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Radial and non-radial decompositions of profit change: an application***BIRESH K. SAHOO^a and KAORU TONE^b**

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Abstract

Grifell-Tatje and Lovell (1999) made a contribution to the literature by decomposing profit change in extended radial DEA framework into six mutually exclusive components. Their approach appears to suffer from two shortcomings. First, radial models do not achieve full efficiency when slacks are present, and therefore, the contributions of each of these components are grossly underestimated. Second, evaluations of these components, using base-period prices as weights, can be potentially misleading. To circumvent over these shortcomings, we, first, introduce non-radial DEA models, and second, provide strong theoretical argument in favor of either current-period prices/average price of both periods as weights to be used to value the contributions of each of these components. The Indian banking sector is taken as a case study to illustrate the radial and non-radial decompositions of profit change so as to empirically examine the role of competition on profit change as well as its six mutually exclusive components. Our broad empirical results are as follows: First, radial and non-radial models yield diametrical opposite sign on the contributions of various components. Second, the increasing efficiency change trend in all ownership groups after 2002 indicates an affirmative gesture about the effect of the reform process on the performance of the Indian banking sector. Third, despite the fact that nationalized banks are the oldest banks, they do not reflect their learning experience in their output-and resource allocation behaviors.

Keywords: Profits; Productivity; Indian Banking; DEA (Radial and Non-radial)

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Radial and non-radial decompositions of profit change: an application

1. Introduction

There is a widely held belief that competition, a driving force behind numerous important policy changes, exerts downward pressure on costs, reduces slacks, provides incentives for the efficient organization of production, and even drives innovation forward. However, despite the belief that the efficacy of competition exists on firm performance (in terms of both productivity and profit), which is not even supported by either any strong theoretical foundation or a large corpus of hard empirical evidence in its favor, this linkage is worth testing on any industry as it is both a legitimate and an interesting issue to investigate. There can probably be two reasons for this exercise. First, profitability and productivity are two important key issues to be investigated as one can argue that competition probably reduces the former but increases the latter. Second, due care must be warranted while investigating issue of this type as it is true that competition in the long run is not independent of firm behavior, i.e., e.g., high performing firms may gain a position of market power.

Though productivity change contributes significantly to profit change, there are probable other determinants, viz., favorable price structure and activity change related factors such as scale change, optimum resource mix and optimum product mix, which all have the potential to contribute to profit change. Profit change decomposition is thus essential in the sense that this can be used for better internal control and performance evaluation purposes.

In much of past business literature, the profit change of any firm is decomposed into three prime components: 1) price change (of both resource and product), 2) productivity change (technical change)¹ and 3) activity change that captures more the effect of changes in the size, and less the effect of the scope of the business². This is precisely due to the argument that shareholders will be interested in the last two components, i.e., volume change component because this has been argued to be an indicator of firm efficiency

¹ These two concepts: productivity change and technical change are in fact not the same, and the former is due to both technical change and efficiency change. This decomposition is due to Färe et al. (1994).

² Various variants of this three-way decomposition are made in past studies (Kurosawa, 1975; Eldor and Sudit, 1981; Chaudry et al., 1985; Miller, 1984, 1987; Miller and Rao, 1989; and Banker et al., 1989, 1996), which is primarily because of the different accounting relations used in their studies.

improvement, i.e., the more positive is the volume change, the greater is the *ex post* efficiency gain for the firm.

However, one of the major problems of existing business studies dealing with this three-way decomposition is that their decomposition lacks the underlying economic theory of production³. In an attempt to fill in this void, Grifell-Tatje and Lovell (1999) proposed a six-way decomposition of profit change⁴ in which profit change is expressed as the sum of *six* mutually exclusive components: two components of total factor productivity change (TFPCH) - pure technical efficiency change (PTEFFCH) and technical change (TCH); three components of activity change (ACTCH) - scale change (SCH), resource-mix change (RMCH) and product-mix change (PMCH); and finally, price change (PCH).

To empirically implement this decomposition, they have used the extended radial data envelopment analysis (DEA) models in which each of these determinants of profit change is evaluated with respect to base-period prices⁵. Their approach suffers from two problems. First, radial DEA models do not achieve full efficiency because slacks remain even after radial projections are made onto the efficient frontier, and therefore contributions of each of these determinants are grossly underestimated. We, therefore, advocate the use of

³ Accounting measures of efficiency via accounting cost variances such as mix and yield variances, do not generally satisfy three fairly weak axioms: 1) an efficiency index should specify when an input-output vector is on the production frontier, 2) an efficiency index should be monotonic in the inputs, and 3) an efficiency index should be homogeneous of degree (plus or minus one) in the inputs, that one generally expects an efficiency indicator to satisfy.

⁴ This decomposition was made based on the two branches of the economics literature. One branch is based on the duality relationship between the structure of production technology and the structure of maximum profit in which profit change is due to: changes in product and resource prices (similar to price effect in business literature), the structure of production technology (similar to activity effect in business literature), the changes in the structure of technology and in operating efficiency (similar to productivity effect in business literature). See Diewert (1973) and Lau (1976) for the detailed treatment on this. Other branch of economic deals with the sources of productivity change in which research efforts were on decomposition of the quantity change (sum of productivity change and activity change) into components capturing the separate effects of the magnitude and biases of technical change, the magnitude of efficiency change, and scale economies. See Fare et al. (1997) and Grifell-Tatje and Lovell (1997b) on this.

⁵ This was simply because in business literature on *variance analysis*, the base period prices and quantities are interpreted as the current period's 'budgeted' or 'forecasted' or 'standard' prices and quantities that are presumed to prevail in the current period. Then, the profit difference represents the difference between the current period's actual value and budgeted performance where the indicators of volume change is interpreted as the contribution of quantity change between actual and budgeted quantities, and the indicator of price change (also called 'price recovery') is interpreted as the contribution of price change between actual and budgeted prices to the *ex post* difference between actual and standard values.

extended non-radial DEA models to circumvent over this problem. Second, the contributions of each of these determinants when evaluated at base-period prices are potentially misleading, which might be due to the fact that productivity contribution (in terms of increasing technical efficiency, input-tradeoff (resource-mix) efficiency and output-tradeoff (product-mix) efficiency) would signal a decline in profit, had they been evaluated at base-period prices. Therefore, a strong theoretical argument can be made in favor of either current-period price or average price of both periods as weights to be used to value the productivity contribution towards the profit change⁶.

Our objective in this paper is therefore to assess the relative strengths of both radial and non-radial decompositions of profit change using not only base and current period prices but also average price of both periods, as weights, to value the contribution of these determinants on profit change. This comparison will be illustrated on Indian commercial banking sector for the period: 1997-98 – 2004-05. The Indian financial sector, which had been operating in a closed and regulated environment, underwent a radical change during the nineties. To induce productive efficiency and competition into the system, Reserve Bank of India (RBI) initiated in 1992 a number of reforms, viz., entry deregulation, branch delicensing, interest rates deregulation, allowing public sector banks to raise up to 49% of their equity in the capital market, etc., which all gave rise to the heightened competitive pressure in the industry. These changes came in the form of greater use of automatic teller machines and internet-banking, huge increase in housing and consumer credit, stronger and more transparent balance sheets and product diversification. A significant intent of these policies is to have a radical transformation in the operating landscape of the Indian commercial banks. So the informational contents of the decomposition of profit change are useful not only to policy makers in evaluating the outcomes of economic reforms, but also to regulators who need to understand and monitor both the consequences of their regulation and the response to their decision by those being regulated.

Also important is to examine the banks' performance behavior in terms of profit change and its six determinants across the entire spectrum of ownership groups, which might yield valuable information concerning performance differentials. This will enable us to verifying the issue of economic linkage of ownership vis-à-vis performance in the light of

⁶ Similarly, one can argue that contribution of price change would signal towards profit change in right direction, had it been evaluated at the base-period prices.

property right hypothesis (Alchian, 1965 and de Alessi, 1980) and public choice theory (Nickskamen, 1971 and Levy, 1987). As per property right hypothesis, private enterprises should perform more efficiently and profitably than public enterprises, i.e., there is a strong link between markets for corporate control and efficiency of private enterprise, which precisely holds for developed countries where capital market functions well. However, in the absence of well-functioning capital markets in a developing country, the Indian banking industry could provide a test for performance differential across the entire ownership groups so as to examine whether reforms process are working.

The reminder of this paper proceeds as follows: Section 2 discusses both radial and non-radial decompositions of profit change in DEA framework, Section 3 discusses the data on Indian commercial banks, Section 4 deals with result and discussion followed by concluding remarks in Section 5.

2. Methodology

We will be discussing first the radial decomposition of profit change by Grifell-Tatje and Lovell (1999), and then introducing the non-radial decomposition in an attempt to get rid of the limitations therein.

2.1 Technology specifications

Consider a base period (denoted by 0) and a current period (denoted by 1), and assume that we deal with 'n' firms (banks) where each firm uses 'm' inputs to produce 's' outputs. For each firm h ($h = 1, 2, \dots, n$), we denote, respectively, the input and output vectors for period t by $x_h^t \in \mathbb{R}^m$ and $y_h^t \in \mathbb{R}^s$. The corresponding input and output matrices are, respectively, defined by $X^t = (x_1^t, x_2^t, \dots, x_n^t) \in \mathbb{R}^{m \times n}$ and $Y^t = (y_1^t, y_2^t, \dots, y_n^t) \in \mathbb{R}^{s \times n}$. Let the input and output price vectors be, respectively, $w_h^t \in \mathbb{R}^m$ and $p_h^t \in \mathbb{R}^s$, and the corresponding price matrices are defined, respectively, by $C^t = (w_1^t, w_2^t, \dots, w_n^t) \in \mathbb{R}^{m \times n}$ and $P^t = (p_1^t, p_2^t, \dots, p_n^t) \in \mathbb{R}^{s \times n}$. Here $t = 0, 1$. Assume that $X^t > 0$ and $Y^t > 0$.

Then, the technology set for period t is defined by $T^t = \{(x^t, y^t) : y^t \text{ can be produced from } x^t\}$. Alternatively, T^t can be described by its input set $L^t(y^t)$ or output set $P^t(x^t)$, defined, respectively, as $L^t(y^t) \equiv \{x^t : (x^t, y^t) \in T^t \forall y^t\}$, and

$P^t(x^t) \equiv \{y^t : (x^t, y^t) \in T^t \forall x^t\}$. The mix-period output set, $P^1(x^0)$ consists of those output vectors, which the input vector in period 0 (x^0) could have produced using technology in period 1. Similarly, the other mix-period output set $P^0(x^1)$ consists of those output vectors, which input vector in period 1 (x^1) could have produced using the technology prevailed in period 0. The mix-period input sets $L^1(y^0)[L^0(y^1)]$ can be similarly defined.

T^t can also be represented by the output/input distance functions (which are due to Shephard, 1970), defined, respectively, as $D_o^t(x^t, y^t) \equiv \inf\{\theta : (y^t/\theta) \in P^t(x^t)\}$ and $D_i^t(x^t, y^t) \equiv \sup\{\delta : (x^t/\delta) \in L^t(y^t)\}$. By construct, $D_o^t(x^t, y^t) \leq 1$ and $D_i^t(x^t, y^t) \geq 1$. The mix-period output distance functions $D_o^1(x^0, y^0)/D_o^0(x^1, y^1)$ can be defined, respectively, as $\inf\{\theta : (y^0/\theta) \in P^1(x^0)\}$ and $\inf\{\theta : (y^1/\theta) \in P^0(x^1)\}$.

2.2 Decomposition of profit change

Suppose that firm h operates at point y_h^0 at $t = 0$ and at point y_h^1 at $t = 1$ (see Figure 1). The profit change, $[\pi_h^1 - \pi_h^0]$ ⁷ is expressed as the difference between the change in revenue, $(R_h^1 - R_h^0)$ and change in cost $(C_h^1 - C_h^0)$, i.e.,

$$[\pi_h^1 - \pi_h^0] = (R_h^1 - R_h^0) - (C_h^1 - C_h^0), \quad (1)$$

where $R_h^t = \sum_{r=1}^s p_{rh}^t y_{rh}^t$ and $C_h^t = \sum_{i=1}^m w_{ih}^t x_{ih}^t$; $t = 0, 1$. This profit change can also be decomposed into volume change (VCH) and price change (PCH)⁸ as follows:

⁷ The alternative branch of index number theory that economist generally used to study is the one that uses a ratio form $(\pi_h^1/\pi_h^0) = ((p^1/p^0)/(w^1/w^0)) * ((y^1/y^0)/(x^1/x^0))$, with the first component representing ratio of output price ratio to input price ratio, and the second component representing the ratio of output-ratio to input-ratio where each variable is represented in vector notation. However, the motivation behind developing profit change in difference form was due to *variance analysis*. See Diewert (2005) for an excellent treatment on index number theory using difference rather than ratio forms.

⁸ The idea of decomposing profit change into volume change and price change was, in fact, rooted in the early industrial engineering literature by Harrison (1918) who made the decomposition of cost change into volume change ('efficiency change' in his terminology) and price change, i.e., $w^1 x^1 - w^0 x^0 = w^0(x^1 - x^0) + x^1(w^1 - w^0)$.

$$\begin{aligned} [\pi_h^1 - \pi_h^0] &= \left[\sum_{r=1}^s (y_{rh}^1 - y_{rh}^0) p_{rh}^1 - \sum_{i=1}^m (x_{ih}^1 - x_{ih}^0) w_{ih}^1 \right] & [\text{VCH}^P] \\ &+ \left[\sum_{r=1}^s (p_{rh}^1 - p_{rh}^0) y_{rh}^0 - \sum_{i=1}^m (w_{ih}^1 - w_{ih}^0) x_{ih}^0 \right] & [\text{PCH}^L] \end{aligned} \quad (2)$$

While $[\text{VCH}^P]$ represents the difference between Paasche output quantity index and Paasche input quantity index, $[\text{PCH}^L]$ represents the difference between Laspeyres output price index and Laspeyres input price index. Further, $[\text{VCH}^P]$ is decomposed into total factor productivity change $[\text{TFPCH}^P]$ and activity change $[\text{ACTCH}^P]$ as

$$\begin{aligned} [\text{VCH}^P] &= \left[\sum_{r=1}^s (y_{rh}^B - y_{rh}^0) p_{rh}^1 - \sum_{r=1}^s (y_{rh}^C - y_{rh}^1) p_{rh}^1 \right] & [\text{TFPCH}^P] \\ &+ \left[\sum_{r=1}^s (y_{rh}^C - y_{rh}^B) p_{rh}^1 - \sum_{i=1}^m (x_{ih}^1 - x_{ih}^0) w_{ih}^1 \right] & [\text{ACTCH}^P] \end{aligned} \quad (3)$$

$[\text{TFPCH}^P]$ is also decomposed into technical change $[\text{TCH}^P]$ and pure technical efficiency change $[\text{PTEFFCH}^P]$ ⁹ with each term being valued at current period prices.

$$\begin{aligned} [\text{TFPCH}^P] &= \left[\sum_{r=1}^s (y_{rh}^B - y_{rh}^A) p_{rh}^1 \right] & [\text{TCH}^P] \\ &+ \left[\sum_{r=1}^s (y_{rh}^A - y_{rh}^0) p_{rh}^1 - \sum_{r=1}^s (y_{rh}^C - y_{rh}^1) p_{rh}^1 \right] & [\text{PTEFFCH}^P] \end{aligned} \quad (4)$$

Here y^A represents the technical efficient output vector for the inefficient firm 'h' in the base period, y^B represents the technical efficient output vector which firm h's base period input vector could yield using the current period technology, and y^C represents the technical efficient output vector for the inefficient firm h in the current period. Note that all these projections are radial in nature. Visual characterization of path from y_h^0 to y_h^1 that describes how each of these components such as $[\text{TFPCH}^P]$, $[\text{ACTCH}^P]$, $[\text{TCH}^P]$ and $[\text{PTEFFCH}^P]$ exerts influence on profit change, can be seen from Figure 1. $[\text{TFPCH}^P]$ exhibits the value difference between two paths: $(y^B - y_h^0)$ in period 0 and $(y^C - y_h^1)$ in

⁹ Färe et al. (1994) are, however, the first to decompose in radial DEA framework the total factor productivity change into technical change, pure efficiency change and scale efficiency change. Since the radial DEA models suffer from the problem of slacks, Cooper et al. (2007), in an attempt to get rid of these problems, suggested the decomposition of the same using non-radial DEA models.

period 1. A part of $[TFPCH^P]$ is due to $[TCH^P]$, which exhibits increase in output in value terms due to the improvement in technology from y^A to y^B , and the remainder is due to $[PTEFFCH^P]$ exhibiting the value difference in pure technical efficiency between two periods, i.e., $(y^A - y_h^0)$ in period 0 and $(y^C - y_h^1)$ in period 1. $[ACTCH^P]$ exhibits the change in output $(y^C - y^B)$ due to change in input $(x_h^1 - x_h^0)$ in value terms, reflecting the consequences of changes in scale and scope of firm.

<<INSERT Figure 1>>

In the light of changing market prices for inputs and outputs, the firm manager has the incentive to produce optimal output-mix using optimal input-mix. Therefore, to disentangle their effects, $[ACTCH^P]$ is further decomposed into three mutually exclusive components: product-mix change $[PMCH^P]$, resource-mix change $[RMCH^P]$ and scale change $[SCH^P]$ ¹⁰, with each term being valued at current period prices, as follows:

$$\begin{aligned}
 [ACTCH^P] = & \left[\sum_{r=1}^s (y_{rh}^C - y_{rh}^D) p_{rh}^1 \right] & [PMCH^P] \\
 & + \left[\sum_{i=1}^m (x_{ih}^E - x_{ih}^1) w_{ih}^1 \right] & [RMCH^P] \\
 & + \left[\sum_{r=1}^s (y_{rh}^D - y_{rh}^B) p_{rh}^1 - \sum_{i=1}^m (x_{ih}^E - x_{ih}^0) w_{ih}^1 \right] & [SCH^P]
 \end{aligned} \tag{5}$$

The visual effect of $[PMCH^P]$ on profit change can be seen from Figure 1 in which it exhibits the value difference between y^C (technically efficient output in period 1) and y^D (technically efficient output generated using current period technology, but holding base-period's output-mix constant). Figure 2 exhibits the effect of $[RMCH^P]$ on profit change.

<<INSERT Figure 2>>

$[RMCH^P]$ exhibits the value difference between x^E (generated from holding period 0's input fixed, but to produce y^D using period 1 technology) and x_h^1 (period 1's

¹⁰ Note that this scale change component captures the notion of returns to scale but not economies of scale. These two concepts have, in fact, distinctive causative factors that do not permit them to be used interchangeably. For a historical discussion on the evolution of the concept of scale and its computational procedure, see, among others, Gold (1981), Sahoo et al. (1999, 2006), Sengupta and Sahoo (2006), and Tone and Sahoo (2003, 2004, 2005, 2006).

actual input). And, finally, $[SCH^P]$ reflects the value difference between the proportionate change in output $(y^D - y^B)$ and proportionate change in inputs $(x^E - x_h^0)$.

However, from both economic and business perspectives, it is worth comparing the six components of profit change using base period prices and/or the average price of both periods as weights. When base-period prices for outputs and inputs are taken as weights, which Grifell-Tatje and Lovell (1999) have used in their study, then one can generate six Laspeyres-type indicators of the components of profit change are as follows:

$$\begin{aligned}
[VCH^L] &= \left[\sum_{r=1}^s (y_{rh}^1 - y_{rh}^0) p_{rh}^0 - \sum_{i=1}^m (x_{ih}^1 - x_{ih}^0) w_{ih}^0 \right] \\
[TFPCH^L] &= \left[\sum_{r=1}^s (y_{rh}^B - y_{rh}^0) p_{rh}^0 - \sum_{r=1}^s (y_{rh}^C - y_{rh}^1) p_{rh}^0 \right] \\
[TCH^L] &= \left[\sum_{r=1}^s (y_{rh}^B - y_{rh}^A) p_{rh}^0 \right] \\
[PTEFFCH^L] &= \left[\sum_{r=1}^s (y_{rh}^A - y_{rh}^0) p_{rh}^0 - \sum_{r=1}^s (y_{rh}^C - y_{rh}^1) p_{rh}^0 \right] \\
[ACTCH^L] &= \left[\sum_{r=1}^s (y_{rh}^C - y_{rh}^B) p_{rh}^0 - \sum_{i=1}^m (x_{ih}^1 - x_{ih}^0) w_{ih}^0 \right] \\
[PMCH^L] &= \left[\sum_{r=1}^s (y_{rh}^C - y_{rh}^D) p_{rh}^0 \right] \\
[RMCH^L] &= \left[\sum_{i=1}^m (x_{ih}^E - x_{ih}^1) w_{ih}^0 \right] \\
[Sch^L] &= \left[\sum_{r=1}^s (y_{rh}^D - y_{rh}^B) p_{rh}^0 - \sum_{i=1}^m (x_{ih}^E - x_{ih}^0) w_{ih}^0 \right] \\
[PCH^P] &= \left[\sum_{r=1}^s (p_{rh}^1 - p_{rh}^0) y_{rh}^1 - \sum_{i=1}^m (w_{ih}^1 - w_{ih}^0) x_{ih}^1 \right]
\end{aligned}$$

$[VCH^L]$ is interpreted in difference form as the difference between Laspeyres output quantity index and Laspeyres input quantity index, and $[PCH^P]$ is interpreted in difference form as the difference between Paaschee output price index and Paaschee input price index.

Note that the reason why one should use the current period's output-input prices as weight for $[VCH^P]$, and base period's output-input quantities as weights for $[PCH^L]$ is that

in case of exogenous prices, the firm manager will have an incentive to maximize revenue

$\sum_{r=1}^s (y_{rh}^1 - y_{rh}^0) p_{rh}^1$ with respect to y_h^1 and minimize cost $\sum_{i=1}^m (x_{ih}^1 - x_{ih}^0) w_{ih}^1$ with respect to

x_h^1 , and thus the volume change component, $\left[\sum_{r=1}^s (y_{rh}^1 - y_{rh}^0) p_{rh}^1 - \sum_{i=1}^m (x_{ih}^1 - x_{ih}^0) w_{ih}^1 \right]$ in

equation (2) is consistent with the profit-maximizing behavior.

However, the problem with the use of Laspeyres and Paasche type measures is that when there is a great change in the prices of inputs and outputs between the two accounting periods, the indicators of [VCH] may be excessively weighted by the prices of the period with the highest prices. Therefore, in this scenario Bennet (1920)'s idea of taking the average price of both periods as weight in computing [VCH] may be considered useful, in which case the six components of profit change for firm h are as follows:

$$\begin{aligned}
 [\text{VCH}^B] &= \left[\sum_{r=1}^s (1/2)(p_{rh}^0 + p_{rh}^1)(y_{rh}^1 - y_{rh}^0) - \sum_{i=1}^m (1/2)(w_{ih}^0 + w_{ih}^1)(x_{ih}^1 - x_{ih}^0) \right]^{11} \\
 [\text{TFPCH}^B] &= \left[\sum_{r=1}^s (1/2)(p_{rh}^0 + p_{rh}^1)(y_{rh}^B - y_{rh}^0) - \sum_{r=1}^s (1/2)(p_{rh}^0 + p_{rh}^1)(y_{rh}^C - y_{rh}^1) \right] \\
 [\text{TCH}^B] &= \left[\sum_{r=1}^s (1/2)(p_{rh}^0 + p_{rh}^1)(y_{rh}^B - y_{rh}^A) \right] \\
 [\text{PTEFFCH}^B] &= \left[\sum_{r=1}^s (1/2)(p_{rh}^0 + p_{rh}^1)(y_{rh}^A - y_{rh}^0) - \sum_{r=1}^s (1/2)(p_{rh}^0 + p_{rh}^1)(y_{rh}^C - y_{rh}^1) \right] \\
 [\text{ACTCH}^B] &= \left[\sum_{r=1}^s (1/2)(p_{rh}^0 + p_{rh}^1)(y_{rh}^C - y_{rh}^B) - \sum_{i=1}^m (1/2)(w_{ih}^0 + w_{ih}^1)(x_{ih}^1 - x_{ih}^0) \right] \\
 [\text{PMCH}^B] &= \left[\sum_{r=1}^s (1/2)(p_{rh}^0 + p_{rh}^1)(y_{rh}^C - y_{rh}^D) \right]
 \end{aligned}$$

¹¹ Following Bennet (1920), one can show that the first component of $[\text{VCH}^B]$, i.e. Bennet indicator of output quantity change is a linear approximation to the area under an output demand curve, and the second component of $[\text{VCH}^B]$, i.e. Bennet indicator of input quantity change as a linear approximation to an area under factor demand curve. And similarly, the first and second components of $[\text{PCH}^B]$ can be, respectively, interpreted as linear approximation to an area under inverse output and input demand curve.

$$[\text{RMCH}^B] = \left[\sum_{i=1}^m (1/2)(w_{ih}^0 + w_{ih}^1)(x_{ih}^E - x_{ih}^1) \right]$$

$$[\text{SCH}^B] = \left[\sum_{r=1}^s (1/2)(p_{rh}^0 + p_{rh}^1)(y_{rh}^D - y_{rh}^B) - \sum_{i=1}^m (1/2)(w_{ih}^0 + w_{ih}^1)(x_{ih}^E - x_{ih}^0) \right]$$

$$[\text{PCH}^B] = \left[\sum_{r=1}^s (1/2)(y_{rh}^0 + y_{rh}^1)(p_{rh}^1 - p_{rh}^0) - \sum_{i=1}^m (1/2)(x_{ih}^0 + x_{ih}^1)(w_{ih}^1 - w_{ih}^0) \right]$$

Note that Bennet indicators of volume change $[\text{VCH}^B]$ and price change $[\text{PCH}^B]$ are, respectively, the simple arithmetic average of the Paasche and Laspeyres indicators of volume and price change¹², and so is the case for the other components. Given the various alternative indicators available, what is then the best indicator to be used in any empirical application on the decomposition of profit change? As argued by Diewert (2005), from the viewpoint of test or axiomatic approach, Bennet indicators are considered best as it satisfies the time reversal test, an important test to be imposed in any context in which data from two periods is symmetric. But, from the viewpoint of an economic approach, Fisher and Tornqvist's superlative indicators are best. However, the Bennet indicators have big advantage over the speculative indicators in terms of one important property, i.e., they are additive over commodities property.

Let us now turn to discuss the estimation procedures of the six components of profit change in radial DEA models as suggested by Grifell-Tatje and Lovell (1999).

2.3 Radial DEA estimation models

To compute y_h^A of firm h, the following LP is set up as follows:

$$\begin{aligned} [D_o^0(x_h^0, y_h^0)]^{-1} &= \max \theta_h^A \\ \text{subject to} \quad & \sum_{j=1}^n y_{rj}^0 \lambda_j^0 - s_r^{0+} = \theta_h^A y_{rh}^0 \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^0 \lambda_j^0 + s_i^{0-} = x_{ih}^0 \quad (\forall i), \\ & \sum_{j=1}^n \lambda_j^0 = 1, \lambda_j^0 \geq 0 \quad (\forall j), s_r^{0+}, s_i^{0-} \geq 0 \quad (\forall r, i). \end{aligned}$$

¹² In the literature, besides Laspeyres, Paasche and Bennet indicators of price change, there are there other indicators of price change by Fisher (1922), Montgomery (1929) and Tornqvist (1936). However, Diewert (2005) has shown that there does appear to have close correspondence between the Bennet, Fisher, Tornqvist and Montgomery indicators of price change whereas the Paasche and Laspeyres indicators of price change are rather very different from each other.

$$\text{So, } y_h^A = (\theta_h^{A*} y_{1h}^0, \theta_h^{A*} y_{2h}^0, \dots, \theta_h^{A*} y_{sh}^0).$$

Next, to estimate y_h^B of firm h, the following LP is set up

$$\begin{aligned} [D_o^1(x_h^0, y_h^0)]^{-1} &= \max \theta_h^B \\ \text{subject to} \quad & \sum_{j=1}^n y_{rj}^1 \lambda_j^1 - s_r^{1+} = \theta_h^B y_{rh}^0 \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^1 \lambda_j^1 + s_i^{1-} = x_{ih}^0 \quad (\forall i), \\ & \sum_{j=1}^n \lambda_j^1 = 1, \lambda_j^1 \geq 0 \quad (\forall j), s_r^{1+}, s_i^{1-} \geq 0 \quad (\forall r, i) \end{aligned}$$

$$\text{So, } y_h^B = (\theta_h^{B*} y_{1h}^0, \theta_h^{B*} y_{2h}^0, \dots, \theta_h^{B*} y_{sh}^0).$$

To estimate y_h^C of firm h, the following LP is set up

$$\begin{aligned} [D_o^1(x_h^1, y_h^1)]^{-1} &= \max \theta_h^C \\ \text{subject to} \quad & \sum_{j=1}^n y_{rj}^1 \lambda_j^1 - s_r^{1+} = \theta_h^C y_{rh}^1 \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^1 \lambda_j^1 + s_i^{1-} = x_{ih}^1 \quad (\forall i), \\ & \sum_{j=1}^n \lambda_j^1 = 1, \lambda_j^1 \geq 0 \quad (\forall j), s_r^{1+}, s_i^{1-} \geq 0 \quad (\forall r, i) \end{aligned}$$

$$\text{So, } y_h^C = (\theta_h^{C*} y_{1h}^1, \theta_h^{C*} y_{2h}^1, \dots, \theta_h^{C*} y_{sh}^1).$$

To estimate y_h^D of firm h, the following LP is set up

$$\begin{aligned} [D_o^1(x_h^1, y_h^0)]^{-1} &= \max \theta_h^D \\ \text{subject to} \quad & \sum_{j=1}^n y_{rj}^1 \lambda_j^1 - s_r^{1+} = \theta_h^D y_{rh}^0 \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^1 \lambda_j^1 + s_i^{1-} = x_{ih}^1 \quad (\forall i), \\ & \sum_{j=1}^n \lambda_j^1 = 1, \lambda_j^1 \geq 0 \quad (\forall j), s_r^{1+}, s_i^{1-} \geq 0 \quad (\forall r, i) \end{aligned}$$

$$\text{So, } y_h^D = (\theta_h^{D*} y_{1h}^0, \theta_h^{D*} y_{2h}^0, \dots, \theta_h^{D*} y_{sh}^0).$$

To estimate x_h^E of firm h, the following LP is set up

$$\begin{aligned} [D_i^1(x_h^0, \hat{y}_h^0)]^{-1} &= \min \varphi_h^E \\ \text{subject to} \quad & \sum_{j=1}^n y_{rj}^1 \lambda_j^1 - s_r^{1+} = y_{rh}^D \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^1 \lambda_j^1 + s_i^{1-} = \varphi_h^E x_{ih}^0 \quad (\forall i), \\ & \sum_{j=1}^n \lambda_j^1 = 1, \lambda_j^1 \geq 0 \quad (\forall j), s_r^{1+}, s_i^{1-} \geq 0 \quad (\forall r, i) \end{aligned}$$

$$\text{So, } x_h^E = (\varphi_h^{E*} x_{1h}^0, \varphi_h^{E*} x_{2h}^0, \dots, \varphi_h^{E*} x_{mh}^0).$$

This above radial scheme can be argued to have two shortcomings. First, the use of base-period prices to value the contribution of [PMCH] and [RMCH] on profit change usually produces inaccurate valuations. For example, let us consider in Figure 3 how a firm changes its product-mix in the light of changing output prices. Suppose that the firm produces inefficiently at y^a in period 0, and can be made operating revenue efficiently by projecting it on to the frontier at y^0 ¹³ since the *iso-revenue* line R^0 at $t = 0$ is tangent to production frontier at point y^0 (optimal product-mix at $t = 0$). However, in period 1 when output prices change, y^1 becomes the optimal product-mix since the *iso-revenue* line R^1 is tangent to the frontier at y^1 . Thus product-mix change in difference form, $(y^1 - y^0)$, when evaluated at current period prices contributes to increased profit by $(R^1 - R^0)$ ¹⁴. However, had this change been evaluated at base period prices, then profit would have declined by $(R^0 - R^0)$. This example justifies the use of current period's prices to be chosen as weight for valuing the contribution of [PMCH] on profit change.

<<INSERT Figure 3>>

Similarly, in the light of changing input prices, as argued by Mensah (1982), the production manager should be held responsible for the impact of changing relative prices on optimal input usage¹⁵, and any cost-minimizing manager has every incentive to substitute cheaper input for the costlier one to induce higher profit. Therefore, one can observe from Figure 4 that the resource-mix change in difference form, $(x^1 - x^0)$ when evaluated at current period prices, will contribute to increased profit by $(C^1 - C^0)$; otherwise, there would be a sign of decline in profit by $(C^0 - C^0)$ ¹⁶ if the assumption of base period prices is

¹³ Revenue efficiency (RE) can be achieved by removing its both technical and allocative inefficiencies. That is, $RE = \text{technical efficiency} \left(\frac{oy^a}{oy^F} \right) \times \text{allocative efficiency} \left(\frac{oy^F}{oy^r} \right)$.

¹⁴ The production manager has therefore every incentive to choose the right product-mix in the light of changing market prices for outputs, and the opportunity cost of not doing so is surprisingly high.

¹⁵ As Callen (1988, footnote 18, p.94) rightly argued, even if the production manager is not held responsible for changing input prices, management would still like to know the opportunity cost of not substituting inputs optimally when there are input price changes.

¹⁶ This cost differential between producing at x^0 and x^1 represents the cost of improperly forecasting input prices – sort of price variance. In the economics literature, this cost differential is called a Konus (1939) price index or a true 'cost-of-living' index, and has implications for cost control in the world of changing input prices. Note that, as argued by Mensah (1982), neither mix

maintained to prevail for the current period. Therefore, one could justify the use of current period's input prices as weight to evaluate the contribution of [RMCH] on profit change.

<<INSERT Figure 4>>

Second, since the radial DEA models do not take slacks¹⁷ into account in evaluating efficiency scores, the contributions of the various components of profit change are grossly undervalued. In an attempt to get rid of this problem, we suggest the use of various variants of slacks-based measure (SBM) of Tone (2001). We now turn to present the non-radial measures in the immediately following section.

2.3 Non-radial DEA estimation models

To compute y_h^A of firm h, the following output-oriented SBM model¹⁸ is set up:

$$\begin{aligned} \theta_h^{A(SBM)} &= \max \left(1 + \frac{1}{s} \sum_{r=1}^s (s_r^{0+} / y_{rh}^0) \right) \\ \text{subject to } &\sum_{j=1}^n y_{rj}^0 \lambda_j^0 - s_r^{0+} = y_{rh}^0 \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^0 \lambda_j^0 + s_i^{0-} = x_{ih}^0 \quad (\forall i), \\ &\sum_{j=1}^n \lambda_j^0 = 1, \lambda_j^0 \geq 0 \quad (\forall j), s_r^{0+}, s_i^{0-} \geq 0 \quad (\forall r, i) \end{aligned}$$

So, $y_h^{A(SBM)} = (y_{1h}^0 + s_1^{0+*}, y_{2h}^0 + s_2^{0+*}, \dots, y_{sh}^0 + s_s^{0+*})$.

Next, to estimate y_h^B of firm h, the following output-oriented SBM model¹⁹ is set up:

nor yield variance can be used to motivate production managers to minimize cost in a world of changing relative input prices since they are not a function of actual input prices.

¹⁷ Slacks are obvious in all reference technologies that are constructed nonparametrically, i.e., when the reference technology is obtained as the convex monotonic hull of the observed input and output vectors. Since Afriat (1972) this nonparametric representation is of particular importance if one follows a 'revealed preference' approach to producer behavior, which has been advocated by Varian (1984) for its use in testing regularity conditions and for nonparametric efficiency measurement itself by Banker et al. (1984).

¹⁸ Alternatively, the Russell non-radial measure equivalent of SBM can be: $\theta_h^{A(NR)} = (1/s) \max \sum_{r=1}^s \theta_{hr}^A$ subject to $\sum_{j=1}^n y_{rj}^0 \lambda_j^0 \geq \theta_{hr}^A y_{rh}^0 \quad (\forall r), \sum_{j=1}^n x_{ij}^0 \lambda_j^0 \leq x_{ih}^0 \quad (\forall i), \sum_{j=1}^n \lambda_j^0 = 1, \lambda_j^0 \geq 0 \quad (\forall j)$. Here, $y_h^{A(NR)} = (\theta_{h1}^{A*} y_{1h}^0, \theta_{h2}^{A*} y_{2h}^0, \dots, \theta_{hs}^{A*} y_{sh}^0)$.

¹⁹ Alternatively, the Russell non-radial measure equivalent of SBM can be: $\theta_h^{B(NR)} = (1/s) \max \sum_{r=1}^s \theta_{hr}^B$ subject to $\sum_{j=1}^n y_{rj}^1 \lambda_j^1 \geq \theta_{hr}^B y_{rh}^0 \quad (\forall r), \sum_{j=1}^n x_{ij}^1 \lambda_j^1 \leq x_{ih}^0 \quad (\forall i), \sum_{j=1}^n \lambda_j^1 = 1, \lambda_j^1 \geq 0 \quad (\forall j)$. Here $y_h^{B(NR)} = (\theta_{h1}^{B*} y_{1h}^0, \theta_{h2}^{B*} y_{2h}^0, \dots, \theta_{hs}^{B*} y_{sh}^0)$.

$$\theta_h^{B(SBM)} = \max \left(1 + \frac{1}{s} \sum_{r=1}^s (s_r^{1+} / y_{rh}^0) \right)$$

$$\text{subject to } \sum_{j=1}^n y_{rj}^1 \lambda_j^1 - s_r^{1+} = y_{rh}^0 \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^1 \lambda_j^1 + s_i^{1-} = x_{ih}^0 \quad (\forall i),$$

$$\sum_{j=1}^n \lambda_j^1 = 1, \lambda_j^1 \geq 0 \quad (\forall j), s_r^{1+}, s_i^{1-} \geq 0 \quad (\forall r, i)$$

$$\text{So, } y_h^{B(SBM)} = (y_{1h}^0 + s_1^{1+*}, y_{2h}^0 + s_2^{1+*}, \dots, y_{sh}^0 + s_s^{1+*}).$$

To estimate y_h^C of firm h, the following output-oriented SBM model²⁰ is set up:

$$\theta_h^{C(NR)} = \max \left(1 + \frac{1}{s} \sum_{r=1}^s (s_r^{1+} / y_{rh}^1) \right)$$

$$\text{subject to } \sum_{j=1}^n y_{rj}^1 \lambda_j^1 - s_r^{1+} = y_{rh}^1 \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^1 \lambda_j^1 + s_i^{1-} = x_{ih}^1 \quad (\forall i),$$

$$\sum_{j=1}^n \lambda_j^1 = 1, \lambda_j^1 \geq 0 \quad (\forall j), s_r^{1+}, s_i^{1-} \geq 0 \quad (\forall r, i)$$

$$\text{So, } y_h^{C(SBM)} = (y_{1h}^1 + s_1^{1+*}, y_{2h}^1 + s_2^{1+*}, \dots, y_{sh}^1 + s_s^{1+*}).$$

To estimate y_h^D of firm h, the following output-oriented SBM model²¹ is set up:

$$\theta_h^{D(SBM)} = \max \left(1 + \frac{1}{s} \sum_{r=1}^s (s_r^{1+} / y_{rh}^0) \right)$$

$$\text{subject to } \sum_{j=1}^n y_{rj}^1 \lambda_j^1 - s_r^{1+} = y_{rh}^0 \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^1 \lambda_j^1 + s_i^{1-} = x_{ih}^1 \quad (\forall i),$$

$$\sum_{j=1}^n \lambda_j^1 = 1, \lambda_j^1 \geq 0 \quad (\forall j), s_r^{1+}, s_i^{1-} \geq 0 \quad (\forall r, i)$$

$$\text{So, } y_h^{D(SBM)} = (y_{1h}^0 + s_1^{1+*}, y_{2h}^0 + s_2^{1+*}, \dots, y_{sh}^0 + s_s^{1+*}).$$

To estimate x_h^E of firm h, the following input-oriented SBM model²² is set up as:

²⁰ Alternatively, the Russell non-radial measure equivalent of SBM can be: $\theta_h^{C(NR)} = (1/s) \max \sum_{r=1}^s \theta_{hr}^C$
subject to $\sum_{j=1}^n y_{rj}^1 \lambda_j^1 \geq \theta_{hr}^A y_{rh}^1 \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^1 \lambda_j^1 \leq x_{ih}^1 \quad (\forall i), \quad \sum_{j=1}^n \lambda_j^1 = 1, \quad \lambda_j^1 \geq 0 \quad (\forall j)$. Here,
 $y_h^{C(NR)} = (\theta_{h1}^{C*} y_{1h}^1, \theta_{h2}^{C*} y_{2h}^1, \dots, \theta_{hs}^{C*} y_{sh}^1)$.

²¹ Alternatively, the Russell non-radial measure equivalent of SBM can be:
 $\theta_h^{D(NR)} = (1/s) \max \sum_{r=1}^s \theta_{hr}^D$ subject to $\sum_{j=1}^n y_{rj}^1 \lambda_j^1 \geq \theta_{hr}^A y_{rh}^0 \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^1 \lambda_j^1 \leq x_{ih}^1 \quad (\forall i), \quad \sum_{j=1}^n \lambda_j^1 = 1,$
 $\lambda_j^1 \geq 0 \quad (\forall j)$. Here $y_h^{D(NR)} = (\theta_{h1}^{D*} y_{1h}^0, \theta_{h2}^{D*} y_{2h}^0, \dots, \theta_{hs}^{D*} y_{sh}^0)$.

$$\begin{aligned} \varphi_h^{E(SBM)} &= \min \left(1 - \frac{1}{m} \sum_{i=1}^m (s_i^{1-} / x_{ih}^0) \right) \\ \text{subject to } &\sum_{j=1}^n y_{rj}^1 \lambda_j^1 - s_r^{1+} = y_{rh}^D \quad (\forall r), \quad \sum_{j=1}^n x_{ij}^1 \lambda_j^1 + s_i^{1-} = x_{ih}^0 \quad (\forall i), \\ &\sum_{j=1}^n \lambda_j^1 = 1, \lambda_j^1 \geq 0 \quad (\forall j), s_r^{1+}, s_i^{1-} \geq 0 \quad (\forall r, i) \end{aligned}$$

$$\text{So, } x_h^{E(SBM)} = (x_{1h}^0 - s_1^{1-*}, x_{2h}^0 - s_2^{1-*}, \dots, x_{mh}^0 - s_m^{1-*}).$$

Thus, using y_h^A , y_h^B , y_h^C , y_h^D , and x_h^E obtained from the SBM measures, one can decompose profit change into six components. However, note that the estimation of points such as y_h^B , y_h^D and x_h^E through both radial and non-radial DEA models are sometimes not feasible in which case we treat the underlying firm under evaluation in the respective DEA models as efficient since there are no reference point in the technology set²³.

Let now turn to discuss the data.

3. The Indian commercial banking data

In the literature there are two approaches, viz., production approach and intermediation approach, to measure bank efficiency. In the former Ferrier and Lovell (1990) use capital, labor and other non-financial inputs to provide deposits and advances. In the latter, however, a bank is treated as a producer of intermediation services - by transforming risk and maturity profile of funds received from depositors to investment or loan portfolio of different risk and maturity profile. Banks also provide services for which specific charges are levied, money value of non-interest income is considered another output variable. To sum up, banks in general are considered to have three outputs: y_1 = Investments (I), y_2 = performing loan assets (PLA) and y_3 = non-interest income (NonII), and three inputs: x_1 = borrowed funds (BF), x_2 = fixed assets (FA) and x_3 = labor (L). See Berger and Mester (1997) for a comprehensive discussion of these two approaches.

²² Alternatively, the Russell non-radial measure equivalent of SBM can be: $\varphi_h^{E(NR)} = (1/m) \min \sum_{i=1}^m \varphi_{hi}^E$ subject to $\sum_{j=1}^n y_{rj}^1 \lambda_j^1 \geq y_{rh}^{D(NR)} \quad (\forall r)$, $\sum_{j=1}^n x_{ij}^1 \lambda_j^1 \leq \varphi_{hi}^E x_{ih}^0 \quad (\forall i)$, $\sum_{j=1}^n \lambda_j^1 = 1$, $\lambda_j^1 \geq 0 \quad (\forall j)$. Here, $x_h^{E(NR)} = (\varphi_{h1}^{E*} x_{1h}^0, \varphi_{h2}^{E*} x_{2h}^0, \dots, \varphi_{hm}^{E*} x_{sh}^0)$.

²³ However, note that Grifell-Tatje and Lovell (1999) did not discuss in their study the occurrence of infeasible solutions while suggesting radial DEA models for the evaluation of y_h^B , y_h^D and x_h^E .

Besides being profit driven, banks are also forced to take up economic and social responsibilities like safety of customers, financing much needed public sector expenditure in various social and economic services, and this study, therefore, has adopted the intermediation approach. The essence of taking PLA, as an output measure is more realizable in Indian context, because only earning asset contributes to revenue of bank and not total loan. This approach is effective in analyzing management's success. Coates (1990) also provides a comprehensive description of the objectives of the Indian banking system for which production approach seems to be inappropriate. All the monetary values of inputs and outputs have been deflated using wholesale price index deflator with base 1993-94.

Concerning the prices of inputs and outputs, the unit prices of the inputs: 'borrowed funds', 'labor' and 'fixed assets' are, respectively, the 'average interest paid per rupee of borrowed funds', [(w) BF], 'average staff cost', [(w) L], and 'non-labor operational cost per rupee amount of fixed asset', [(w) FA]; and outputs: 'investments', 'performing loan assets' and 'non-interest income' are, respectively, the 'average interest earned on per rupee unit of investment', [(p) I], 'average interest earned on per rupee unit of performing loan assets', [(p) PLA], and 'non-interest fee-based income on per rupee of working funds, [(p) NonII]. The input and output data as well as their prices have been taken from the various sections of 'Statistical Tables Relating to Banks in India', Reserve bank of India and from Indian Banking Association publications. The relevant data are downloaded from http://www.rbi.org.in/rbi-sourcefiles/annualdata/bs_annualdata.aspx.

Our study covers eight years commencing from the financial year 1997-98²⁴. This is the year in which competition intensifies in the banking industry with a total of around 100 banks, a shift from around 80 banks in the preceding years²⁵. The Regional Rural Banks have their operations limited to a few contiguous districts and mostly serve credit to local farmers and a few small-scale enterprises. Because these banks operate for some special purpose, and provide service to a small target group, they have been excluded from our study to avoid inconsistencies. Since data are not available for all the banks for all the years, we have

²⁴ The year 1997-98 is henceforth treated as 1998, and so are the cases for other financial years.

²⁵ It would have been interesting to examine productivity performance variations of banks just after the financial liberalization was introduced in 1991. However, the unavailability of data on unit prices of inputs of banks up to 1996, which are required to estimate the various components of profit change, forced us to conduct this study starting with the year 1998.

considered a balanced panel data on 71 banks (26 nationalized banks (NB), 27 Indian private banks (PB) and 18 foreign banks (FB)) over a period of eight years: 1998 - 2005²⁶.

4. Result and discussion

Prior to formal modeling, it is common in empirical work in DEA literature (Fare et al., 1987, Grosskopf and Valdmanis, 1987 and Rangan et al., 1988) to present descriptive statistics on the input-output data, which serves to provide some intuition on the plausibility of the derivative DEA-efficiency coefficients. Table 1 exhibits the descriptive statistics of all the input-output variables, and their respective unit prices, where average NonII and FA values are found more or less constant over all the eight years. All the variables are measured in crores of rupees. (1 crore = 10 million). Composite output (y), composite input (x)²⁷ and their significant constituents have grown fairly steadily over years (excepting for the year 1999). This trend holds true for cost and revenue figures as well. Also evident are the steadily increasing variations in output and input variables, as reflected in their standard deviation (SD) scores, being more than their means.

<<INSERT Table 1>>

4.1 Results on radial DEA models

We exhibit in Table 2 to illustrate the difference in (average) estimates on results concerning profit change and its six components for Indian commercial banking sector obtained from Laspeyre, Paaschee and Bennet type decompositions. As was expected, we observe some contrasting estimates on some components of profit change obtained from Laspeyre and Paaschee type decompositions. For example, volume change in 2001-2000, price change in 2001-2000 and 2002-2001, total factor productivity change in 1999-1998 and 2005-2004, activity change in 2001-2000, technical change 2005-2004, product-mix change in 1999-1998, and scale change in 2000-1999, 2002-2001, 2003-2002, 2004-2003, and 2005-2004. Also

²⁶ We have considered only those banks that have consistently shown positive profits throughout all the eight years. However, our results are unaffected by the inclusion of the non-profit making banks since they are not the frontier determining banks. Also note that their numbers are only nine.

²⁷ The composite output and input are, respectively, defined as $y = \sum_{r=1}^3 s_r y_r$ and $x = \sum_{i=1}^3 s_i x_i$ where s_r and s_i are, respectively, the r^{th} output's revenue-share and i^{th} input's cost share, i.e., $s_r = p_r y_r / \sum_{r=1}^3 p_r y_r$ and $s_i = w_i x_i / \sum_{i=1}^3 w_i x_i$.

apparent distinction between these two sets of estimates on each of these components is their sheer magnitudes, which could significantly influence the policy makers in evaluating the outcomes of economic reforms in terms of distributional consequences. That is why, one should only focus on analyzing the results obtained from Bennet-type decomposition.

<<INSERT Table 2>>

Excepting the last year of our study period, there is, on average, an increasing trend in the growth of operating profit. On a closer look at the two broader sources of profit change, we find mostly the contribution of volume change positive (excepting for 2000-1999) and price change negative (excepting for 2000-1999 and 2005-2004). However, even though the contribution of price change is negative, the contribution of positive volume change is strong enough to outweigh the negative price change to give rise to positive profit. The apparent sources of negative price change can be seen from Table 1 through the constant or negative trends in output prices and positive trends in input prices. The falling trends in output prices and positive trends in input prices are understandable from the deregulation of Indian commercial banking sector, and consequent increase in competition.

On seeing the components of volume change, we find the contribution of activity change positive and significant throughout, whereas that of total factor productivity change is mix. Out of seven-year periods, we find TFPCH contributing positively only for three years and negatively for four years. On analyzing the components of TFPCH, we observe the contribution of both pure technical efficiency change and technical change mostly negative (i.e., in five out of seven periods in each case).

The prime determinant of positive profit change is the positive activity change, which is, in turn, due to the very large resource-mix change and small product-mix change, both of which are positive throughout in our study periods. However, even though the contribution of scale change component to activity change is negative and large, its effect was completely offset predominantly by the large positive resource-mix change. The reasons for large positive resource-mix change can be due to the steady fall in the trends of input resource prices, which enable the profit-maximizing managers to substitute cheaper resources for costlier ones to induce higher profit.

To sum up, out of six components of profit change, only two components, i.e., resource-mix change and product-mix change contribute positively, and the remaining four components, i.e., price change, technical change, technical efficiency change and scale

change contribute negatively to profit change. However, the radial estimates on these components might give conflicting signals to the direction of profit change since the radial-DEA models suffer from the problem of slacks. It will therefore now be worth comparing these estimates with those obtained from non-radial DEA models, which we are presenting in just the immediately following section.

4.2 Results on non-radial DEA models

Table 3 exhibits the comparative estimates on various components of profit change obtained from both radial and non-radial Bennet-type schemes. We exclude the two broad components such as [VCH] and [PCH] as their computations are made directly from the observed data, and do not depend upon any DEA-type radial and non-radial technologies. One can during our study period the diametrically opposite signs in the directions of the estimates of various components of profit change obtained from radial and non-radial DEA models (indicated in bold figures). For example, in the period 1999-1998, average radial PTEFFCH, PMCH and RMCH estimates reveal contributing positively to profit change whereas the corresponding non-radial estimates contributing negatively; and radial TCH and SCH contributing negatively whereas the corresponding non-radial estimates contributing positively. The most important finding observed from these two sets of estimates throughout our study period is that that while radial models yield positive RMCH and negative SCH, their non-radial counterparts yield just the opposite, for the banking industry.

<<INSERT Table 3>>

The diametrically opposite findings raise one important question before the researchers concerning which measure to use. The answer to this question largely depends on the belief on the way the efficiency is measured in a DEA setting. In the radial measure, the assumption of equiproportionate increases in all outputs has been taken as a rule though there is no *a priori* reason to measure output efficiency radially, even for homothetic technologies. This means that there is no trade off between outputs, which is counter intuitive. Price information would generally indicate that the opportunity costs of production of one output over another are not the same. Consequently it might be optimal to expand outputs in non-equal proportions reflecting their differing opportunity costs²⁸.

²⁸ To argue for why the non-equiproportionate changes in outputs for multi-output firms is a reality, Chambers and Mitchell (2001) said: "...many modern firms rather routinely change their output mix

The most important reason why non-radial measure was introduced pertains to the problem that the radial measure does not always satisfy the fundamental condition known as ‘indication of efficient vectors’. That is, for some types of production technologies that are estimated nonparametrically, the radial projection can, in fact, still be an inefficient point in the commonly accepted sense of Koopmans (1951)²⁹. And, given the fact that the way the real-life multi-output firms frequently change their output mixes, we do believe that the non-radial measure of efficiency reflects the empirical realities more. We now then turn to analyze the summary results, based on the non-radial estimates, on each of these six components of profit change.

First, a closer look at profit change and its three broad components such as [TFPCH], [ACTCH] and [PCH] over years (see Figure 5) reveals that while [TFPCH] contributes positively in five out of seven sample periods, [ACTCH] and [PCH] negatively, respectively, in four and five out of seven sample periods, to profit change. Second, looking at the two components of [TFPCH] (see Figure 6), we find [TCH] contributing positively, and [PTEFFCH] negatively, in five out of seven periods. Though the average banking industry indicates substantial progress in technology, the management of technology has not

by moving in and out of different product lines in response to perceived market opportunities. Further, it is not unusual to encounter firms that were once highly specialized in a single product line that subsequently move into entirely new product lines in an attempt to capture new markets, prevent entry by potential competitors, or simply to “diversify their productive portfolio.” For example, Schmalensee (1978) documented that the six leading producers of breakfast cereals introduced roughly eighty new brands between 1950 and 1972!” (p.35).

²⁹ However, in spite of ‘indication problem’, the radial efficiency measures have been not only very popular but also widely used. See Cherchye and Van Puyrenbroeck (1999) who have cited four reasons for this. 1) The reference technologies on the empirical level normally approximate in nature and therefore the indication problem may be considered as an accidental and somewhat artificial consequence. 2) The axiomatic approach on the theoretical level, as further developed by various authors such as e.g., Bol (1986), Russell (1988, 1990) and Christensen et al. (1999), has forwarded the insight that no universally best measure exists, which has also been shown empirically by Sengupta and Sahoo (2005). 3) These axioms refer to desirable mathematical characteristics of an efficiency function, which are noted originally by Shephard (1970), and in an efficiency measurement context by Färe and Lovell (1978), Bol (1986, 1988) and Russell (1985, 1988, 1990). However, even though convexity postulate is under severe attack because it assumes away many important technological features such as indivisibilities, economies of scale and scope, some authors e.g., Kopp (1981) or Russell (1985) clearly took a favorable stance towards the radial measure, given its economic interpretation for the class of convex monotonic technologies. 4) Ferrier and Lovell (1990) have claimed that slacks may be viewed essentially as resulting from allocative rather than technical efficiency. Slacks appear because of the piecewise linear structure imposed on the technology set. To Forsund (1998), this way of determining technology is really an expression of our ignorance, and represents a pessimistic limit.

been proper, and therefore, attention is warranted to enhance the operational efficiency of banks. Third, on an examination of the three components of [ACTCH] (see Figure 7), we find mostly both [RMCH] and [PMCH] contributing negatively, and [SCH] positively, to profit change. This finding indicates that the management of banking industry needs to chalk out strategies to significantly improve its both input and output allocations in the light of frequently changing market prices.

<<INSERT Figures: 5, 6, & 7>>

We now turn to examine the trend behaviors of profit change and its six components of the Indian commercial banks with respect to ownership. Figure 8 exhibits the trend behaviors of profit change with respect to ownership. Though the nationalized banks seem to show higher profit change in absolute terms than the private and foreign banks, the latter groups exhibit higher profit growth up to period 2004-2003. Both private and foreign banks groups suddenly started deteriorating in their profit-maximizing behavior in the last period, and nationalized banks even one period before. This finding helps us partially supporting the hypothesis that competition in the banking industry cannot sustain profit accrual over years.

<<INSERT Figure 8>>

We now turn to exhibit the three major sources of profit change with respect to ownership. The first such source is [TFPCH], whose trend behaviors are exhibited in Figure 9 with respect to ownership. As was expected, one could clearly see the nationalized banks outperforming both private and foreign banks. It is also to be worth pointing that the foreign banks, though, started with negative growth, seemed to be doing at par with private sector banks. The reasons for substantial productivity contribution to profit from the nationalized banks could be due to their large scale investment in new technology, which has resulted in large technical progress (see Figure 12), and scale advantages, which they are able to reap due to their big size (see Figure 16).

<<INSERT Figure 9>>

The second major source is [ACTCH] whose trend behaviors with respect to ownership are exhibited in Figure 10. Though both nationalized and private banks started very badly in their respective scale and scope operations in the beginning of our study period, the nationalized banks seem outperform their rivals since 2001. But, the reverse is the case for the foreign banks, which started very well in the beginning, but could not maintain their

pace, even deteriorated by contributing negatively to profit change. However, the finding of foreign banks behaving relatively at par with private banks clearly indicate that with the deregulation of the banking sector in India, foreign banks are not only found playing an active role in Indian financial market but also setting performance standards.

<<INSERT Figure 10>>

The third major source is price change whose trend is exhibited in Figure 11. As was expected, both private and foreign banks exhibit better pricing behavior in contributing positively to profit change. Nationalized banks seem to be very inefficient in this activity, and their pricing behavior contributes to negative profit. The finding of superior price performance of private and foreign banks might be due to that because of their universal banking nature, they are more successful to offer a series of innovative product offerings with lucrative pricing catering to various customer segments.

<<INSERT Figure 11>>

We now turn to examine the trends of the two determinants of [TFPCH] with respect to ownership in terms of their contribution to profit change. Figure 12 exhibits [TCH] trends with respect to ownership. Even though all the bank groups exhibit technical progress (except the period 1999-1998) contributing positively to profit change, the nationalized banks are ahead in this endeavor. However, the management of new technology adopted by all bank groups has been poor, which has been reflected in their negative behavior concerning operational efficiency change. Figure 13 exhibit such [PTEFFCH] trends. One could see the foreign banks exhibiting relatively better operational efficiency behavior compared to both nationalized and private banks, and between the latter two bank groups, the former exhibits the worst performance. This finding of nationalized banks performing poor might be due to the fact that even though the acceptance of technology has already crept in, the utilization has not been maximized. This is simply because public sector banks were facing serious resistance to change from their employees to adapt to changing conditions because of introduction of new technologies.

<<INSERT Figures: 12 & 13>>

However, the variation in trend performance of each ownership group remains more or less the same, reflecting their similar familiarity with the regulatory system in terms of dependence on wholesale or corporate resources, inter-bank market borrowings, refinance of assets, etc.

Further, it can be seen that all the bank groups are observed to be improving in their operational efficiency behavior since 2002, which might be argued to arise from intense competition in the banking industry. Leibenstein (1966) maintains that exposure to competition will generate improvement in efficiency (i.e., X-efficiency or technical efficiency). He argues that enterprises exposed to competition respond by eliminating internal inefficiency, and seek out opportunities for innovation. To Stigler (1976), this X-efficiency gain is nothing but an increase in the intensity of labor or, equivalently, a reduction in on-the-job leisure. Ganley and Grahl (1988) pointed out that, where labor productivity has increased due to such competition; there is evidence of increased work intensity. A closer look at our data set reveals that labor productivity has improved marginally (NB: from 0.004 to 0.008, PB: from 0.014 to 0.089, and FB: from 0.122 to 0.241 over the period), confirming the above-mentioned claim of increased work intensity, which has helped all the bank groups marginally improving in their operational efficiency behavior.

Finally, the three determinants of [ACTCH] exhibiting the scale and scope operations can be examined in terms of ownership to assess their potential contributions to profit change. The first such determinant is product-mix change whose trends are exhibited in Figure 14. As expected, nationalized banks perform very poor in choosing on their optimal allocation of output-mix.

<<INSERT Figure 14>>

Figure 15 exhibits trend behavior of second components of [ACTCH], i.e., resource-mix change with respect to ownership. Surprisingly, all the ownership groups contribute negatively to profit change in the scope operation of their resource allocation behaviors. However, as expected, both private and nationalized banks exhibit relatively better practices in their operations.

<<INSERT Figure 15>>

In spite of the facts that nationalized banks are the oldest banks with strong asset base, their output and resource allocation performances are at stake. This might be due to the fact that with the emergence of new private and foreign banks offering a series of innovative product through universal banking, the public sector banks have also devised a market responsive product-mix concerning saving and invest plans offering attractive returns, and they are going through the process of overhauling with significant decentralization in the management and organizational structure, causing huge loss in allocative efficiency. Also

important to note that the relatively poor output and resource allocation performance of the nationalized banks can be explained in part arising not only from their responsibilities to serve small depositors, a group generally ignored by foreign banks and many new private sector banks, but also from the provision of low-paid services like tax collection, maintaining and supervising pension and provident fund accounts.

Even though institutional conditions are favorable to all banks groups, the relatively lackluster performance in output and resource allocations of the nationalized banks can be understandable because of X-inefficiency factors arising from government ownership³⁰, which might be argued to be leading to diminishing return to income, reduction in interest spread, and the presence of scale economies due to fixed cost. Note that like nationalized banks, old private sector banks are also very poor in their optimal allocation of output and resource mixes. It is the only the superior performances of new private sector banks that drive up the average performance of all private sector banks.

Finally, the scale change, the last component of [ACTCH], is exhibited in Figure 16 with respect to ownership. All the ownership groups, though contribute positively in their scale operation to profit change, the performance of nationalized banks is outstanding. This might be due to that since they are old; they are able to reflect their learning experience in their scaling behavior.

<<INSERT Figure 16>>

5. Concluding remarks

Grifell-Tatje and Lovell (1999) made a contribution to the literature by decomposing profit change in an extended radial DEA framework into six mutually exclusive components that are of practical use to managers where each of these components is evaluated at base-period prices. Their approach can be argued to have two problems. First, radial DEA models do not achieve full efficiency because slacks remain even after radial projections are made onto the production frontier, and therefore the contributions of the various components of profit change are grossly underestimated. Second, the contributions of these components when evaluated at base-period prices are potentially misleading, which might be due to the fact that

³⁰ Government officials are in general more inclined to pursue their own interests, or interest of pressure group, rather than interests of public. Frequently changing objectives of nationalized banks arising from government's attempts to accommodate diverse interest groups creates hindrances in their allocation behaviors.

productivity contribution (in terms of increasing technical efficiency, input-tradeoff (resource-mix) efficiency and output-tradeoff (product-mix) efficiency) would signal an opposite sign in profit, had they been evaluated at current-period prices. To circumvent over these problems, our contribution is, therefore, first, to introduce the non-radial models, and second, to provide strong theoretical argument in favor of either current-period prices/average of both period prices as weights to be used to value the productivity contributions towards profit change.

We have taken Indian commercial banking sector for the period: 1997-98 – 2004-05 as a case study to illustrate the radial and non-radial decompositions of profit change so as to empirically examine the role of competition on profit change with respect to each of these six mutually exclusive components. Our broad empirical results are indicative in many ways as follows:

1. The fact that radial and non-radial models yield diametrical opposite sign for some of the determinants of profit raises concern concerning which measure to use in any empirical application. We have, however, argued for the non-radial measure to bode well because it is analytically rich and empirically more demanding as well.
2. As regards to the three broad components of profit change, [TFPCH] contributes positively, and [ACTCH] negatively, in four out of seven sample periods, and [PCH] negatively in five out of seven periods, to profit change. Further, on a closer look at the two components of [TFPCH], we find [TCH] contributing positively, and [PTEFFCH] negatively, in five out of seven periods. Though the average banking industry indicates substantial progress in technology, the management of new technology has been very poor. Similarly, an examination of the three components of [ACTCH] reveals that [RMCH] contributes negatively, and [SCH] positively, to profit change throughout whereas [PMCH] contributes negatively in five out of seven periods. This finding indicates that the management of banking industry needs to chalk out strategies to significantly improve its both input and output allocations in the light of their frequently changing market prices arising out of competition.

3. The recovering efficiency change trend behavior in all ownership groups after 2002 appear to indicate an affirmative gesture about the effect of the reform process on the performance of the Indian banking sector.

4. Despite the fact that nationalized banks are the oldest banks with strong asset base, their output and resource allocation performances are at stake, which might be due to X-inefficiency factors arising from government ownership. However, the role of capital market in improving the weak relationship between the market for corporate control and efficiency of private enterprise assumed by property right hypothesis is yet to be seen.

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Table 1: Summary statistics for Indian banks: 1997-98 - 2004-05

		1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05
(O) I	Mean	20.615	23.891	28.404	32.756	37.102	43.173	53.414	53.884
	SD	45.647	51.241	61.410	72.643	89.576	111.576	142.663	143.917
(O) PLA	Mean	66.392	149.415	75.348	83.679	89.630	97.734	109.363	110.324
	SD	149.105	701.636	185.142	210.525	219.883	230.052	243.612	245.753
(O) NonII	Mean	0.891	1.060	1.059	1.241	1.268	1.336	1.458	1.471
	SD	2.371	2.464	2.683	2.770	2.954	3.163	3.440	3.470
Y	Mean	43.446	86.554	51.820	58.133	63.287	70.371	81.290	82.005
	SD	96.587	357.338	122.928	141.219	154.441	170.258	191.446	193.128
(I) BF	Mean	2.067	2.184	3.268	3.522	4.077	5.657	9.770	9.856
	SD	6.211	6.969	7.874	7.687	9.099	12.704	23.339	23.544
(I) FA	Mean	0.959	1.070	1.181	1.198	1.204	1.255	1.419	1.432
	SD	1.531	1.753	2.099	2.164	2.133	2.146	2.425	2.446
(I) L	Mean	11530	11359	11301	11419	10754	10501	11046	11143
	SD	29688	29417	28929	28843	27627	26668	27451	27692
X	Mean	2456.603	2348.595	2346.146	2305.229	2425.808	2628.666	3063.996	3090.951
	SD	6939.791	6829.633	6467.732	6130.776	6513.525	6972.524	8053.851	8124.636
(P) I	Mean	0.392	0.327	0.302	0.280	0.263	0.262	0.275	0.277
	SD	0.203	0.124	0.135	0.113	0.089	0.105	0.145	0.146
(P) PLA	Mean	0.101	0.105	0.106	0.104	0.102	0.101	0.103	0.104
	SD	0.024	0.023	0.016	0.015	0.013	0.018	0.033	0.033
(P) NonII	Mean	0.018	0.023	0.017	0.022	0.019	0.019	0.021	0.021
	SD	0.014	0.019	0.018	0.025	0.023	0.027	0.041	0.041
(C) BF	Mean	4.939	5.573	8.606	8.682	6.348	9.872	23.957	24.168
	SD	7.390	8.502	24.753	33.110	10.721	20.483	72.793	73.433
(C) FA	Mean	1.420	1.522	1.889	1.629	1.436	1.529	1.813	1.829
	SD	3.155	3.803	5.255	4.174	2.614	2.847	3.621	3.653
(C) L	Mean	0.0001	0.0007	0.0005	0.0005	0.0008	0.0042	0.0041	0.0046
	SD	0.0002	0.0037	0.0027	0.0016	0.0030	0.0228	0.0182	0.0212
REVENUE	Mean	12.202	13.008	14.659	15.779	17.367	19.285	22.091	22.481
	SD	28.137	28.807	32.674	35.236	38.847	42.878	48.416	49.271
COST	Mean	5.733	7.041	7.162	7.568	8.365	9.801	11.160	11.427
	SD	13.393	15.921	15.962	17.138	19.371	22.250	25.792	26.295

Table 2: Profit Change and its Components in Laspeyre, Paaschee and Bennet Type Measures

Laspeyre	Π -CH	VCH	PCH	TFPCH	ACTCH	TCH	PTEFFCH	PMCH	RMCH	SCH
1999-1998	0.4150	8.4016	-7.9866	-0.0352	8.4368	-0.3841	0.3489	8.3339	209.9739	-209.8710
2000-1999	0.8363	-1.3563	2.1926	-2.3876	1.0313	-1.3956	-0.9920	2.0147	228.6685	-229.6519
2001-2000	0.6990	-0.5758	1.2748	-0.3622	-0.2137	-1.0160	0.6539	0.8605	1973.0559	-1974.1300
2002-2001	0.9299	0.9217	0.0082	-0.4434	1.3650	-0.4001	-0.0433	1.3814	188.6456	-188.6620
2003-2002	1.0437	1.1339	-0.0902	0.4763	0.6577	1.7404	-1.2641	1.0104	153.6225	-153.9752
2004-2003	1.1246	1.5596	-0.1044	1.4129	0.1466	2.7319	-1.3190	0.9750	141.0940	-141.9224
2005-2004	0.2214	0.1102	0.1112	0.0039	0.1064	0.0428	-0.0390	0.0001	148.9207	-148.8144
Paaschee	Π -CH	VCH	PCH	TFPCH	ACTCH	TCH	PTEFFCH	PMCH	RMCH	SCH
1999-1998	0.4150	2.3891	-1.9741	0.0540	2.3351	-0.3668	0.4207	-0.3023	4.8407	-2.2033
2000-1999	0.8363	-7.9449	8.7812	-12.7346	4.7896	-11.8019	-0.9326	1.7270	1.5870	1.4757
2001-2000	0.6990	2.4409	-1.7419	-0.3178	2.7587	-1.0014	0.6836	0.6836	2.1507	-0.0757
2002-2001	0.9299	2.6953	-1.7654	-0.4789	3.1742	-0.4343	-0.0446	1.2803	1.6028	0.2910
2003-2002	1.0437	3.0364	-1.9926	0.5277	2.5087	1.7788	-1.2510	0.8516	1.1230	0.5340
2004-2003	1.1246	3.6458	-2.1907	1.4746	2.1712	2.7809	-1.3063	0.7934	0.7816	0.5962
2005-2004	0.2214	0.1112	0.1102	-0.6431	0.7543	-0.6038	-0.0393	0.0000	0.0000	0.7543
Bennet	Π -CH	VCH	PCH	TFPCH	ACTCH	TCH	PTEFFCH	PMCH	RMCH	SCH
1999-1998	0.4150	5.3953	-4.9803	0.0094	5.3860	-0.3755	0.3848	4.0158	107.4073	-106.0371
2000-1999	0.8363	-4.6506	5.4869	-7.5611	2.9105	-6.5987	-0.9623	1.8709	115.1277	-114.0881
2001-2000	0.6990	0.9325	-0.2335	-0.3400	1.2725	-1.0087	0.6688	0.7720	987.6033	-987.1029
2002-2001	0.9299	1.8085	-0.8786	-0.4611	2.2696	-0.4172	-0.0440	1.3308	95.1242	-94.1855
2003-2002	1.0437	2.0852	-1.0414	0.5020	1.5832	1.7596	-1.2576	0.9310	77.3727	-76.7206
2004-2003	1.1246	2.6027	-1.1476	1.4438	1.1589	2.7564	-1.3127	0.8842	70.9378	-70.6631
2005-2004	0.2214	0.1107	0.1107	-0.3196	0.4303	-0.2805	-0.0391	0.0000	74.4604	-74.0301

Table 3: A Comparison Between Radial and Non-radial Schemes (Bennet Type Measures)

Year	Scheme	TFPCH	ACTCH	TCH	PTEFFCH	PMCH	RMCH	SCH
1999-1998	R	0.0094	5.3860	-0.3755	0.3848	4.0158	107.4073	-106.0371
	NR	25.9573	-20.5619	93.0114	-67.0542	-35.7988	-1.3192	16.5560
2000-1999	R	-7.5611	2.9105	-6.5987	-0.9623	1.8709	115.1277	-114.0881
	NR	-0.0098	-4.6408	-66.7089	66.6990	-4.9783	-2.4782	2.8158
2001-2000	R	-0.3400	1.2725	-1.0087	0.6688	0.7720	987.6033	-987.1029
	NR	1.3455	-0.4130	0.5474	0.7981	-0.5989	-1.7487	1.9347
2002-2001	R	-0.4611	2.2696	-0.4172	-0.0440	1.3308	95.1242	-94.1855
	NR	0.9928	0.8157	1.1254	-0.1326	-0.0634	-0.9755	1.8546
2003-2002	R	0.5020	1.5832	1.7596	-1.2576	0.9310	77.3727	-76.7206
	NR	1.4189	0.6663	3.3307	-1.9119	0.0996	-1.2280	1.7947
2004-2003	R	1.4438	1.1589	2.7564	-1.3127	0.8842	70.9378	-70.6631
	NR	2.6697	-0.0670	4.0554	-1.3857	0.0766	-1.7684	1.6248
2005-2004	R	-0.3196	0.4303	-0.2805	-0.0391	0.0000	74.4604	-74.0301
	NR	-0.0748	0.1855	-0.02145	-0.0534	-0.0433	-0.1133	0.3421

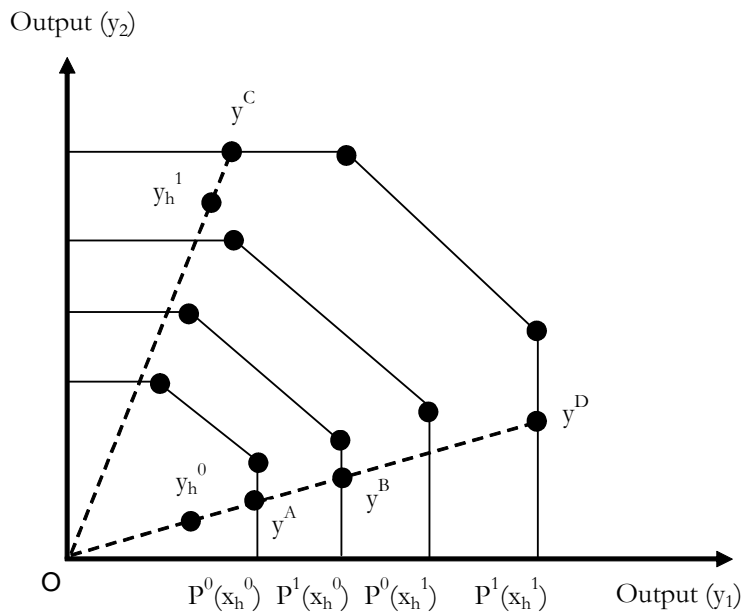


Figure 1: Decomposition of Profit Change ($s = 2$)

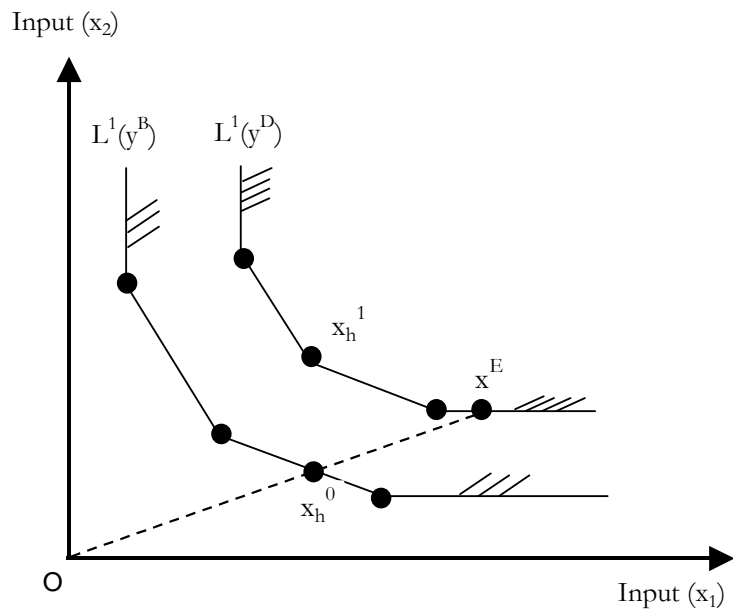


Figure 2: Decomposition of Profit Change ($m = 2$)

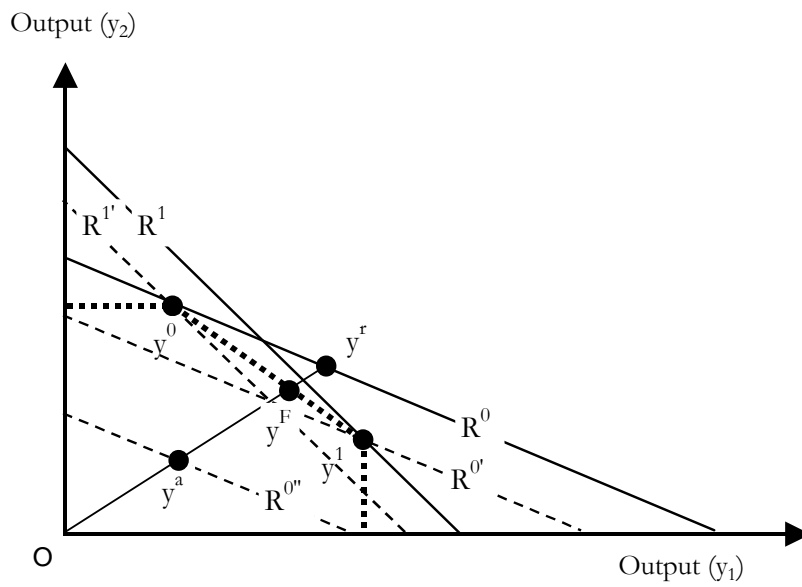


Figure 3: Valuation of Product-mix Change

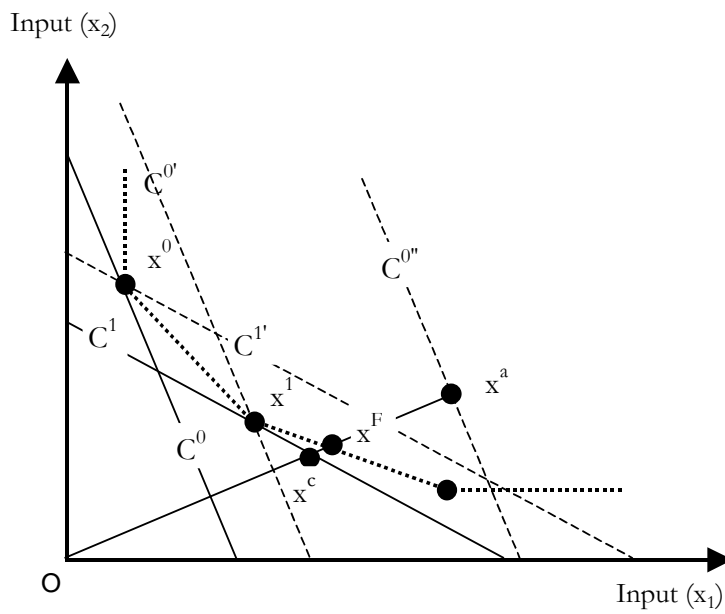


Figure 4: Valuation of Resource-Mix Change

