bangladesh Standard Industrial Classification' (BSIC).

The decomposition of output growth into its two major components provided valuable perspectives concerning productivity. Although most industries experienced accelerated output growth from the early to late 1980s, growth rates were not as high as anticipated. Moreover, growth of inputs contributed significantly to output growth in almost all industries, and in many industries input use increased at approximately the same rates as output growth. This occurred because firms were encouraged to inject more resources as a consequence of the incentive structure provided by the government in the 1970s and 1980s, particularly in the trade sectors. Total factor productivity growth did contribute substantially to output growth in some industries such as fish and sea foods industries during the periods 1981–87 and 1987–91. In some other industries, although total factor productivity growth improved from the early to late eighties, growth of inputs still remained the major contributor to output growth.

Total factor productivity growth is usually defined as the growth in output not explained by input growth, i.e.

$$\Delta \text{total factor productivity} = \underbrace{\left(y_{2i,t} - y_{1i,t-1}\right)}_{Output\ Growth} - \underbrace{\dot{y}_x}_{Input\ Growth}$$

From Equation (12), it can be written as:

$$\Delta\text{total factor productivity} = \{(\text{productive capacity realisation}_1 - \text{productive capacity realisation}_2)\} + TP \qquad (14)$$

Now, total factor productivity growth in (14) between period (t-1) and t for the ith firm can be estimated as

$$\Delta\text{total factor productivity} = \ln\left(\frac{TFP_{i,t}}{TFP_{i,t-1}}\right)$$

$$= \{(y1^*_{i,t-1} - y1_{i,t-1}) - (y2^*_{i,t} - y2_{i,t})\} + (y1^*_{i,t} - y1^*_{i,t-1}) \qquad (15)$$

where y1* and y2* (in logarithms) are the frontier outputs with input level X1 and X2 in periods 1 and 2 respectively (see figure 1). These two total factor productivity components are analytically distinct, and may have quite different policy implications (Nishimizu and Page 1982).

None of the earlier studies in Bangladesh has decomposed total factor productivity growth into its various components. However, there are a few studies (Nishimizu and Page 1982; Bauer 1990; Fan 1991; Kalirajan, Obwona and Zhao 1996) in the literature which decompose total factor productivity growth into change in technical efficiency and technical progress. Using firm-level data from the US electric utility industry, Callan (1986) estimated the total factor productivity growth as the sum of technical progress and the change in capacity realisation. These two components of total factor productivity growth were obtained by modelling capacity realisation as an argument in the cost function, and taking total derivatives of the cost function with respect to time. Moreover, the specification of the cost function implicitly assumes that the cost function shifts neutrally and that the rate of technical change is constant over time. These assumptions are restrictive.

Following Equation (15), components of total factor productivity growth are calculated using firm-level data for the selected industry groups. Industry-wide empirical estimates of average rate of changes in capacity realisation and technological progress are presented in Table 4.

The total factor productivity growth rates in the food processing industry group were disappointingly low, ranging from 0.13 per cent per annum to 3.03 per cent per annum between 1981 and 1987, but only one industry (fish and seafood) exceeded 1.6 per cent (Table 4). Changes in capacity realisation rates for various sectors of this industry group were not significant showing that these industries failed to improve performance with the existing production technology, some even declined marginally during this period. The maximum rate was only 0.10 per cent in the fish and sea food sector. This industry also experienced the highest rate of technological progress, at nearly 3 per cent per annum. The recent origin of this industry, and steeply rising external demand, probably led to this growth. The above results conform with those of HIID (1990) and Sahota et al. (1991), although they used traditional growth accounting method and total factor productivity was measured as the residual.

The average rates of total factor productivity growth of different sectors of the food processing industry group did not increase much during the post-reform period (1987–1991). Edible oils, grain milling, and sugar factories experienced negative total factor productivity growth rates. Average rates of capacity realisation among these sectors improved from the previous period but did not grow fast enough to outweigh the negative rates of technological progress.

Table 4 **Decomposition of annual average total factor productivity growth rates of food processing industries, 1981 to 1991 (in percentage)**

Industries	No. of firms	1981–87 TFP growth	1981–87 Change in PCR	1981–87 Tech. prog.	1987–91 TFP growth	1987–91 Change in PCR	1987–91 Tech. prog.
Dairy products (3112)	4	1.374	0.004	1.370	1.357	0.088	1.269
Fish and sea foods (3114)	5	3.027	0.100	2.927	2.573	0.044	2.529
Hydrogenated veg. oils (3115)	3	1.073	-0.003	1.075	1.084	-0.094	1.178
Edible oils (3116)	5	0.688	-0.010	0.698	-0.358	0.050	-0.407
Grain milling (3118)	5	0.841	0.036	0.805	-0.951	0.065	-1.016
Rice milling (3119)	5	1.382	-0.029	1.410	0.397	0.053	0.344
Bakery products (3122)	6	1.127	0.051	1.075	0.658	0.016	0.642
Sugar factories (3123)	9	0.127	-0.009	0.137	-0.911	0.079	-0.990
Tea and coffee processing (3126)	49	1.096	0.022	1.074	1.407	0.062	1.346
Tea and coffee blending (3127)	2	1.618	-0.010	1.628	1.689	0.069	1.783

Notes: Negative signs for changes in capacity realisation mean that capacity realisation declined from previous period to latter period and that of total factor productivity growth implies negligible growth in factor productivity (since the estimates are based on logarithms). TFP = total factor productivity; PCR = productive capacity realisation.
Source: Same as Table 4.

Although some industries experienced declining rates of technological progress from the early eighties to late eighties, technological progress still accounted for the majority of total factor productivity growth. Technological progress generally originates from many sources, but learning by doing and imported new technologies are two important factors. In Bangladesh, technological progress stemmed from the latter source, due to the opening of the domestic economy to the world market.[4] In spite of the adoption of new technology for several years, manufacturing performance remains sluggish. As reported in a 1987 Asian Development Bank study, firms simply import foreign equipment but use it according to the prevailing norm. No individual efforts were undertaken to improve the realisation of existing resources, particularly in large firms, thus no really effective change took place in the production method. Since, industrial enterprises do not have their own in-house research and development activities or effective linkages with government sponsored research and development organisations, modifications or improvements of imported technology and the rate of innovation have been very low in recent years. New technology, with old methods of application of input failed to provide any significant 'technological break-through' through innovation (ILO 1991; World Bank 1992).

Conclusion

Relaxing the assumptions of constant slope and varying intercept of conventional stochastic frontier production functions, this paper uses a random coefficient production frontier to estimate firm-specific capacity realisation indices. In estimating these indices, this approach takes into account the differences in individual input responses to output, regardless of the amount of input applied, implying that the production frontier shifts non-neutrally. Firm-level data from Bangladesh food processing industries have been used for the empirical estimation. The results show that there is a wide variation in capacity realisation among firms, though some experienced significant improvement over the sample period. The results also indicate that there has been substantial unrealised productive capacity in Bangladesh food manufacturing which could be eliminated.

The decomposition of output growth into input growth, change in capacity realisation and technical progress, shows that output growth across firms was caused mainly by input growth. Technical progress occurred in recent years in Bangladesh, due to economic reforms which facilitated the withdrawal of import licensing and bans. Capacity realisation among firms, however, contributed little to total factor productivity. The implication is that there is still potential to increase output in Bangladesh food industries by realising the substantial unrealised productive capacity. However, how firms eliminate their unrealised productive capacity is not discussed in this paper.

Notes

[1] This point was first discussed in Nizhimizu and Page (1982) and later in Bauer (1990); Fan (1991) and Färe et al. (1994). All their methodologies are different from the one used in this paper.

[2] Further limitations of lnear programming and other deterministic approaches of measureing Farrell type efficiency are extensively discussed in Kalirajan and Shand (1994a).

[3] This method involves iterative procedures and iterations continue until parameter D s are stabilised. Interested readers are referred to Swamy (1970, 1971), Swamy and Mehta (1975) and Griffiths (1972).

[4] Recent economic reforms in Bangladesh also include the removal of quantitative restrictions, rationalisation of the tariff structure, unification of multiple exchange rates, various incentives for imports by export oriented firms, etc. to encourage production and productivity.

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Appendix Table A1 **Industry-wide productive capacity realisation indices for 1981, 1987, and 1991 (per cent)**

Name of industries	No of firms	1981			1987			1991		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Dairy products (3112)	4	48.071	86.223	61.240	51.730	88.524	61.504	62.970	83.423	72.655
Fish and sea foods (3114)	5	40.692	52.835	46.912	51.191	63.522	57.678	58.412	69.490	77.745
Hydrogenated veg. oil (3115)	3	84.069	100.00	91.075	85.078	100.00	90.929	78.729	86.055	81.411
Edible oil (3116)	5	57.138	88.346	78.145	52.177	90.422	76.903	61.915	100.00	82.122
Grain milling (3118)	5	46.257	78.969	62.186	52.415	78.833	65.705	62.574	80.579	72.293
Rice milling (3119)	5	44.049	75.527	59.563	35.084	85.419	56.446	46.201	81.441	62.032
Bakery products (3122)	6	37.582	64.105	49.747	39.895	80.797	54.569	42.079	86.260	56.429
Sugar factories (3123)	9	30.311	47.486	38.527	30.109	48.721	37.690	32.944	62.298	45.473
Tea and coffee processing (3126)	49	30.555	85.970	45.542	38.278	79.586	48.034	39.975	88.629	53.973
Tea and coffee blending (3127)	2	50.751	84.062	67.406	55.436	77.210	66.323	66.654	79.905	73.279
Total	93	30.311	100.00	51.318	30.109	100.00	53.284	32.944	100.00	58.787

Note: Numbers in parentheses are industrial code according to 'Bangladesh Standard Industrial Classification' (BSIC). See, also note to Table 1.