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Tianshu Zhao

(University of Stirling)

Barbara Casu
(Cass Business School, City University London)

Alessandra Ferrari
(University of Reading)

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Tianshu Zhao[a], Barbara Casu[b,*], Alessandra Ferrari[c*]

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Abstract:

This paper examines the impact of regulatory reform on TFP growth and its sources and on the relationship between ownership and cost efficiency for Indian banks in 1992-2004. The methodology consists of the joint use of parametric and non-parametric techniques to estimate efficiency frontiers. Both approaches show that the Indian banking industry, after an initial adjustment phase, experienced sustained productivity growth driven mainly by technological progress. Results also indicate a changing relationship between cost efficiency and ownership structure along with the reform processes, and decreasing mean cost efficiency at the aggregate industry level.

Key words: Deregulation; Productivity Change; Ownership; DEA; Malmquist Index; Stochastic Frontier Analysis.

JEL Classification: G21; G28; G32; D24; C16; C23

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[a] Department of Economics, Stirling University, UK (tianshu.zhao@stir.ac.uk) ; [b] Cass Business School, City University, London, UK (b.casu@city.ac.uk) ; [c*] Corresponding Author : School of Economics, The University of Reading, UK (a.ferrari@henley.reading.ac.uk).

1. Introduction

Recent years have witnessed a tendency towards the reform of banking sectors almost everywhere in the world, the emphasis typically being on developing competition in order to promote productive financial systems and to help the general development of the economy. Deregulation is usually expected to stimulate productivity growth via the general advancement of production technology and the efficiency improvements of individual banks. The positive impact of financial reforms on the technology of production is typically based on two arguments. First, the reduction of regulatory costs will decrease the cost of producing a given level of output. Second, regulatory reforms usually reduce restrictions on activities, thereby offering the opportunity for banks to take advantage of economies of scale and scope. Efficiency improvements are expected to arise from the increased competitive pressures that reduce managerial sloth and slack and reduce the relevance of the corporate governance structure. Despite these theoretical hypotheses, the existing empirical evidence is extremely mixed, with some studies reporting improvements in productivity following financial reforms while others suggest little, no, or even negative productivity growth[1]. The controversy relates also to the sources of productivity growth (technological progress, scale or efficiency improvements) as well as on the relevance of corporate governance, i.e. the relationship between ownership structure and efficiency and productivity changes[2]. A final contributory factor to this empirical inconsistency is that different, competing methodologies can be used to analyse these issues.

The aim of this paper is to provide solid evidence on the effects of regulatory reforms on productivity growth, its sources and on the relationship between cost efficiency and ownership structure. The data set is a balanced panel of 65 commercial banks, which includes public sector, domestic private and foreign banks continuously operating in India over the reform period 1992-2004. Methodologically, we use two complementary approaches to estimate cost frontiers and then to measure productivity change and its components: the non parametric Data Envelopment Analysis (DEA), followed by a Malmquist index of Total Factor Productivity (TFP); and the parametric, Stochastic Frontier Analysis (SFA), followed by the measurement of a Divisia index. Unlike most of the literature, for the decomposition of the Malmquist index we do not follow Färe *et al.* (1994), since their method, albeit very popular, is actually valid only under the assumption of constant returns to scale. We follow instead the method proposed by Ray and Desli (1997), which is valid under variable returns to scale and allows the proper separation of scale effects from the rest. This has obvious public policy implications, and is one of the most important applications of productivity indexes (Kumbhakar and Lovell, 2003). Since one of the aims is to test whether the different methodologies lead to similar policy conclusions, both approaches share a common framework in terms of dataset, variables definition and behavioural assumptions.

Furthermore, the Indian case is particularly suited to our research questions since it is a representative illustration of a gradualist approach to reform a banking system that was characterised by “financial repression”. The reforms started in 1992 and were guided by two Narasimham Committee reports, in 1991 and 1998 respectively. The period 1992-1997 saw the introduction of policy instruments aimed at promoting competition (deregulation), whereas from 1998 onwards the policy focus shifted towards the long run stability of the banking system (prudential re-regulation). [3] The whole reform process and its effects can thus be divided, at least in theory, in two stages with the year 1997 as the watershed. Moreover, the Indian Government introduced a uniform regulatory framework to the different ownership structures, which gives us an opportunity to investigate the impact of regulatory reform on the ownership-performance relationship in a market with a level playing field.[4] Finally, despite its relevance, empirical investigations of the Indian case are surprisingly sparse. [5]

The rest of the paper is organised as follows: Section 2 outlines the methodology used for measuring cost efficiency, total factor productivity (TFP) change and its decomposition. Section 3 discusses the data set and variables. Section 4 discusses the empirical findings and Section 5 concludes.

2. Methodology

Total factor productivity change is the measurement of the change in outputs controlling for the inputs used, and it can be divided into different components. The estimation of efficiency frontiers provides a mean for measuring productivity change and it comprises two main approaches: the parametric, econometric estimation of stochastic frontiers (SFA) and the non-parametric Data Envelopment Analysis (DEA). Parametric techniques require an explicit specification of a production function common to all observations, and link inefficiency and its changes to a composite error term composed by random errors and inefficiency whereas technical change is linked to the estimated function's parameters. DEA, on the other hand, is a linear programming technique that “envelops” the actual observations in the sample; it has the advantage of not requiring the specification of a production function, therefore allowing more heterogeneity among observations, but the disadvantage of being a deterministic methodology, so that any deviation from the frontier is attributed to inefficiency and the estimations are very sensitive to outliers. The two approaches have therefore complementary characteristics and consistency in their results strengthens the analysis and is particularly useful for regulators and other decision makers (Bauer *et al.*, 1998; Casu *et al.*, 2004).

More in detail, suppose that at any time t there are N firms that use a vector of k inputs, $X = (x_1, x_2, ...x_k)$, to produce a vector of m outputs, $Y = (y_1, y_{2,} ...y_m)$. The inputs feasibility set $L^t(Y^t)$ represents all the output levels that are feasible at any time t, i.e. that can be produced with given inputs levels. It is in this context that one defines the concepts of productivity and efficiency: the former is a general measure of the ratio of output(s) to input(s), the latter entails a comparison of the actual (observed) ratio to an optimal one which is usually referred to as the “frontier”: the maximum attainable output given a set of inputs, or the minimum level of inputs required to produce a given level of output. Efficiency of a particular firm is then defined as a distance from this frontier, i.e. by means of a “distance function”. The distance function was defined by Shephard (1953, 1970), and it is the reciprocal of the efficiency measure of Debreu (1951) and Farrell (1957); in an input-minimisation orientation it is defined as the equiproportionate decrease in inputs necessary to reach the frontier, i.e. it is a *radial* measure.

Using Shephard's notation, in the input minimisation perspective the input distance function is

$$D^t\left(Y^t, X^t\right) = \sup_{\lambda}\left\{\lambda : \frac{X^t}{\lambda} \in L^t(Y^t)\right\} \tag{1}$$

where $D^t \geq 1$: values of D^t equal to 1 indicate efficiency, and values larger than 1 indicate inefficiency.

In the next two subsections we describe how the frontier and therefore the distance function can be estimated using non parametric and parametric techniques.

2.1. The non-parametric approach of DEA

DEA is a mathematical linear programming technique, initially proposed by Charnes, Cooper, and Rhodes (1978, 1981), that constructs a piece-wise linear convex frontier from the linear combination of the best practices among the observations. It is against this best practice that the efficiency of each firm is then assessed. The input-oriented technical efficiency of each firm in the sample, under the assumption of constant returns to scale (CRS), is measured as:

$$\begin{aligned}
&\{D^t{}_c(x_{it}, y_{it})\}^{-1} = \min_{\theta,\lambda} \theta_i \\
&\text{s.t.} \quad \sum_{r=1}^{N} y^t{}_{mr}\lambda^t{}_r \geq y^t{}_{mi} \\
&\qquad \sum_{r=1}^{N} x^t{}_{kr}\lambda^t{}_r \leq \theta_i x^t{}_{ki} \\
&\qquad \lambda^t{}_r \geq 0
\end{aligned} \tag{2}$$

where $\theta_i = 1/D_i^t$ is the scalar technical efficiency score for unit *i*, and $\theta_i \leq 1$, with $\theta_i = 1$ implying technical efficiency and viceversa. The set up can be changed to allow for variable returns to scale (VRS) by introducing the restriction $\sum_{r=1}^{N} \lambda_r^{\,t} = 1$. The above calculations are repeated N times, once for each firm in the sample.

Productivity change can be measured by means of a Malmquist index (Malmquist 1953; Caves *et al.*, 1982), which is a measure of the change in the ratio of outputs to inputs over time and is defined as

$$M(x_{t+1}, y_{t+1,} x_{t,} y_t) = \left(\frac{D_c^{\,t}(y_t, x_t)}{D_c^{\,t}(y_{t+1}, x_{t+1})} * \frac{D_c^{\,t+1}(y_t, x_t)}{D_c^{\,t+1}(y_{t+1}, x_{t+1})} \right)^{1/2} \qquad (3)$$

where the subscript c indicates CRS. Equation (3) is the geometric mean of the ratios of distance functions estimated using times t and $t+1$ as a benchmark. The index is correctly defined even if the available technology is characterised by VRS, as long as the potential contribution of scale economies to productivity change is incorporated into its decomposition (Mukherjee et al, 2001; Orea, 2002).

Färe *et al.*, (1994) provided the first non-parametric decomposition of the Malmquist index by rearranging equation (3) so as to distinguish the changes in technical efficiency (the movements of units towards, or away from, the frontier) from technological progress (the movement of the frontier itself). However their decomposition has the shortcoming of being valid only under CRS. To allow for VRS and for the separation of scale effects from the remaining changes, we follow Ray and Desli (1997), and define the Malmquist index as:

$$M(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{D_v^{\,t}(x_t, y_t)}{D_v^{\,t+1}(x_{t+1}, y_{t+1})}\right] * \left[\frac{D_v^{\,t+1}(x_t, y_t)}{D_v^{\,t}(x_t, y_t)} \frac{D_v^{\,t+1}(x_{t+1}, y_{t+1})}{D_v^{\,t}(x_{t+1}, y_{t+1})}\right]^{1/2} *$$

$$* \left[\frac{D_c^{\,t+1}(x_t, y_t)}{D_v^{\,t+1}(x_t, y_t)} \frac{D_v^{\,t+1}(x_{t+1}, y_{t+1})}{D_c^{\,t+1}(x_{t+1}, y_{t+1})} \frac{D_c^{\,t}(x_t, y_t)}{D_v^{\,t}(x_t, y_t)} \frac{D_v^{\,t}(x_{t+1}, y_{t+1})}{D_c^{\,t}(x_{t+1}, y_{t+1})}\right]^{1/2} \qquad (4)$$

The right hand side of equation (4) is made up of three separate components, which are respectively the change in technical efficiency, technological change, and scale change. For each of them a score larger/smaller than unity indicates an improvement/worsening of the corresponding measure and a score equal to 1 indicates no change. The same is true for the overall TFP measure resulting from the multiplication of the three scores.

2.2. The parametric approach of SFA

The stochastic frontier model was proposed independently and at the same time by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broek (1977). In its essence the model consists of a (cost or production or profit) function with a composite error term, made up of two separate, although jointly estimated, components: stochastic noise and inefficiency. As discussed in Section 1, theory predicts that regulatory reform will alter the existing cost-output relationship. We therefore estimate a stochastic cost frontier, under the assumption that firms aim at minimizing their total operating costs subject to the production possibility frontier and some exogenously given factors. Since we want to establish a link between regulatory change and productivity growth, we model these exogenous factors through a time trend variable covering the whole regulatory reform period (1992-2004) and a variable indicating the switch of regulatory reform from the first stage (1992-1997) to the second stage (1998-2004). By doing so, we investigate the cost-output dynamics for the whole reform process in general and its variation between the first and the second stage in particular. Under certain regularity conditions, the model can be written in very general terms as:

$$\ln C_{it} = \ln C(W, Y, R, T; \beta) + u_{it} + v_{it} \quad (5)$$

and

$$u_{it} = \delta' Z + \varepsilon_{it} \quad (6)$$

Equation (5) represents the cost frontier, where C_{it} is the observed total operating cost of firm *i* at time *t,* a function of the vector of inputs prices W and of the vector of outputs Y. R is a dummy variable set equal to 1 for the period 1998-2004 and zero otherwise. T is a time trend capturing exogenous technological change, which will be introduced in the equation quadratically. β is a vector of technological parameters to be estimated.

u_{it} is the non-negative cost inefficiency term which is assumed to be independently but not identically distributed. It is obtained by the truncation at zero of a normally distributed variable, namely $u_{it} \sim N^+(\delta' Z_{it}, \sigma_u^2)$.

v_{it} is a random error coming from a normal distribution with mean 0 and constant variance σ_v^2 and independent of both the regressors in (5) and of u_{it}.

Equation (6) models the determinants of inefficiency as a set of bank-specific explanatory variables Z with a vector δ of parameters to estimate. The random error $\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$ is truncated at the variable point $-\delta' Z_{it}$ to allow for the non-negativity constraint on u_{it}, so that $\varepsilon_{it} \geq -\delta' Z_{it}$. ε_{it} is assumed to be independently but not necessarily identically distributed, nor is it required to be non-negative.

To estimate (5) we choose the flexible translog functional form[6] so the model becomes:

$$
\begin{aligned}
\ln C_{it} &= \beta_0 + \sum_{m=1}^{m} \alpha_m \ln y_{mit} + \sum_{k=1}^{k} \beta_k \ln w_{kit} + \sum_{m=1}^{m} \sum_{j=1}^{m} \alpha_{mj} \ln y_{mit} \ln y_{jit} + \\
&+ \sum_{n=1}^{k} \sum_{k=1}^{k} \beta_{nk} \ln w_{nit} \ln w_{kit} + \sum_{k=1}^{k} \sum_{m=1}^{m} \gamma_{km} \ln w_{kit} \ln y_{mit} + \\
&+ \lambda_1 T + \lambda_2 T^2 + \sum_{m=1}^{m} \theta_m T \ln y_{mit} + \sum_{k=1}^{k} \zeta_k T \ln w_{kit} + \\
&+ a_r R + a_{rt} RT + \sum_{m=1}^{m} \ell_m R \ln y_{mit} + \sum_{k=1}^{k} \rho_k R \ln w_{kit} + v_{it} + u_{it}
\end{aligned}
\qquad (7)
$$

The analysis of the effect of regulatory reform on the relationship between cost efficiency and ownership structure is modelled in equation (6), which becomes:

$$
\begin{aligned}
u_{it} &= \delta_0 + \delta_1 D_F + \delta_2 D_P + \delta_3 D_F T + \delta_4 D_P T + \delta_5 T + \delta_6 R + \delta_7 RT + \delta_8 RD_F \\
&+ \delta_9 RD_P + \delta_{10} RD_F T + \delta_{11} RD_P T + \delta_{12} T^2 + \varepsilon_{it}
\end{aligned}
\qquad (8)
$$

Equation (8) includes 12 explanatory variables to reflect the separate and interactive effects of time, change in regulatory reform stages and ownership structure. D_F and D_P are ownership dummy variables, taking a value of 1 for foreign and private banks respectively. R, T and ε_{it} are defined as before, so public sector banks before 1998 are the reference ownership category.

To measure productivity change we follow the procedure outlined in Kumbhakar and Lovell (2003) and calculate a Divisia index with multiple inputs and multiple outputs[7], which is defined as

$$\dot{TFP} = \dot{Y} - \dot{X} = \sum_m P_m \dot{y}_m - \sum_k S_k \dot{x}_k \qquad (9)$$

where $P_m = p_m y_m / TR$ is the observed revenue share of output y_m, p_m is the price of output y_m and $TR = \sum_m p_m y_m$ is total revenue. $S_k = w_k x_k / C$ is the observed cost share of individual input factors. Equation (9) can be rewritten as:

$$\dot{TFP} = [1 - \varepsilon(Y, W, R, T; \beta)]\dot{Y}^c + \sum_{k=1}^{k} [S_k - S_k(Y, W, R, T; \beta)]\dot{w}_k + \\ -\frac{\partial U}{\partial t} - \dot{C}(Y, W, R, T; \beta) - \frac{\partial \ln C}{\partial R} + (\dot{Y} - \dot{Y}^c) \qquad (10)$$

To keep the analytical detail at a minimum[8], we can see equation (10) as comprising 6 components: a positive net value in each of them translates into a positive growth in TFP, to be interpreted as follows. The first component measures *the scale effect*, with a positive value indicating an improvement in the scale of operation and viceversa. If returns to scale are increasing, cost elasticity ε <1 and so an increase in output $\left(\dot{Y}^c > 0\right)$ contributes positively to TFP. Similarly if ε > 1 and $\dot{Y}^c < 0$. The second component is a measure of allocative inefficiency, specified as a deviation of the observed inputs cost shares from their optimal ones. The third component measures the total change in cost inefficiency over time (i.e. allocative and technical). A negative value of the time derivative would imply a decrease in inefficiency and therefore an improvement in TFP growth. Technical change is represented by the fourth and fifth components: the former represents shifts of the frontier due to the passing of time, the so-called *disembodied cost technology change*; the latter captures exclusively the impact on TFP of the switch in regulatory focus before and after 1998.

Finally, following Kumbhakar and Lozano-Vivas (2005) we name the term $(\dot{Y} - \dot{Y}^c)$ the *mark-up effect*: it represents departures from marginal cost pricing and/or from an equi-proportionate mark-up for every output (Denny *et al.*, 1981). To compute equation (10) we will use the parameters estimates of equations (7) and (8).

3. Data and variables definition

For our analysis we consider commercial banks continuously operating throughout the period 1992-2004. Focusing on the behaviour of continuously operating banks is all the more important given the substantial changes in the environment in which those banks operated during our study period. The data were collected from the Reserve Bank of India. With the guide of homogeneity criteria, we excluded regional rural banks due to their regional business focus, which is different from the nation- wide operations of other commercial banks. Data were analysed for inconsistencies and outliers. If banks merged during the period of observation, we chose to aggregate their financial statements and treat them as a single composite bank for the entire period. In sum, the data set contains 13 years of accounting data for 65 banks[9] (27 public, 20 domestic private and 18 foreign), for a total of 845 observations. All data were deflated using the GDP deflator using 1991 as a base.

To identify the inputs and outputs variables we follow the intermediation approach (Sealey and Lindley, 1977). For both the parametric and non-parametric analysis we employ a three-output specification: performing loans[10], other earning assets[11] and fee-based income. The revenues with respect to these three outputs are given by interest income on loans[12], interest income on total other earning assets and non-interest income respectively. The specification of the inputs is instead slightly different. In the parametric approach we employ a two-input definition, namely, total loanable funds (the sum of deposits and money market funding) and non-interest operating cost (the expenditure associated with labour and physical capital). The price for total loanable funds is calculated as the ratio of total interest expenditure to total loanable funds, and the price for non-interest operating cost is given by the ratio between non-interest operating cost and total assets. In the non-parametric approach we aggregate the two cost expenditures into a single input. This different treatment on the inputs side is due first of all to the well-known dimensionality problem associated with DEA, which arises as the number of variables increases relative to the number of observations: this leads to more units being wrongly rated as efficient, because the high number of constraints specified makes the units incomparable with each other[13]. Given the aims of this study, we are particularly concerned with two forms of potential bias that the dimensionality problem could cause: too high levels of efficiency would imply little room for improvement, therefore, empirical evidence would tend to report that efficiency change makes no contribution to productivity growth. Secondly, the estimated technology frontier might be unstable, giving confusing results about technical change (Thirtle *et al.* 2003). Our suspicions were confirmed when we tried alternative inputs specifications: almost 15% of the observations were identified as super-efficient in each cross-section[14] and the average technical efficiency scores were higher than 0.90. Finally, an additional benefit of this specification is that the single total cost input which is minimised in DEA is much more readily comparable with the cost frontier estimated econometrically, so in the end the three components of TFP growth derived from equation (4) match their parametric counterparts. Summary statistics for outputs and inputs are given in Table 1.

<Insert Table 1 here>

4. Empirical results

4.1 Non-parametric approach

For the analysis of TFP change, Table 2 illustrates the year-by-year Malmquist index results and their components for the whole industry and in the two sub periods.

<Insert Table 2 here>

Over the entire sample period the industry registers an average annual TFP growth rate of 5.07 %, which is explained almost entirely by technical change (5.06%), whereas technical efficiency contributes only by a 0.8% per year and scale effects appear to have a negative effect (-0.79%). These changes are not however uniform. The first years of the reform, between 1992 and 1997, are characterised by oscillations in technical change, which on average regresses by a –1.19% a year, and corresponding, opposite efficiency changes (2.16%); this is followed by a period of relative stability and then by steady improvements especially from 2000 onwards. In the second stages of the reform, technological progress leads the TFP improvements with average yearly increases of 9.77%, whereas efficiency declines by -0.16% and scale effects remain negative (-0.79%). These results suggest that banks had an initial period of adjustment to the new operational environment, during which they concentrated into improving their efficiency within the more traditional technological framework. Only after a few years, into the later stages of the reform, technological change really starts to take off, pushing the frontier outwards; a higher frontier is more difficult to reach, which explains the negative efficiency change; its value is however relatively small so that the sector overall experiences positive TFP changes of over 8% per year.

As regards the relationship between ownership and efficiency, Table 3 shows the yearly average efficiency scores for the three ownership types.

<Insert Table 3 here>

The highest average efficiency score over the whole period is enjoyed by public banks (88%), followed by foreign banks (86%) and private banks (79%). Foreign banks start off as the most efficient but are soon caught up by public banks which overtake them in 1996 and maintain higher efficiency levels pretty much ever since, although the difference between the two ownerships is not significant (see Table 4). Private banks are rated as the least efficient during the whole sample period, even though they display an improvement over time. The results on domestic private banks are not very surprising. They are the smaller banks that remained privately owned following two rounds of nationalisation, and their main customers are informationally opaque small firms. Their operating conditions were initially relatively weak and they presumably feared being nationalised if they became well-established. Foreign banks have theoretically the double advantage of a strong customer base, characterised by large, well established and credit-worthy firms, as well as a better operational structure and international standards. The results however indicate that their advantage is only short lived since public banks are capable of adjusting to the new operational conditions and catch up.

4.2 The parametric approach

For the parametric analysis we follow Battese and Coelli (1995) and estimate equations (7) and (8) simultaneously with a Maximum Likelihood one-step procedure. Linear homogeneity of degree one in input prices and Young's symmetry are imposed prior to estimation. A series of hypotheses related to the nature of the frontier model[15] and to the consistency of the cost function with its theoretical properties is then tested by means of Likelihood Ratio (LR) tests. The null hypothesis is rejected at a 1% level of significance in all cases except for the joint significance of the interaction between the dummy variable and the other covariates. Moreover, the presence of these interactive terms turns out to be inconsistent with several regularity conditions of the cost function. We therefore withdraw these variables and re-estimate equations (7) and (8). The new estimations pass all the tests and the results are reported in Table 5, which shows that 19 out of the 22 parameters of the cost frontier and 11 out of the 13 parameters of the cost inefficiency model are significant at least at the 10% level[16]. The results on the analysis of TFP growth and its components are reported in Table 6.

<Insert Table 5 here>

<Insert Table 6 here>

Looking first at Table 6, consistently with the non parametric analysis, TFP shows a positive growth over the whole sample period (in this case a much lower 1.1 % per year) mainly due to the positive improvements that take place in 1998-2004. In particular, for the period 1992-1997 the same oscillations detected by the Malmquist index, and that translated there into mild yearly improvements, are detected here, and lead to an average yearly decline in TFP (-

1.5%). This is more than recovered in 1998-2004, with a stable yearly average growth of 3.0%; so the trend is the same but the estimates are smaller than those detected by the non-parametric technique. This is not surprising and can be easily explained by the stochastic vs. deterministic nature of the two approaches. The results on technological change are remarkably more similar instead. Technological change appears again to be the major contributor to growth for the whole sample period, with a value of 5% per year entirely due to the large positive improvements in 1998-2004 (9.1% per year, very close to the Malmquist 9.77%), whereas the growth is negative in 1992-1997 (-0.6%). With respect to its two sub components, disembodied cost technology change appears to determine the general pattern, while the switch of regulatory focus only induces a once-and-for-all upward shift of the cost frontier rather than affecting the general direction of change. Efficiency changes and scale effects are again showed as less relevant: the scale effect has an almost negligible impact, in this case a positive 0.1%, slightly more relevant at the beginning (0.4%) but nonexistent in the end. Cost efficiency change, which in the parametric model includes both technical and allocative inefficiency, is continuously negative, overall and in the two sub-periods. Finally, the mark-up effect is negative and equal to -0.3%.

The results on ownership and cost efficiency are presented in the second half of Table 5 and they are very similar to the DEA ones. Foreign banks start off again as significantly more efficient than public banks (δ_1<0) but this advantage decreases over time (δ_3>0), until they are definitely overtaken by public banks after 1998 (as indicated by the significant negative δ_7 and positive δ_8). Domestic private banks have lower cost efficiency than public banks (δ_2>0) and their attempt to catch up is not successful, as indicated by the negative but non significant estimate of δ_9. The results also indicate a difference in the impact of the switch in regulatory focus across ownerships. In particular, foreign banks seem to be better equipped to adapt to policy changes (δ_{10}<0) whereas both public and domestic banks are negatively affected. In other words, the results again indicate that foreign banks have an advantage in the speed with which they can adjust to policy changes, but that public banks are capable of catching up eventually. The interactive trend variables also make it reasonable to expect another round of inter-ownership efficiency reshuffle after the change in regulatory focus. The two methodologies are therefore in great accord as regards the overall patterns of efficiency and its changes and they differ only in the size and significance they attach to the differences among ownership, with the only exception of the superiority of public to private banks pre-1998. This is neither worrying nor surprising as it is very likely due to the way in which the two methodologies deal with random errors.

To sum up, although some differences between the two methodologies exist, the central point appears to be the same. TFP growth is positive and mainly due to technological progress in the later stages of the reform. The relationship between cost efficiency and ownership structure changes over the two sub periods with public banks catching up with the initial advantage of foreign ones and eventually overtaking them, whilst private banks remain the least efficient. Given the leading role of technological progress, changes in cost efficiency and scale are less relevant in both cases.

Considering the number of methodological differences that distinguish these two competing approaches, even with the attempts we made to improve their comparability, these results are very positive indeed. To further consolidate our findings on the consistency of the positive impact of regulatory reform on TFP growth and the main contribution of cost technology, we calculate the correlation coefficient of TFP growth and cost technology change between the alternative approaches. To do this, we have to bear in mind that while the Malmquist index is a measure of productivity *growth*, the Divisia index is a measure of productivity *growth rate*. In order to facilitate the comparison of results, following Kumbhakar and Sarkar (2003), among others, we construct a cumulative TFP index as:

$$TFP_t = TFP_{t-1}(1 + \dot{TFP}_t) \qquad (11)$$

where $\dot{TFP}_t$ is the growth rate of TFP between t-1 and t[17], and $(1 + \dot{\mathrm{TFP}}_t)$ is the growth of TFP between t-1 and t. The correlation coefficient in cost technology growth is 0.877 and the correlation coefficient in TFP growth is 0.913, which are very satisfying results.

In summary, both approaches suggest that the Indian banking sector experienced sustained productivity growth, driven mainly by technological progress, after an initial adjustment phase. Our results therefore support the theoretical view that regulatory reforms stimulate cost technology progress and enhance productivity, and that their impact on TFP growth needs some time of adjustment before it can materialise. The joint results also seem to suggest that the main impact of regulatory reform on cost efficiency is on inter-ownership reshuffle rather than an increase in the average level for the whole industry.

5. Conclusions

This paper contributes to the current policy debates on the impact of regulatory reform on TFP growth and its sources and on the relationship between cost efficiency and ownership structure; it does so via the joint application of the non-parametric techniques of DEA and the parametric techniques of SFA specifically to increase the robustness of the results, since the two methodologies have almost opposite, complementary characteristics. The specific case analysed is the Indian commercial banking sector in the years 1992 to 2004, which cover two separate stages of deregulation and re-regulation; the data is a balanced panel which includes continuously operating public sector, domestic private and foreign banks.

The principal conclusion of this paper is that the two different approaches considered give very similar results and provide empirical evidence of the positive effect of deregulation on TFP growth and in particular on technological progress. Furthermore they both indicate that the main impact of regulatory reform on cost efficiency is on inter-ownership reshuffle rather than an increase in the average level for the whole industry, with banks reacting at different speeds to policy changes.

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Table 1: Variables summary statistics (1992-2004) [a,b]

Variable	*Mean*	*Median*	*Min*	*Max*	*Stdev*
C	6793.475	2645.624	12.059	137723.501	13992.490
y_1	31968.117	12614.725	9.504	667623.982	65974.518
y_2	31114.470	10447.179	24.660	1028342.543	77493.409
y_3	1239.518	469.569	0.478	33331.540	2734.282
w_1	0.079	0.074	0.017	1.076	0.041
w_2	0.026	0.026	0.004	0.335	0.014
TR1	3647.718	1532.040	0.525	56967.924	6950.413
TR2	3376.434	1254.054	3.403	94368.948	7941.345

[a] C= total operating cost; y_1: performing loans; y_2: other earning assets; y_3: fee-based income; w_1: loanable funds price; w_2 = non-operating cost price; TR1: income on loans, TR2: income on other earning assets. [b] All the data are expressed in Rs mil. and are deflated data using 1991 as the base year.

Table 2: DEA- based Malmquist productivity change index and its components, 1992-2004[a, b].

Year	*Efficiency change (VRS)*	*Technical change (VRS)*	*Scale change*	*Mamquist index*
1993	1.037	0.941	1.008	0.985
1994	0.887	1.368	0.997	1.209
1995	1.204	0.847	0.971	0.991
1996	1.039	0.837	0.994	0.864
1997	0.967	1.032	1.002	0.999
1998	1.011	1.032	0.981	1.023
1999	0.977	1.007	1.002	0.986
2000	0.989	1.107	0.992	1.086
2001	1.046	1.004	0.992	1.043
2002	1.005	1.173	0.999	1.178
2003	1.019	1.083	0.979	1.080
2004	0.945	1.309	0.989	1.223
Geometric mean(92-04)	1.008	1.051	0.992	1.051
Geometric mean (92-97)	1.022	0.988	0.994	1.004
Geometric mean (98-04)	0.998	1.098	0.991	1.086

[a] A value smaller than one indicates decline; a value larger than one indicates growth.

[b] The Malmquist productivity growth index is the product of efficiency change, technical change and scale change (Ray and Desli, 1997)

Table 3: DEA efficiency scores by ownership and under against VRS, 1992-2004

Ownership type/year	***Efficiency scores (VRS)***		
	Foreign	***Private***	***Public***
1992	0.78	0.73	0.84
1993	0.90	0.72	0.82
1994	0.82	0.60	0.77
1995	0.89	0.80	0.88
1996	0.89	0.87	0.90
1997	0.86	0.81	0.90
1998	0.85	0.82	0.92
1999	0.85	0.80	0.91
2000	0.86	0.77	0.89
2001	0.90	0.83	0.90
2002	0.85	0.89	0.89
2003	0.89	0.90	0.90
2004	0.89	0.78	0.88
Mean:1992-1997	0.86	0.76	0.85
Mean:1998-2004	0.87	0.83	0.90
Mean:1992-2004	0.86	0.79	0.88

Table 4: Statistical test on the difference in efficiency measurement across ownerships

	Foreign vs Public		***Foreign vs Private***		***Public vs Private***	
	t-test	***Mann-Whiteney U test***	***t-test***	***Mann-Whiteney U test***	***t-test***	***Mann-Whiteney U test***
1992-1997	0.12	0.52	2.71**	2.68**	-3.24**	3.14**
1998-2004	-1.09	0.46	1.36	1.14	-3.33**	3.03**
1992-2004	-0.57	0.39	2.36**	2.13**	-3.52**	3.48**

Note: ** and * are significant at 10% and 5% level respectively.

Table 5: Maximum Likelihood estimates of the translog cost frontier (equations (7) and (8))

Variable	*Parameter*	*Estimate*	*Standard error*
Cost Function			
Intercept	β_0	11.256	0.022**
$\ln y_1$	α_1	0.539	0.027**
$\ln y_2$	α_2	0.442	0.026**
$\ln y_3$	α_3	0.002	0.013
$\ln w_1$	β_1	0.886	0.035**
$\ln y_1*\ln y_1$	α_{11}	0.070	0.012**
$\ln y_1*\ln y_2$	α_{12}	-0.078	0.017**
$\ln y_1*\ln y_3$	α_{13}	0.022	0.005**
$\ln y_2*\ln y_2$	α_{22}	0.108	0.020**
$\ln y_2*\ln y_3$	α_{23}	-0.025	0.004**
$\ln y_3*\ln y_3$	α_{33}	-0.002	0.002
$\ln w_1*\ln w_1$	β_{11}	-0.047	0.025*
$\ln w_1*\ln y_1$	δ_{11}	-0.074	0.017**
$\ln w_1*\ln y_2$	δ_{12}	0.074	0.017**
$\ln w_1*\ln y_3$	δ_{13}	-0.016	0.012
T	λ_1	0.074	0.008**
T*T	λ_2	-0.009	0.001**
$\ln y_1*T$	θ_1	-0.012	0.003**
$\ln y_2*T$	θ_2	0.016	0.003**
$\ln y_3*T$	θ_3	-0.003	0.001**
$\ln w_1*T$	ζ_1	-0.035	0.004**
R	α_r	0.069	0.027**
Inefficiency model			
Intercept	δ_0	-0.937	0.299**
Df	δ_1	-0.779	0.410**
Dp	δ_2	1.172	0.296**
TDf	δ_3	0.256	0.094**
TDp	δ_4	-0.313	0.110**
T	δ_5	0.095	0.086
R	δ_6	-1.406	0.486**
RT	δ_7	0.213	0.095**
RDf	δ_8	1.658	0.470**
RDp	δ_9	-0.398	0.312
RTDf	δ_{10}	-0.311	0.095**
RTDp	δ_{11}	0.265	0.107**
T*T	δ_{12}	-0.008	0.004**
σ^2		0.037	0.003
γ		0.785	0.036**
Log likelihood function		578.22	

Note: $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\gamma = \sigma_u^2 / \sigma^2$. *, **: significant at 10% and 5% respectively.

Table 6: Divisia index results of TFP growth rate and its components (1992-2004).

Years	***Scale effect***	***Markup effect***	***Cost technology***	***Cost inefficiency***	***Total TFP growth rate***
1992/1993	0.005	-0.022	-0.042	-0.016	-0.075
1993/1994	0.007	0.004	-0.026	0.003	-0.012
1994/1995	0.003	0.014	-0.010	0.001	0.008
1995/1996	0.002	0.024	0.013	0.002	0.041
1996/1997	0.003	-0.028	0.033	-0.048	-0.040
1997/1998	-0.001	-0.009	-0.019	-0.021	0.050
1998/1999	0.002	-0.039	0.066	-0.013	0.016
1999/2000	0.000	0.009	0.083	-0.059	0.033
2000/2001	0.001	-0.012	0.101	-0.062	0.028
2001/2002	-0.002	0.026	0.119	-0.054	0.089
2002/2003	-0.002	0.014	0.136	-0.092	0.056
2003/2004	-0.001	-0.021	0.148	-0.090	0.036
Average (92-97)	0.004	-0.002	-0.006	-0.011	-0.015
Average (98-04)	0.000	-0.005	0.091	-0.056	0.030
Average (92-04)	0.001	-0.003	0.050	-0.037	0.011

[1] For detailed reviews of the impact of financial reforms on the productivity change of banking systems see for example Mukherjee *et al*, (2001), and Kumbhakar and Sarkar (2003).

[2] Deregulation seems to increase efficiency for all banks but does not result in inter-ownership convergence (Bonaccorsi di Patti and Hardy, 2005); different ownerships react with different speeds to the change of regulatory environment (Isik and Hassan, 2003; Leightner and Lovell, 1998); ownership structure becomes neutral in terms of productivity growth and a diverse ownership structure also function as a stimulus to market competition (Sturm and Williams, 2004). A detailed literature review on this issue can be found in Sturm and Williams (2004).

[3] Structural deregulation was characterised by the removal of entry restrictions to private ownership, liberalization of interest rates on deposits and lending, and an increase in the range of permitted activities. Prudential norms related to assets classification, income recognition, provisioning, risk-based capital adequacy and informational disclosure.

[4] See Cole (2009) for a discussion of the relevance of bank ownership and economic growth.

[5] See Zhao *et al*. (2008, 2009) for a review of the efficiency and productivity studies related to the Indian banking system.

[6] Diewert (1976) shows that the implicit functional form of the Divisia index is the translog.

[7] The subscripts, i and t, are omitted for convenience in the presentation. Dotted variables indicate the growth rate between any two periods t and t+1.

[8] Technical details are cumbersome, and the reader is remanded to Kumbhakar and Lovell (2003).

[9] All yearly observations refer to the end of March of each year, which is the financial reporting date.

[10] Performing loans are measured as the difference between total loans and non-performing loans.

[11] Other earning assets aggregate government securities, other approved securities, shares, debentures and bonds, subsidiaries and joint ventures and other investment outside India (i.e. total investment).

[12] According to the accounting practice followed by the Indian banking sector post-1992, income accrual would cease once the loan is recognized as non-performing. Therefore, the interest received on loans recorded in the loss and profit account is associated with the performing loans.

[13] A simulation by Smith (1997) showed that even though the number of observations was over 13 times the number of variables, the model still overestimated the true efficiency by 27.1%.

[14] A unit is defined as super-efficient when its technical efficiency score is much larger than unity once compared with a linear combination of all other units apart from itself (Andersen and Pertersen, 1993).

[15] The following hypotheses were tested: the adequacy of a more restrictive Cobb-Douglas functional form; the existence of technological change; the existence of non-neutral technological change; whether technology is homothetic; the significance of a policy-shift effect; the significance of a policy-shift bias towards one particular input or output; the significance of inefficiency; the stochastic nature of inefficiency; the overall significance of the inefficiency model.

[16] Lower levels of significance on the translog are not uncommon due to the presence of the quadratic and interactive terms.

[17] In our estimations, we set TFP_{1992} at unity.