Chapter IV

METHODOLOGY AND DATASET

The deliberation of Chapter III on the review of literature indicates that, in methodology, we should decide upon: (a) the basic approach of the methodology, i.e. whether we opt for the DEA or the EFA as our methodological framework; (b) identification of the variables (both inputs and outputs); and (c) the functional relationship among the variables. These are the subject-matters of the first three sections that follow. Once the model is thus specified and calibrated, Section IV briefly discusses certain issues of estimation relating to time-series data, and Section V gives the details of the source of data and also their descriptions in a summary form. Section VI concludes.

Section I: Methodology: DEA, GLS and MLE

By virtue of being a programming model, as adumbrated in Chapter III, the DEA has the advantage of analysing the data without parameterization, i.e. without any assumption of underlying distribution. Nor does it require any functional concept among the variables under study. It is based first on the identification/estimation of the most efficient production frontier, and then comparing it with the production frontier of a given producer. Its main advantage, however, gives rise to a serious drawback: the absence of parameterisation makes this model deterministic so that there is no room for statistical noises. Thus, any deviation that arises from the most efficient production frontier is regarded as inefficiency, which generates suspicion as to the existence of contaminated efficiency scores. In other words, there is every possibility that the efficiency scores are infested by omitted variables, statistical noises and measurement errors.[246] Moreover, since the DEA is a comparative technique, the efficiency score of a firm depends upon those of others, and hence cannot be further analysed by way of the regression method. This is so because it violates the assumption of independence within the sample.[247]

At the cost of repetition, we note here that the concept of X-efficiency suffers from malapropism in the literature.[248] The problems of asymmetric information, principal agent relationship and model misspecification,[249] that lead to X-efficiency are absent in a deterministic relationship like that of the DEA where every inputs are, by assumption, well defined. The programming approach underlying the DEA entails that all of the outputs that are produced are attributed to the inputs that enter into its production such that that there are no stochastic variations in the process. Every deviation from the optima is regarded as X-inefficiency. In fact, Leibenstein erred on this issue in 1992 in his joint article with Maital on DEA.[250] They advocate the use of DEA as the best method for measuring X-inefficiency on the ground that DEA is capable of taking into consideration 'ordinal measurements'[251] that measure motivation and personality which are proxies for the X-(in)efficiency component of the model. However, in his article in 1966, he points out that X-inefficiency arises due to factors that cannot be marketed and/or cannot be quantified. As to the measurement problem, he writes in the 1992 article that by way of 'ordinal measurements', those factors can be incorporated in a DEA model. But other important points he identified

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[246] Greene, 'The econometric Approach ', p.76

[247] Hahn, 'Measuring Performance'

[248] For details of the misinterpretation of the concept, see Ray and Sanyal, pp.156-157

[249] These are same as Leibenstein's three issues underpinning X-inefficiencies. See his article 'Allocative efficiency Vs "X-efficiency"', p. 407.

[250] Leibenstein and Maital, 'Empirical Estimation'

[251] Ibid, p.429

in 1966 – such as incomplete labour contracts, non-market factors of production, unknown production function as also 'interdependence and uncertainty' that 'lead competing firms to cooperate tacitly with each other in some respects, and to imitate each other with respect to technique, to some degree'[252] – are only typical to 'The Residual'[253] in any empirical study, which the DEA cannot account for. The DEA's inability to incorporate the stochastic component is addressed in the methodology of what is termed as Stochastic Data Envelopment Analysis (SDEA). It allows a certain level of uncertainty in the data set, by recognising the 'two sided deviation in addition to the one sided deviation for inefficiency'.[254] But the methodology, as developed by Banker, is less popular in the literature[255] for two major reasons: (a) the judgement on a firm's efficiency level is dependent in this model on a hypothetical weight vector, attached to various input and output variables, and (b) the model gives inconclusive results in some empirical cases (as for some firms in Banker's illustrative application), whereas the MAD (minimum absolute deviations) regression and the OLS model, as tried in the same application, generate conclusive results.[256]

In our attempt to analyse the effects of economic reforms on the banks' X-efficiency, we stay true to the original concept of X-efficiency, as conceived by Leibenstein in 1966, by using the stochastic model. Broadly, there are two methods for measuring X-efficiency in the stochastic frontier approach, both of which assume that X-inefficiency is embedded in the estimated error terms (ε_i):

$$Y = X\hat{\beta} + \varepsilon_i \qquad (4.1)$$

[252] Leibenstein, 'Allocative efficiency Vs "X-efficiency"', p. 407.
[253] Ibid, p. 406
[254] Banker, 'Stochastic Data Envelopment Approach'
[255] Only one empirical paper using a similar methodology has come to my notice. See Chen, A 'Comparison of Chance-Constrained DEA and Stochastic Frontier Analysis: Bank Efficiency in Taiwan'
[256] Banker, 'Stochastic Data Envelopment Approach', pp. 21-24

where $\hat{\beta}$ is the vector of estimated parameters. The primitive one, belonging to the error-in-equation model, seeks to further regress ε_i on time t so that the white noise component of ε_i is delineated. The parameters in this model may be estimated using Kmenta's generalised least square method.[257]

The generalised least square model can be specified as

$$Y = X\beta + \varepsilon_i \quad (4.2)$$

where Y is an $(nX1)$ vector of the sample values of Y, X is an (nXk) matrix of sample values of X_{i1}, X_{i2}, ...X_{ik}, β is a $(kX1)$ vector of parameters and ε is n $(nX1)$ vector of disturbance terms. The variance-covariance matrix is denoted as $\Omega = E(\varepsilon' \varepsilon')$ and

$$\Omega = \begin{pmatrix} E(\varepsilon_{11}^2) E(\varepsilon_{11}\varepsilon_{12}) \;.....\; E(\varepsilon_{11}\varepsilon_{1T}) .... E(\varepsilon_{11}\varepsilon_{NT}) \\ E(\varepsilon_{12}\varepsilon_{11}) E(\varepsilon_{12}^2) \;.....\; E(\varepsilon_{12}\varepsilon_{1T}) .... E(\varepsilon_{12}\varepsilon_{NT}) \\ \vdots \qquad \vdots \qquad \vdots \qquad \vdots \\ E(\varepsilon_{NT}\varepsilon_{11}) \quad E(\varepsilon_{NT}\varepsilon_{12}) \;.....\; E(\varepsilon_{NT}\varepsilon_{1T}) .... E(\varepsilon_{NT}^2) \end{pmatrix} \quad (4.3)$$

This Ω- matrix signifies that the model is cross-sectionally heteroskedastic and time-wise autoregressive. That is,

257 Kmenta, *Elements of Econometrics*, pp.508-513

$$E(\varepsilon_{it}^2) = \sigma_i^2 \qquad (4.4) \qquad \text{[heteroskedacticity]}$$

$$E(\varepsilon_{it}\varepsilon_{jt}) = 0 \qquad i \neq j \qquad (4.5) \qquad \text{[cross sectional interdependence]}$$

$$\varepsilon_{it} = \rho_i \varepsilon_{,t-1} + \epsilon_{it} \qquad (4.6) \qquad \text{[autoregression]}$$

where $$\epsilon_{it} \sim N(0, \sigma_{\epsilon i}^2)$$

$$\epsilon_{i0} \sim N\left(0, \frac{\sigma_{\epsilon i}^2}{1-\rho_i^2}\right)$$

$E(\varepsilon_{i,t-1}, \epsilon_{jt}) = 0$ for all i, j

It is thus required that we should know **Ω**. Following Kmenta we may estimate the **Ω** matrix as follows. We at first apply OLS on the data, and store their residuals. Those residuals are then regressed on their lag values to get $\hat{\rho}_i$. The $\hat{\rho}_i's$ are used to transform the equation (3.2) as follows

$$Y_{it}^* = \beta_1 X_{it,1}^* + \beta_2 X_{it,2}^* + \ldots \ldots .. + \beta_K X_{it,K}^* + \epsilon_{it}^* \qquad (4.7)$$

where

$$Y_{it}^* = Y_{it} - \hat{\rho}_i Y_{i,t-1}$$

$$X_{it,K}^* = X_{it,K} - \hat{\rho}_i X_{i,t-1,K}$$

$$\epsilon_{it}^* = \epsilon_{it} - \hat{\rho}_i \epsilon_{i,t-1,K}$$

$$t = 1,2,3 \ldots . T$$

$$i = 1,2,3 \ldots . N$$

By doing so we correct for autoregression and make the series non autoregressive. Since the $\hat{\rho}_i$ values are estimates for individual banks, the banks with unit root (i.e. $\hat{\rho}_i \geq 1$) should not be taken into consideration.

Now, to correct for heteroskedacticity, we find out the variance of the $\hat{\epsilon}_{it}^{*}$ terms and correct the series of both $X_{it,K}^{*}$ and Y_{it}^{*} by dividing them by the estimated variance of $\hat{\epsilon}_{it}^{*}$. The variance of $\hat{\epsilon}_{it}^{*}$ is obtained as follows

$$s_{\epsilon i}^{2} = \frac{1}{T-K-1}\sum_{t=2}^{T} \hat{\epsilon}_{it}^{*2} \qquad (4.8)$$

The transformed variables then assume the following form:

$$Y_{it}^{**} = \beta_1 X_{it,1}^{**} + \beta_2 X_{it,2}^{**} + \cdots \ldots \ldots \ldots + \beta_K X_{it,K}^{**} + \epsilon_{it}^{**} \qquad (4.9)$$

where

$$Y_{it}^{**} = \frac{Y_{it}^{*}}{s_{\epsilon i}}$$

$$X_{it}^{**} = \frac{X_{it,K}^{*}}{s_{\epsilon i}}$$

$$\epsilon_{it}^{**} = \frac{\epsilon_{it}^{*}}{s_{\epsilon i}}$$

$$t = 1,2,3 \ldots T$$

$$i = 1,2,3 \ldots . N$$

After the data have been so transformed, the OLS method can be used to fit the translog cost function. The residuals in this stage of estimation represent a composite series of pure white noises and the X-inefficiency. To delineate them, it is customary to use the following model:

$$ln\varepsilon_{i_i} = ln\,\gamma_i + ln\lambda_i t + ln\xi_i \qquad (4.10)$$

Equation 4.10 breaks the residual into the time invariant X-efficiency (γ_i), the time variant X-efficiency (λ_i) and the pure white noise component (ξ_i). We may then transform the terms $\ln\gamma_i$ and $\ln\lambda_i$ into normalized X-efficiency measures as follows:

Time invariant X-efficiency (TI-XEF) = exp ($\ln\gamma_i^{\min} - \ln\gamma_i$)

Time variant X-efficiency (TV-XEF) = exp ($\lambda t^{\min} - \lambda_i t$)

where the superscript 'min' indicates the minimum value for all firms over time.

For a specific bank, the coefficients of equation 4.10 are analysed in the following manner.

1) Positive value γ_i implies time invariantly X-inefficiency
2) Negative value γ_i implies time invariantly X-efficiency
3) Positive λ_i implies time variantly X-inefficiency
4) Negative λ_i implies time variantly X-efficiency.

Table 4.1: Logic of inference for alternative values of parameter

Sign of the Intercept	Level of significance	Sign of Slope	Level of Significance	Inference*
		Negative	Significant	TIX-E
		Positive	Insignificant	TVX-E
Negative	Significant	Negative	Insignificant	TIX-E
		Positive	Significant	TVX-IE
		Negative	Significant	TIX-E
		Positive	Insignificant	TVX-E
Negative	Insignificant	Negative	Insignificant	TIX-E
		Positive	Significant	TVX-IE
		Negative	Significant	TIX-IE
		Positive	Insignificant	TVX-E
Positive	Significant	Negative	Insignificant	TIX-IE
		Positive	Significant	TVX-IE
		Negative	Significant	TIX-IE
		Positive	Insignificant	TVX-E
Positive	Insignificant	Negative	Insignificant	TIX-IE
		Positive	Significant	TVX-IE

*TIX-E: Time Invariant X-efficient
TVX-E: Time Variant X-efficient
TIX-IE: Time Invariant X-inefficient
TVX-IE: Time Variant X-inefficient

Two problems are associated with the GLS methodology. One, while transforming data for more than once, the precision of information contained in the data set is lost to a good extent. Two, we have seen that, for removing autocorrelation in the first step, this methodology requires certain banks (for which $\rho \geq 1$) to keep out of analysis. Because of these problems, the GLS methodology is less preferred now-a-days.

An alternative method gains importance in the literature, which involves single-stage estimation. Similar to the previous methodology, it also assumes that the X-efficiency is embedded in the estimated error term; but noting that $\varepsilon_i = u_i + v_i$, it proceeds to estimate the X-efficiency (u_i) from the conditional probability distribution of $u_{i,}$ given ε_i, more precisely, $E(u_i|\varepsilon_i)$, instead of regressing $\varepsilon_i$on time. There are again two methodologies. The first was by Aigner, Lovell and Schimidt[258], which we have already discussed in the previous chapter. The other method is developed in Battese and Coelli,[259] which the study uses along with that of Kmenta's GLS method. This methodology is widely used in the empirical literature on efficiency – for example, in Christopoulos,[260] Shanmugam and Das[261] and Bhattacharyya and Pal[262]. A slightly modified methodology incorporating the underlying factors of inefficiency is also used - in Sensarma,[263] for example. Since we seek here to assess the effects of India's economic reforms on the efficiency of banks (rather than investigating the factors underlying their efficiency/inefficiency), the modified Battese-Coelli[264] method is avoided. Some empirical studies such as Cebenoyan *et al*,[265] Srivastava,[266] Rai and Allen ,[267] and Altunbas et al[268] use the methodology of Jondrow, Lovell, Materov and Schimidt (JLMS) that precedes the Battese-Coelli methodology. The JLMS method decomposes the error term $\varepsilon_i = v_i - u_i$ (where v_i is the white noise and u_i the efficiency component) by way of the conditional distribution of u_i given ε_i. Because of further improvisation of this methodology in Battese and Coelli, as detailed below, we rely on the latter.

[258]Aigner *et al*, 'Formulation and Estimation'
[259]Battese and Coelli, 'Frontier Production function'
[260]Christopoulos*et al*,'Efficiency of the Greek banking system'
[261]Shanmugam and Das, 'Efficiency of Indian Commercial'
[262]Bhattacharyya and Pal , 'Financial Reforms and Technical Efficiency'
[263]Sensarma, 'Cost and Profit efficiency'
[264]Battese and Coelli, 'A Stochastic Frontier Production Function'
[265] Cebenoyan *et al*, 'The Relative efficiency of Stock versus Mutual S&Ls'
[266] Srivastava, 'Size, Efficiency and Financial Reforms in Indian Banking'
[267] Rai and Allen, 'Operational Efficiency in Banking'
[268] Altunbas *et al*, 'Efficiency in European Banking'

The Battese-Coelli methodology defines a production frontier for panel data that accounts for technical efficiencies of firms to vary over time:[269]

$$Y_{it} = f(X_{it}; \beta) \exp(v_{it} - u_{it}) \quad (4.11)$$

$$u_{it} = \eta_{it} u_i = \{\exp[-\eta(t-T)]) u_i t \in \mathscr{J}(i); i = 1,2, \dots \dots .. N \quad (4.12)$$

where Y_{it} represents the production of the ith firm at the tth period; X_{it} is the input vector that is associated with the production of i^{th} firm at the t^{th} period and β the vector of unknown parameters. The white noise v_{it} is, by assumption, independently and identically distributed $N(0, \sigma_v^2)$ and the efficiency vector u_i is non-negative, independent and identically distributed $N(\mu, \sigma^2)$. η_{it} is an unknown scalar parameter indicating time-variant efficiency for ith firm at tth period. $\mathscr{J}(i)$ represents the set of T_i time periods among the T periods involved for which the observation for the i^{th} firm is obtained.[270] In this method, the effect of u_{it} depends upon the value of η, that is, the technical efficiency of a firm increases, decreases or remains constant according as $\eta > 0$, $\eta < 0$ and $\eta = 0$. In view of the rigidity of this specification, an alternative way is to decompose η_{it} as follows:

$$\eta_{it} = 1 + \eta_1(t-T) + \eta_2(t-T)^2 \qquad (4.13)$$

where η_1 and η_2 are unknown parameters. When, $\eta_1 = \eta_2 = 0$ it represents a case of time invariant model.

Technical efficiency is, however, defined as

$$TE_{it} = \exp(-u_{it}) \qquad (4.14)$$

[269] Battese and Coelli, 'Frontier Production function', p 154
[270] Ibid, p.154

with

$$E[\exp(-u_{it})\,|E_i] = \left\{\frac{1-\Phi[\eta_{it}\sigma_i^* - \left(\mu_i^*/\sigma_i^*\right)]}{1-\Phi(-\mu_i^*/\sigma_i^*)}\right\} exp\left[-\eta_{it}\mu_i^* + \tfrac{1}{2}\eta_{it}^2\sigma_i^{*2}\right] \quad (4.15)^{271}$$

where $E_{it} \equiv v_{it} - u_{it}$ and E_i represents the $(T_i X\ 1)$ vector of $E_{it}^{'}s$.; and also

$$\mu_i^* = \frac{\mu\sigma_v^2 - \eta_i^{'}E_i\sigma^2}{\sigma_v^2 + \eta_i^{'}\eta_i\sigma^2} \qquad (4.16)$$

$$\sigma_i^{*2} = \frac{\sigma_v^2\sigma^2}{\sigma_v^2 + \eta_i^{'}\eta_i\sigma^2} \qquad (4.17)$$

The mean technical efficiency of the firm at t^{th} time period,

$$TE_t \equiv E[\exp(-\eta_t u_i)] \qquad (4.18)$$

where

$$\eta_t = exp[-\eta(t-T)]$$

$$TE_i = \left\{\frac{1-\Phi[\eta_t\sigma - (\mu/\sigma)]}{[1-\Phi(-\mu/\sigma)]}\right\} exp\left[-\eta_t\mu + \tfrac{1}{2}\eta_t^2\sigma^2\right] \qquad (4.19)$$

Though Battese and Coelli develops the methodology on the basis of production function, this functional specification is rarely used in empirical researches. For one thing, the production function approach requires the specification of inputs and outputs in physical terms, which complicates the measurement issues. Measurement of inputs is specifically difficult since it involves the questions like the

[271] This has been derived from the joint density function of u_i and v_i, which generates a joint density function of u_i and E_i. For details, see Battess and Coelli (1992), Annexure, pp. 163-167

level of skill of individual workers, vintages of different plants and machinery and so on. Coupled with this problem is its drawback that production approach can deal with only one output at a time, although modern banks always go for multi-products. In view of these shortcomings of the production approach, the cost function approach appears more suitable, especially in point of the fact that it can accommodate multiple outputs, along with multiple inputs, in a single equation. Its added advantage is that it considers the input prices, not the inputs, so that the variables are in monetary terms. The use of the cost function is, however, rationalised by the Shepherd's lemma, which establishes, as shown below, a duality between the production function and the cost function. The lemma considers an isoquant $q^0 = f(X_1, X_2)$ and the first- order condition for cost minimisation:

$$\frac{dX_2}{dX_1} = \frac{r_1}{r_2} \qquad (4.20)$$

which yields the input demand functions as:

$$X_1 = \psi_1\left(\frac{r_1}{r_2}, q^0\right) \qquad (4.21)$$

$$X_2 = \psi_2\left(\frac{r_1}{r_2}, q^0\right) \qquad (4.22)$$

Then, from the cost equation $C = r_1 x_1 + r_2 x_2$ and the first-order conditions$r_i = \lambda f_i$, we obtain

$$\frac{\partial C}{\partial r_i} = x_i + \lambda\left(f_1 \frac{\partial \psi_1}{\partial r_i} + f_2 \frac{\partial \psi_2}{\partial r_i}\right) = x_i > 0 \qquad (4.23)$$

where λ is the Lagrange multiplier, and the bracketed term equals to zero along the isoquant . This equation is known as the Shepherds lemma. By virtue of this lemma, we can establish duality between a production function and a cost function.[272]

For the purpose of using the stochastic cost frontier, we can convert the production function into a cost function, which in logarithms, assumes the following form.

$$lnTC_n = f(lnQ_i, lnP_j) + \varepsilon_n \qquad (4.24)$$

That is,

$$lnTC_n = f(lnQ_i, lnP_j) + u_n + v_n \qquad (4.25)$$

where $u_n + v_n = \varepsilon_{n.}$

The cost efficiency of the firm is given as

$$CE = \frac{C^{min}}{C} = \exp(-u_n) \qquad (4.26)$$

Section II: The Variables

The use of SFA requires that we should define the input and output variables, and also the underlying relationship among them. But the identification of the input and output variables warrants a conceptual clarity as to commercial banking. There are two alternative approaches towards the task of commercial banking. It may be regarded as an intermediary institution between the deficit units (the investors) and the surplus units (the savers) in the society. By taking funds from the latter at the deposit rate of interest, it provides the funds to the former at the lending rate of interest, and the

[272] For details, see Henderson and Quandt, pp. 117-119

spread between those interest rates represents its income. This is known as the intermediary approach to the nature of commercial banking. The alternative is what is called the production approach, whereby banks are treated as a producer of financial assets, producing various banking services using various inputs including land, labour and capital in their respective physical units. Note that in the intermediation approach, banks are viewed as facilitating the transformation of the deposits (inputs) into outputs. But, in the production approach, deposits are regarded as output since it is an activity that leads to the increase in operating expenses.[273] Thus, the use of EFA requires us to decide on this issue for the selection of input and output variables. Some authors believe that the bank is a producer while the others consider them as intermediary in the financial market.[274]

We have already seen in the previous chapter that the output variables using the intermediation approach (or the asset approach)are loans, investments, deposits, off-balance-sheet activities; and the input variables are labour, fixed assets and physical capital. Following the intermediation approach we have taken two output variables, (a) loans and advances, and (b) investments, and three input variables, (a) labour, (b) borrowed fund, and (c) capital. These variables are used in Srivastava[275], Das and Drine[276], Mahesh[277], Rajan et al[278], Bhattachryya and Pal[279], Shanmugam and Das[280], Sensarma[281] and Ray and Sanyal[282].

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[273]Srivastava, 'Size Efficiency and Financial Reforms'

[274]According to Sealey and Lindsey, any measure can be used as output and input as long as it is consistent with the researchers' goal.

[275] Srivastava, 'Size, Efficiency and Financial Reforms '

[276] Das and Drine, 'Financial Liberalisation'

[277]Mahesh, 'Liberalisation and Efficiency'

[278]Rajan *et al*, 'Efficiency and Productivity Growth'

[279] Bhattachryya and Pal, 'Financial Reforms and Technical Efficiency'

[280] Shanmugam and Das, 'Efficiency of Indian Commercial Banks'

[281]Sensarma, 'Cost and Profit efficiency'

[282] Ray and Sanyal, 'X-efficiency revisited'

There are also debates in the literature about how these variables should be defined. To this context, following Srivastava, Kwan[283], Altunbas et al [284],[285], Chang et al[286], and Mester[287], we define the variables as follows:

$$\text{Cost (C)} = \text{interest expenses} + \text{operating expenses}$$

Output variables

$$Q_1 = \text{Loans and Advances}$$

$$Q_2 = \text{Investments}$$

Input variables

$$\text{Price of Labour } (r_1) = \frac{\text{Wages}}{\text{Number of employees}}$$

$$\text{Price of fund } (r_2) = \frac{\text{Total Interest Expended}}{\text{Total deposits and borrowings}}$$

$$\text{Price of Capital } (r_3) = \frac{\text{Office Expenses}}{\text{Fixed Assets}}$$

[283] Kwan, 'The X-efficiency'
[284] Altunbas *et al*, 'Efficiency and Risk'
[285] Altunbas *et al*, 'Efficiency in European Banking'
[286] Chang *et al*, 'Efficiency of Multinational banks'
[287] Mester, 'Efficiency in Savings and Loan Industry'

Section III: Functional form

The previous chapter also discusses the alternative functional specifications that are used in the empirical literature on efficiency measurement. We adopt here a translog cost function, which, given our input and output variables, assumes the following form:

$$
\begin{aligned}
&lnC \\
&= \alpha_0 + \alpha_1 lnQ_1 + \alpha_2 lnQ_2 + \alpha_3 lnr_1 + \alpha_4 lnr_2 + \alpha_5 lnr_3 + {}^1\!/_2\, \alpha_{11} lnQ_1 lnQ_1 \\
&+ {}^1\!/_2\, \alpha_{22} lnQ_2 lnQ_2 + {}^1\!/_2\, \alpha_{33} lnr_1 lnr_1 + {}^1\!/_2\, \alpha_{44} lnr_2 lnr_2 + {}^1\!/_2\, \alpha_{55} lnr_3 lnr_3 \\
&+ \alpha_{12} lnQ_1 lnQ_2 + \alpha_{13} lnQ_1 lnr_1 + \alpha_{14} lnQ_1 lnr_2 + \alpha_{15} lnQ_1 lnr_3 + \alpha_{23} lnQ_2 lnr_1 \\
&+ \alpha_{24} lnQ_2 lnr_2 + \alpha_{25} lnQ_2 lnr_3 + \alpha_{34} lnr_1 lnr_2 + \alpha_{35} lnr_1 lnr_3 + \alpha_{45} lnr_2 lnr_3 \\
&+ \varepsilon \qquad (4.27)
\end{aligned}
$$

There are altogether 21 parameters in Equation 4.27. The large number of parameters in such models underscores the need for pooled data in this study. Its time series runs over 19 years so that those parameters cannot be estimated only by the time series data. They can be estimated over the cross-section data as this study takes into account 25 public sector banks, 17 private domestic banks and 15 private foreign banks, that is, 57 banks in aggregate. But two problems crop up to this end. One, the degrees of freedom would be less – only 36. Two, X-efficiency is often conceived as a dynamic phenomenon that varies over time – in fact, the time-variant X-efficiency is current in the literature. A cross-sectional empirical study cannot address these issues. Employing panel data is, therefore, the only option in a study like this. There are 1083 observations in this study so that the degrees of freedom come to 1061.

Section IV: Unit root test

Before the estimation of parameters involved in our model, we should undertake the test for panel unit root to examine whether the panel is stationary.[288] According to Gujarati, a process is said to be 'stationary if its mean and variance is constant over time and the value of the co-variance between the two time periods depends only on the distance or gap or lag between the two time periods and not the actual time at which the covariance is computed.'[289] If a panel is not stationary, the estimated values of the parameters are not reliable. In other words, if the mean and the variance do not remain the same for the series at whatever point in time it is measured, i.e. if the unit root problem prevails, it affects the behavioural properties of the data. A presence of the unit root problem is generally called as 'trending'. If two variables are trending over time, their regression would be spurious. The assumption of asymptotic properties does not hold in such cases, and the t-ratios do not follow the t-distribution. However, stationarity can be of two types, trend stationarity and stochastic stationarity. The commonly used tests to detect the unit root problem are the Dickey-Fuller test (DF), the Augmented Dickey-Fuller test (ADF) and the Levin-Lin-Chu test (LLC).

Dickey-Fuller test is also known as the tau test. The test is conducted under three different null hypotheses relating to the three equations, 4.28 – 4.30.

$$\Delta Y_t = \delta Y_{t-1} + u_t \qquad (4.28)$$

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + u_t \qquad (4.29)$$

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + u_t \qquad (4.30)$$

[288] This test for the panel data has gained importance after the paper by Levin and Lin in 1992 and in 2002 by Levin Lin and Chu.

[289] Gujarati, *Basic Econometrics*, p.797

where t is the time trend. In each of the above cases, the null hypothesis is that δ = 0, i.e. there is a unit root problem.

The DF test assumes that the error terms are uncorrelated. The ADF is an improvement over the DF in that it assumes the error terms correlated among themselves. The ADF augments the three regression equation of the DF into one

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-1} + \varepsilon_t \qquad (4.31)$$

where the null hypothesis is δ =0. This study adopts the ADF test.

The ADF test cannot, however, find out the unit root problem in a panel data. Rather than performing ADF on individual cross-sectional data, pooling approach yields a better result. One of the pioneers in panel unit root is Levin and Lin who developed the methodology in 1993 and developed further in 2002 as Levin Lin and Chu test. Following Levin, Lin and Chu's approach, as adopted in their paper in 2002, we perform the unit root test. This method is particularly useful when the time dimension is small and the number of cross sections large.[290]

The Levin Lin and Chu method considers the following hypotheses:

H_0 (Null hypothesis): each time series contain a unit root

H_1 (Alternate hypothesis): each time series is stationary

The model rests on the following assumptions:

(i) The y_{it} is generated by one of the following three models

Model 1: $\Delta y_{it} = \rho y_{it-1} + \varepsilon_{it}$ (4.32)

[290]Levin *et al*, 'Unit root test in panel data', p.3

Model 2: $\Delta y_{it} = \alpha_{0i} + \rho y_{it-1} + \varepsilon_{it}$ (4.33)

Model 3: $\Delta y_{it} = \alpha_{0i} + \alpha_{1i}t + \rho y_{it-1} + \varepsilon_{it}$ (4.34)

(ii) The error process ε_{it} is distributed idependently and follows a stationary invertible ARMA process for each individual.

Homoskedacticity (i.e. equal variance for the error terms) is an important assumption of the classical linear regression model. The presence of heteroskedacticity leads the estimator to be best linear and unbiased but it no longer remains the efficient estimator

For the description of the production/cost function in the banking literature, the most widely used functional form is the translog function. We use the standard translog cost function in our analysis.

This study uses panel data for estimation purposes. Many advantages are associated with it. Firstly, panel data give more information as the panels bring in the advantage of both cross section and time series data. This makes the panel data better suited to detect changes than a simple cross section or a simple time series data.[291] Secondly, by pooling the data we increase the degrees of freedom for the estimators we deal with. The translog cost function, as we will see shortly, involves a large number of parameters where the number of observation is critical. This is all the more important since there are a limited number of banks in India so that cross-section data would generate a low degree of freedom. It is also limited in a time-series framework since the financial sector reforms took place only in 1991. Obviously, then, the use of panel data is the only alternative. The additional argument is that both time series and cross section data have certain exclusive advantages. Those advantages are 'pooled'

[291]Gujarati, *Basic Econometric*, p.623

together if we deal with the panel data. Kumbhakar adds that panel data helps us to do away with the assumption of independence between the technical efficiency and the regressors.[292]

This study makes use of the balanced longitudinal panel, that is, the time series for each bank is placed followed by the time series of another bank. Our panel is balanced in the sense that there are equal numbers of observations for each bank.

Section V: Summary and comparison of variables used

Our discussion in methodology suggests that the dataset should include six variables, namely total cost (C), two output variables - (a) loans and advances (Q_1) and (b) investment (Q_2), - and three Input prices - (a) price of labour (r_1), (b) price of fund (r_2), and (c) price of capital (r_3). These variables have already been defined in the previous section. The time period of the study spans over a period of 19 years starting from 1994 to 2012. Since we seek to employ a balanced panel, this study avoids the banks that have missing values in the time span under study, and also those that do not exist prior to 1998. Only 57 banks qualify these criteria. Of these, 25 banks belong to the public sector (PSB), 17 to the private domestic sector (PDB), and the rest 15 to the private foreign sector (PFB). The data are presented in the annexure 2-4, and table 4.3 contains their statistical summaries.

In the statistical summary for each variable, the table is arranged according to the ownership of banks, namely, public sector banks, private domestic banks and private foreign banks. In 2012, there were altogether 26 public sector banks, 44 foreign private banks and 20 private domestic banks. But, in 1994, there were 27 public sector banks, 24 private domestic banks and 23 private foreign banks. For balanced panel and for data constraints – in particular, missing values in the data set -

[292] Kumbhakar and Lovell, *Stochastic frontier analysis*, p.96

we have not considered two public sector banks, three private sector domestic banks and twenty nine private foreign banks. This leaves us with 25 public sector banks, 17 private domestic banks and 15 private foreign banks in this study. The requisite data for estimation of the model are collected from various publications of the Reserve bank of India, namely, the Profile of Banks (various issues) and the Statistical Return of Banks (various issues).[293]

Table 4.2 gives an overview of the activities of different types of banks. Four basic characteristics are discussed here: paid-up capital, branches, employment and deposits. The average paid-up capital amounts to Rs.56,360.46 lakhs for public sector banks, Rs.11,922.43 lakhs for private domestic banks, and Rs. 59,092.96 lakhs for private foreign banks, suggesting that foreign banks run with higher capital base, compared even to public sector banks. The ratio between them stands at 1: 0.95. The gap appears astonishing if private domestic banks are brought under study. Compared to them, private foreign banks' paid-up capital exceeds about five times. These data reflect the problem of the capital adequacy ratio, about which the international banking authority is concerned.[294] The capital adequacy ratio had been as low as 11.28 for public sector banks[295], 12.21 for private domestic banks, and 15.40 for private foreign banks in 2001. It improved to 12.11, 14.50, and 26.81 respectively in 2012.

It is, however, customary to read capital along with labour, which helps us to understand the banking technology, especially as to its capital-intensity. The level of employment stood, on the average, at 31,533 in public sector banks, 5438 in private

[293] www.rbi.org.in on 23rd November 2014

[294] One of the three pillars of Basel III is capital adequacy to meet risk. It is defined as the ratio of Tier1 capital, Tier 2 capital Tier 3 capital to the risk weighted average.

[295] Indian Bank has a negative CAR in March 2002.

domestic banks and 957 in private foreign banks. Therefore, the average capital-labour ratio comes to 1: 0.5594, 1: 0.4561 and 1: 0.0162 for the respective groups of banks. Thus, the banking technology in the public sector appears most labour-intensive. This result confirms the fact that profit maximisation is not the primary objective of those banks;[296] But they continue the practice of social banking that was institutionalised in India in the early 1969 prior to the nationalisation of major banks.[297] The capital intensity is, however, highest among private foreign banks, and they have achieved it by way of mechanising the banking technology at the highest level. Higher capital intensity among foreign banks is also learnt from the fact that the capital per branch was Rs.5211 lakhs for them as against Rs. 33 lakhs for private banks and Rs.27 lakhs for public sector banks. They score high in terms of staff per branch as well. For the respective groups of banks, it comes to 84.469, 15.172 and 15.206.

It is interesting to note that, by the index of deposits per branch, private foreign banks are again the topper. It was about Rs.55,535 lakhs for them - as against Rs.5,728 lakhs for private domestic banks and Rs.3,312 lakhs for public sector banks. Thus, deposits per branch stood at about 10 times higher than that for private domestic banks and at about 17 times than that for public sector banks. This might be explained by the fact that the foreign banks had very few branches in comparison to the private banks and public banks. However, deposits generated per unit of capital are highest among private domestic banks. It was Rs 172.207 lakhs for them, but only Rs. 121.8791 lakhs for public sector banks and Rs 10.657 lakhs for private foreign banks.

[296]The managerial theories of firm state that such firms should have more employment than a profit maximizing firms.
[297]Natarajan and Parameswaran, *Indian banking,* pp. 24-25

Table 4.2 Paid-up capital, employment, branches and deposits of commercial banks in India (Average for 1994-2012)

(Rs. In Lakhs)

Particulars	Public Sector Banks			Private Domestic Banks			Private Foreign Banks		
	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest	Average
Paid-up Capital	187100.5 $(INDB)$	17993474 (SBH)	56360.46	72417.85 $(ICICI)$	28.36 $(TAMNB)$	11922.43	151442.8 $(BARCB)$	3298.09 $(ADCOMB)$	59092.96
Employment	216982.7 (SBI)	10323.42 (SBM)	31533.16	19499.42 $(ICICI)$	657.68 $(NAINB)$	5438.15	4553.11 $(STANCB)$	50.68 $(OMINB)$	957.88
Branches	10466.79 (SBI)	646.158 (SBM)	2073.72	853.63 $(ICICI)$	71.74 $(NAINB)$	358.43	62.26 $(STANCB)$	1 $(JPMC)$	11.34
Deposits	40516653 (SBI)	1768534 (SBM)	6869163	10094488 $(ICICI)$	118011.8 $(NAINB)$	2053127	2238978 $(STANCB)$	78875.37 $(ADCOMB)$	629769.2

Source: Annexure.5-8

Table 4.3 Annual Average values of the variables under study, 1994-2012
(Rs in Lakhs)

Particulars	Public Sector Banks (no. of banks = 25)	Private Domestic Banks (no. of banks = 17)	Private Foreign Banks (no. of banks = 15)
Cost	564,200 (22,568)	197,123 (11,595)	66,957 (4,464)
Loan and Advances	4,668,683 (186,747) [8.27]	1573728 (92,572) [7.98]	494281 (32,952) [7.38]
Investment	2,427,270 (97,091) [4.30]	889,292 (52,311) [4.51]	377,320 (25,155) [5.64]
Price of Labour	3.3431	2.9473	13.0028
Price of fund	0.0630	0.0659	0.0621
Price of Capital	0.2372	0.2152	0.6850

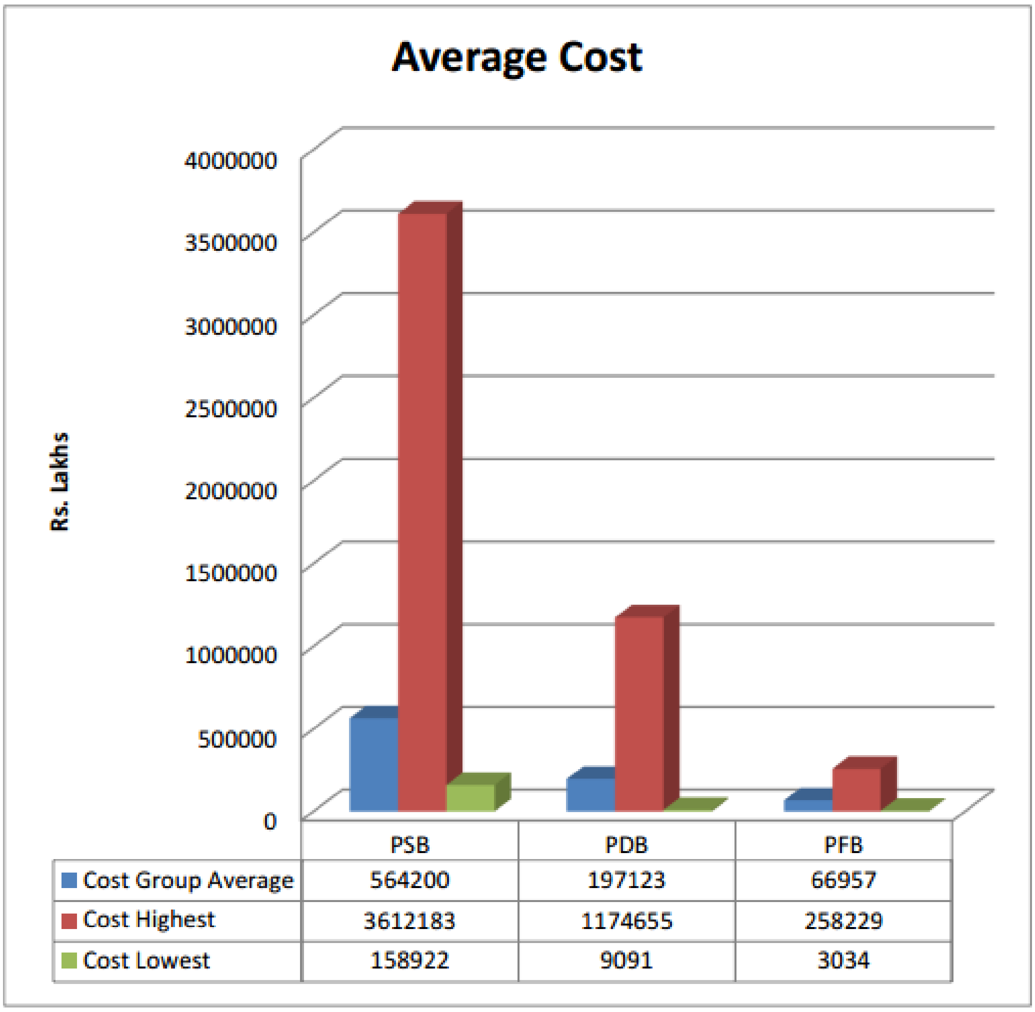
Source: Annexure 9-11

N.B. Figures in the first bracket indicate the respective values per bank, and the third bracket their values per unit of cost.

Table 4.3 represents the annual average values of the variables under study over 1994-2012. Since the banks are not of equal number in all groups, those figures may be misleading. We, therefore, present those average values per bank. Since various outputs are produced by incurring operating costs, interest payments as well as using paid-up capital, we also express the outputs per unit of cost (i.e. operating costs and interest payments) and per unit of capital employed. For the cost and output variables, the intra-group variations are shown by placing the group average side by side the highest and lowest figures in Figures 4.1-4.3.

The cost variable, however, assumes the highest value for public sector banks – Rs 22,568 lakhs per bank – followed by private domestic banks (Rs. 11,595 lakhs), and private foreign banks (Rs. 4,464 lakhs). Among all banks, the State Bank of India (a public sector bank) assumes the highest value, and the Oman International bank (a private foreign bank), the lowest value (Fig. 4.1). Insofar as the cost, by definition, indicates the volume of business (i.e. the scale of operations), these figures entail that public sector banks are by far the largest banking organisations in India – about double in size compared to private domestic banks, and five times than that of private foreign banks. These observations have also been corroborated in the previous table where we have found that, in terms of the number of branches, employees, as well as deposits, public sector banks scored the highest.

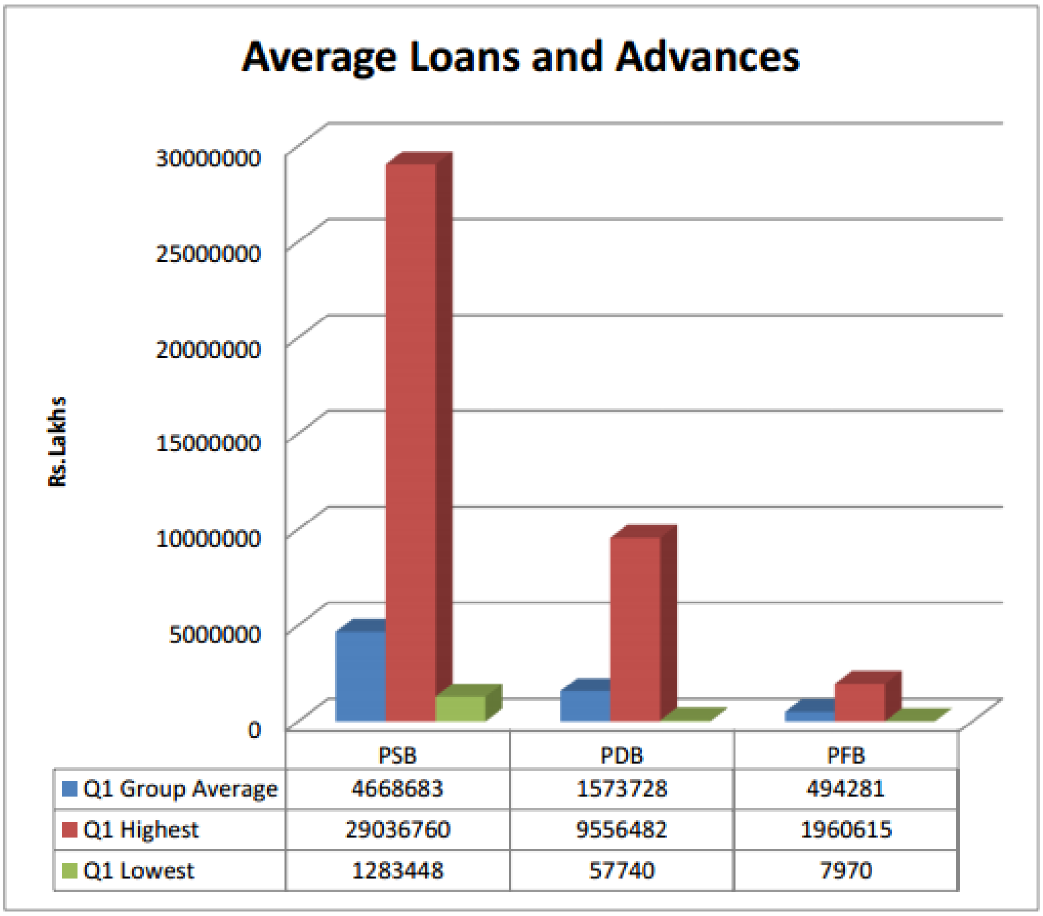
Fig 4.1. The cost variable



Source: Annexure 9

If we look at the output variable, loans and advances, the scale-wise difference among various groups is again confirmed. For each bank, it assumes a value of Rs. 186,747 lakhs for public sector banks, Rs. 92,572 lakhs for private domestic banks, and Rs. 32,952 lakhs for private foreign banks. The bank-specific analysis (Fig. 4.2), however, shows that, for all banks taken together, loans and advances are highest for the State Bank of India, and lowest for the Oman International bank. The extent of scale difference in this case is almost same as we notice in respect of cost. Public sector banks are 2.01 times larger than private domestic banks, and 5.66 times larger than private foreign banks. Larger scale, indeed, generates the economies of scale. This is confirmed in figures relating to the level of this output per unit of cost. Each unit of cost yields this output by Rs. 8.27 for public sector banks, Rs. 7.98 for private domestic banks, and Rs. 7.38 for private foreign banks.

Fig 4.2 Output variable (Q_1): Average Loans and Advances

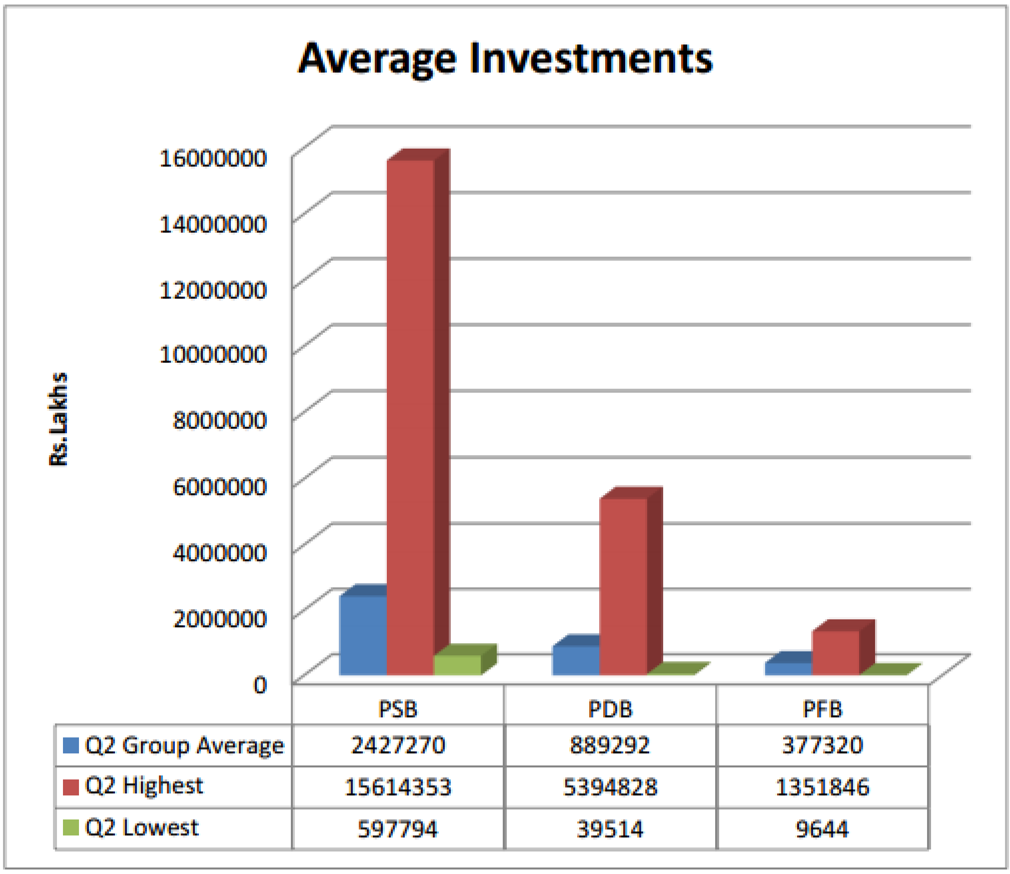


Source: Annexure 10

However, from the standpoint of the other output variable, namely, investment, a different scenario emerges, despite the fact that its ranking per unit of bank remains the same - Rs. 97,091 lakhs for public sector banks, Rs. 52,311 lakhs for private domestic banks and Rs. 25,155 lakhs for private foreign banks. The ranking of banks is also same as before in terms of the extremities - the State Bank of India is the largest and the Oman International bank, the smallest. But the investment per unit of cost comes to Rs. 4.30, Rs. 4.51 and Rs. 5.64 respectively. This is not indeed a case of scale inefficiency, but might be an outcome of scope inefficiency, and/or X- inefficiency. The former case arises due to larger product-mix, and, in the case of private banks (both domestic and foreign), we notice more of off-balance-sheet investments. The issue of X-efficiency becomes relevant in view of the fact that, in the post-reform period, risk elements have multiplied in India's banking business, whereas the risk-absorbing mechanism has not been adequately developed. In such circumstances, the managers in public-sector banks are scared to properly invest the available fund, giving rise to the problem of what is called 'lazy banking'.[298] Managers in the private sector, on the other hand, are to work with risks under the pressure of market competitions - an important component of Leibenstein's X-efficiency concept.

[298] Mohan, 'Economic Growth', p. 1

Fig 4.3 The output variable (Q_2): Average Investment



Source: Annexure 11

Amongst the input price variables, only the price of labour varies widely across the bank groups. It was 3.3431 for public sector banks, 2.9473 for private domestic banks and 13.0028 for private foreign banks. There is no significant difference between the former two groups, only 13.42 per cent. But, compared to public sector banks, private foreign banks provide 3.88 times higher compensation. This may be explained by the marginal productivity theorem, which states that the factors of production are compensated according to their marginal productivities. In this case, we have already noticed that private foreign banks operate with a highly capital-intensive technology so that the marginal productivity of their staff should be much higher than that in other banks. Hence, those banks are able to pay higher salaries. The prices of fund are, however, seen close to each other for different groups. It was Rs. 0.0630 for public sector banks, Rs. 0.0659 for private domestic banks and Rs. 0.0621 for private foreign banks – a variation of only 1.06 per cent between the highest and lowest figures. Perhaps, it is due to RBI's interest rate policy for commercial banking, which has been de-regulated only in the fourth quarter of 2011.

Section VI:

This chapter thus resolves four basic issues regarding the methodology. First, it discusses in detail two alternative methods for the measurement of efficiency, the Data Envelopment Analysis (DEA) and the Stochastic Frontier Analysis (SFA). After a thorough exposition of their comparative efficacies in the measurement of commercial banks' X-efficiency, it appears that the latter tool is better suited for our purpose. Secondly, of various functional forms that are in use in the literature, we decide to employ the translog specification, which can represent multi-product firms, and accommodates, at the same time, various swings in average costs. Thirdly, it deliberates on the question of whether commercial banking is a production agent or an intermediate institution since the identification of inputs and outputs depends on this issue. After a comparative analysis between the production approach and the intermediary approach, we take up the latter for our purpose. Fourthly, among alternative sets of inputs and outputs that various authors adopt, this study develops a model based on two outputs, (i) loans and advances, and (ii) investment, and three input prices, (i) price of labour, (ii) price of fund, and (iii) price of capital. Lastly, the SFA literature also witnesses various methods of estimation. We propose to employ two competing tools, the GLS method and the MLE method so that we can arrive at a better set of judgements.

For the sake of higher degrees of freedom, as also to obtain the advantages of both time series and cross-section data, we propose to use the panel data for the purpose of computation. But its use warrants the test of the existence of unit root in the panel data. We initially propose to apply the augmented Dickey-Fuller (ADF) Test and Levin-Lin-Chu (LLC) Test, but finally advocate the latter for its suitability in the panel data.

This study deals with India's commercial banking institutions. It takes up 57 banks to analyse the effects of the financial sector reforms on their X-efficiencies. Of them, there are 25 public sector banks, 17 private domestic banks and 15 private foreign banks. We discuss in a nutshell four basic features of these organisations – paid-up capital, deposits, branches and employment – categorising them in the above-mentioned groups. We have also presented, and briefly discussed, data relating to model variables - the cost variable, the output variables and the input variables.