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ROLE OF MANAGEMENT DECISION VARIABLES IN DETERMINING TECHNOLOGICAL PROGRESS AND TECHNICAL EFFICIENCY IN INDIAN ELECTRONICS INDUSTRY

Rumki Majumdar M.H. Bala Subrahmanya

Abstract

This paper analyses the influence of management on Technical Efficiency Change (TEC) and Technological Progress (TP) in the communication equipment and consumer electronics sub-sectors of Indian hardware electronics industry. Each sub-sector comprises 13 sample firms for two time periods. The primary objective is to determine the relative contribution of TP and TEC to TFP Growth (TFPG) and to establish the influence of firm specific operational management decision variables on these two components. The study finds that both the sub-sectors have strived and achieved steady TP but not TEC in the period of economic liberalisation to cope with the intensifying competition. The management decisions with respect to asset and profit utilization, vertical integration, among others, improved TP and TE in the sub-sectors. However, R&D investments and technology imports proved costly for TFP indicating inadequate efforts and/or poor resource utilisation by the management. Management was found to be complacent in terms of improving or developing their own technology as indicated by their higher dependence on import of raw materials and no influence of R&D on TP.

Key Word: Total Factor Productivity Growth, Management Decision Variables, Stochastic Production Function, Electronics Hardware Industry, Economic Liberalisation

Classification: Empirical Research Paper

1. Introduction

Growth in Total Factor Productivity (TFP) or what is popularly termed as 'Abramovitz residual-measure of ignorance' refers to the growth of output due to inputs unaccounted for in a production process explicitly (Pallikara, 2004). An interesting way to interpret this measure of ignorance would be to attribute this productivity growth to the role of management and their efficiency at the business enterprise. In fact, Hannula (2002) did interpret total (factor) productivity as a measure of competitiveness at the business enterprise. Here operational stages of business unit including purchasing, marketing, finance, sales and support services contribute to total (factor) productivity.

In India the role of management and managerial activities did not get the required fillip before 1990s as it did in other developed nations owing to heavy state interventions, licensing policies and domination of public sector undertakings in all major economic activities. Individual activities, for example by entrepreneurs, were held of little relevance. "Opening up" of the Indian economy after 1991 led to development of a free market, initiated "autonomy" by encouraging growth of private ownership, established "restructuring" to adapt to the world market and formation of an entrepreneurship (Ghosh, 2005). With liberalisation, Indian economic agents and entrepreneurs got exposed to more intense competition, which enabled them to seize new opportunities and reap benefits of their association with the rest of the world. This paper explores the role of management with higher degree of authority, greater freedom to take decisions, and more independence and responsibility after liberalisation in influencing the growth of TFP (TFPG). The focus is on two important sub-sectors of Indian hardware electronics industry. This is a novel work in the literature of TFPG as well as in the context of Indian hardware electronics

industries as not much work has been done to explore the role of management on TFPG exclusively.

The paper adopts the frontier production function approach that identifies the role of technical efficiency and technological progress in overall firm performance (OECD, 2000 and Mahadevan, 2002). Technical Efficiency Change (TEC) refers to a growth of TFP shown by a movement towards or away from the production frontier signifying gains/losses in technical efficiency. On the other hand, Technology Progress (TP) refers to growth of TFP due to shift in the frontier itself implying technological progress or regress.

The paper is structured to comprises seven sections. Section 2 describes the objectives and scope of the paper while section 3 outlines the sources of data. Section 4 and its subsections describe the theoretical framework/ methodology together with description of management decision variables and the decision making model. Section 5 comprises analysis and results and Section 6 outlines the inferences drawn from the results. Section 7 presents the summary of the paper.

2. **Objectives and Scope**

The objective of the paper is to determine the factors contributing to TEC and TP which in turn determine TFPG, the focus being primarily on operational managerial decision making variables of the sample firms belonging to electronics industry. This paper aims to analyse *behaviour of firms belonging to the same industry* rather than on an industry or an aggregate sector because we believe aggregate analysis fails to provide consistent measures of any

industry's performance. The first reason is that there exist real differences in the production process that are adopted to produce outputs which are very different in nature and characteristics. Therefore, comparing or aggregating them becomes impractical. Second, factors that influence the productivity and efficiency differ for different industries and categorizing such factors as similar/ equivalent factors for all the industries seems not feasible. According to Han (2002), sectors that are too dissimilar when pooled together to estimate production frontier and thereby used to estimate TFPG and its components may result in biased estimates. Third, in order to understand the exclusive role of management on TFPG of a firm, it is necessary to control the impact of external factors. Choice of firms from the same industry controls for the influence of industrial policy, industrial structure and macro-economic environment, with the exception of perhaps, infrastructure facilities. Therefore, if liberalisation has to have any dissimilarity in the influence on TFPG of firms of the same industry, then they should influence factors that are undoubtedly firm specific in nature.

The Indian electronics industry is an obvious choice; the industry is heterogeneous in terms of the output produced and the products are amenable to the use-based classification adopted for the Indian industrial sector as a whole. Also, the sector has a long history of liberalisation and the role of the state has been changing with greater market forces. The chosen two sub-sectors, namely communication equipment and consumer electronics, fulfill both the criteria.

This study is based on two phases of 12 years of liberalization era i.e. from 1993 to 2004. The first phase comprises six years from 1993 to 1998 and the second phase comprises six years from 1999 to 2004. The year 1998 has been considered the point of separation for the two periods for

the reason that a separate ministry was formed for Communication and Information Technology in 1997. The Department of Electronics was merged with the Department of Information Technology (IT) as a part of the Ministry in October 1998 (DOE, 1999 and Joseph, 2007). Also, Telecommunication Regulatory Authority of India (TRAI) was established in 1997-98. This division of time period has been done mainly to ascertain whether the major policy changes introduced in 1997/98 made any difference in terms of factor productivities in one period relative to the other or not.

The study is based on a total of 26 sample firms that operated continuously during the period of study in the two sub-sectors of electronics industry: 13 firms each belong to communication equipment sub-sector and consumer electronics sub-sector, respectively. Though 26 sample firms may not be an exhaustive representation of the electronics industry but represents a wholesome picture of the industry during the period considered for the study.

3. Sources of Data

The scope of this study is confined to the corporate sector in the two sub-sectors of Indian electronics industry due to unavailability of consistent data for unregistered sector and for small and medium firms. PROWESS database brought out by Centre for Monitoring Indian Economy Pvt. Ltd. (CMIE) has been used to obtain firm level data. The 26 sample firms are considered for this study based on the availability of continuous data that existed from 1993 to 2004.

Various editions of Annual Survey of Industries (ASI), the database published by the Central Statistical Organisation, Government of India have also been used to obtain data on total

emoluments of employees and man days-employees to estimate wages per hour. The deflating series for electronics industry has been calculated from the wholesale price indices of the electrical industrial machinery and its components at 1993-94 that are obtained from Business Beacon, another database published by CMIE. The capital formation price indices at 1993-94 prices have been estimated from the series for gross fixed capital formation in manufacturing industries obtained from various issues of the National Account Statistics, Government of India.

4. Methodology

The primary objective of this study is to determine the relative contribution of Technological Progress (TP) and Technical Efficiency Change (TEC) to TFPG and establish the influence of firm specific operational management decision variables on these two components of TFPG. A three-step approach has been followed. The first step is to determine a potential stochastic production function. The second step is to measure TFPG for each firm over the two periods and to derive the relative contribution of TEC and TP to TFPG. The third step deals with the analysis of the influence of management decision variables on TEC and TP using a management decision model on a panel data. Since the paper emphasizes on the third step, the first two steps are briefly explained.

4.1. The Production Function Model

The study has used stochastic production function approach to estimate TFPG. The production function model is based on the parametric method of estimating stochastic production function

proposed independently by Aigner et al. (1977) and Meeusen and Van den Broeck (1977). Pitt and Lee (1981) specified the panel data version of Aigner et al. (1977) half normal model. This study has introduced a slight modification to the model proposed by Pitt and Lee (1981) in order to cater to the objectives. Two separate stochastic production functions (with constant coefficients) have been estimated for the two sub-sectors, namely communication equipment and consumer electronics subsectors. Again, for each sub-sector two separate production functions for the two time periods have been estimated comprising years 1993-1998 for period 1 and 1999-2004 for period 2. Therefore, in total four stochastic production functions have been estimated each with a panel of 13 firms and 6 years data. To account for the in between years within each time period, five dummies (for six intermediate years) have been introduced. The year specific dummies represent the various industry specific policies taken by the government or industry specific events or other macroeconomic related changes that may or may not have influence on the production function/s but are difficult to account in the model explicitly.

Value added[1] has been used as the dependent variable in the production function. The input variables namely labour hours[2] and capital stock at replacement values are the independent variables in the value added production function. All these variables have been measured at constant prices with base price at 1993-94.[3] Labour hours have been estimated from the data available on salaries and wages from Prowess (Srivastava 1996). Capital stock has been calculated from Gross Fixed Asset net of revaluation and work in progress following the methodology of Srivastava (1996) and Hashim and Dadi (1973). The details of the methodologies are not included here considering the length of the paper.

The general translog production function is proposed involving the interaction terms, interaction among input factors and also the interaction of dummies with the input factors for a sub-sector (h) and for a time period (j) in equation 1.

$$y_{it} = \alpha + \sum_{k}^{K} x_{kit} * \beta_k + \sum_{m}^{M} D_m * \nu_m + \sum_{k}^{K}\sum_{k'}^{K} \eta_{kk'} * x_{kit} * x_{k'it}' + (\sum_{m}^{M}\sum_{k}^{K} D_m * x_{kit}) * \lambda_{mk} + v_i - u_{it}$$

$$i = 1,2,...i_h; kk' = 1,2,....K; t = 1,2...T; m = 1,2...M \qquad [1]$$

where, D is a (1*m) vector of dummy variables, m = 1,2…5

$D_1 = 1$ when year =1994 for period 1 and 2000 for period 2

$= 0$ otherwise

$D_2 = 1$ when year =1995 for period 1 and 2001 for period 2

$= 0$ otherwise

$D_3 = 1$ when year =1996 for period 1 and 2002 for period 2

$= 0$ otherwise

$D_4 = 1$ when year =1997 for period 1 and 2003 for period 2

$= 0$ otherwise

$D_5 = 1$ when year =1998 for period 1 and 2004 for period 2

$= 0$ otherwise

The equation holds for sub-sector h, h=1, 2.

j represents number of time period, j=1, 2.

k represents input factor. This study has labour and capital as the two inputs. Therefore, k= 1, 2.

t represents years within a time period j, t=1, 2,..6

i represents number of firms that belong to each sub-sector h (h =1, 2)

i = 13 for Communication Equipment

= 13 for Consumer Electronics

Here y_{it} represents log of value added of the i^{th} firm belonging to a sub-sector at the t^{th} year of jth time period. x_{kit} represents the log of k^{th} input variable for i^{th} firm at t^{th} year. D_m represents the dummy for the years within a period, with m = 1,2, …t-1. The output may be influenced by various random factors, such as the effects of weather, strikes, luck etc., on the value of output variable, together with the combined effects of unspecified input variables in the production function. v_i, accounts for such measurement error and influence of all the other random factors and are independently and identically distributed normal random variables with zero mean and constant variance, σ^2_v. The technical inefficiency u_i are non-negative and are assumed to follow a truncated normal distribution with mean μ_{ui} and constant variance, σ^2_u in this model specification. β_k is the coefficient for k^{th} inputs, v_m is the coefficient for the m^{th} dummy, $\eta_{kk'}$ is the coefficient for the interaction of the two input factors and λ_{mk} is the coefficient for the interaction of m^{th} dummy and the k^{th} input.

4.2. Decomposition of Output Growth into its Components

The second step of the analysis is to decompose Output Growth (OG) for the two sub-sectors over the two phases of liberalisation, into Input Growth (IG) and TFP Growth (TFPG). The

TFPG has been further decomposed into TEC and TP. For this, the methodology established by Kalirajan et al. (1996) and Kalirajan and Shand (1997) has been adopted to decompose OG into IG, TEC and TP.

Diagrammatically the growth of TFP is shown by a movement towards the production frontier that signifies gains in technical efficiency and by a shift in the frontier itself implying technological progress or regress. A potential frontier $\hat{F}$ is the production function that has the technical inefficiency component, $u_i = 0$. The coefficient of the estimated stochastic production function is also the coefficient of the potential frontier and represents the deterministic frontier without the random component. There exists only one $\hat{F}$ for a given technology and as per Hicks neutral assumption, any change in technology brings about a parallel shift in the frontier.

Figure 1 may come here

The vertical distance between the potential output and the actual output of a given firm, that is, TE1 in period 1 and TE2 in period 2 measures technical inefficiency respectively. Therefore, the change in technical efficiency over time is the difference between TE1 and TE2. The increase in output Y_1^{**} from Y_1^{*} for given output X_1 or the increase in output from Y_2^{*} from Y_2^{**} for the given output X_2 is due to technological progress. Since the shift in the production function is hicks neutral, the technological progress calculated either way would be the same. This is depicted in Figure 1.

Referring to the Figure 1, the decomposition can be mathematically shown as:

$$\text{Output Growth from period 1 to period 2} = \left|Y_2 - Y_1\right|$$

$$\begin{aligned} D &= y_2 - y_1 \\ &= \left[y_1^{*} - y_1\right] + \left[y_1^{**} - y_1^{*}\right] + \left[y_2 - y_1^{**}\right] \\ &= \left[y_1^{*} - y_1\right] + \left[y_1^{**} - y_1^{*}\right] + \left[y_2 - y_1^{**}\right] + \left[y_2^{*} - y_2^{*}\right] \\ &= \left[y_1^{*} - y_1\right] + \left[y_1^{**} - y_1^{*}\right] + \left[y_2^{*} - y_2\right] + \left[y_2^{*} - y_1^{**}\right] \\ &= \left\{\left[y_1^{*} - y_1\right] - \left[y_2^{*} - y_2\right]\right\} + \left[y_1^{**} - y_1^{*}\right] + \left[y_2^{*} - y_1^{**}\right] \\ &= \left\{TE_1 - TE_2\right\} + TP + IG \end{aligned} \qquad [2]$$

Where, $D = y_2 - y_1$ is the output growth, $TE_1 - TE_2$ is the change in the technical efficiency, TP is the technological progress, and IG is the input growth.3

4.3. Managerial Decision and Efficiency Variables defining Technical Efficiency Change and Technological Progress and Management Decisions Model

Unlike conventional studies, this study tries to capture the influence of firm specific attributes of management decision making and management efficiency variables on TEC and TP. Before proposing the model, it is necessary to describe the management decision variables and the control variables.

In reality the two components of TFPG, namely TP and TEC are two overlapping concepts and are complementary in nature. It is therefore difficult to specify factors that exclusively influence a change in TE and in TP, respectively. It is highly probable that factors that have an impact on the TEC may also affect the TP and vice versa. Therefore, same set of variables have been used to explain TEC and TP separately. As far as external factors are concerned, all the firms in this study are subjected to similar industrial policy, industrial structure and macro-economic environment, with the exception of perhaps, infrastructure facilities. Therefore, this study primarily focuses on firm specific managerial decisions and managerial efficiencies to explain the behaviour of TEC and TP.

4.3. a. The Management Decision Variables

Since both TEC and TP are growth/ change concepts over two periods, management decision variables are also expressed in terms of their growth between years of the two periods: 1993-98 and 1999-2004. Therefore, the growth of all the variables have been measured for years in period II ($\tau+1$) over the years in period 1 (τ), for e.g. growth in 1999 over 1993, 2000 over 1994, 2001 over 1995 and so on. The selection has been made on the basis of the availability of data together with the fact that the variables are measurable. The variables so decided are as follows:

a) **R and D (both in current and capital account) Intensity:** Firm's effort to develop, adapt and absorb new technology is measured by the amount the management of the firm allocates for R&D.

   Growth in R&D intensity may not have an instantaneous impact on the production and TFPG, especially for technology intensive electronics industry. Therefore, maximum of two

lags and the current R&D intensity have been considered. Any further lags could not be accommodated since some of the firms in the sub-sectors did not exist before 1991.

b) **Inventory Management:** Inventory expenditure of a firm includes closing stocks of raw materials, stores and spares, finished goods and semi-finished goods. Efficiency in management of inventory is measured relative to the sales (Pandey, 2002)

Raw Material Import Intensity Growth: It is the management of the firm that decides what raw materials need to be imported and in what proportion to the total raw materials required for production so as to minimize the cost of production (Joseph, 2007).

For the present analysis, it is assumed that this variable does not influence the technology of a firm unless the firm has no significant expenditure on technology import. This assumption is necessary to do away with the problem of multi-collinearity among the explanatory variables.

c) **Technology Import Intensity:** A firm is said to be to lly intensive if it is able to adapt new technologies that are being developed worldwide. Again, it is the vision and initiative of the management to improve production technology with a view to expand in future. In the absence of in house facilities and lack of domestic infrastructure to support such initiatives, it is obvious for management to look for availing better technology through import of technology. One of the possible ways to measure technology improvement efforts is to account for the royalty that firms pay to import new technology and/ or through foreign collaboration or association. However, complete data on the amount spent on royalty and

know-how were not available. Also, a very few of the sample firms had foreign collaborations or associations.

d) **Competitiveness and Profitability of Firm:** A firm's management efficiency in decision making over time or against its competitors is to consider asset performance measured as return on capital investment/ employed. This

f) **Operating Margin:** Decisions taken by the management related to pricing strategy and operating efficiency determines the quality of a company/ firm. Operating margin gives analysts an idea of whether a firm is earning more or less (before interest and taxes) on per rupee of sales. It is measured by (Emery, 1991):

g) **Change in Vertical Integration**: It is a measure of degree of specialisation that a firm achieves by focusing more into their core production and subcontracting supplementary production to others with the purpose of cutting costs (Maddigan, 1981).

4.3.b Control Variables

Besides management, the firms in the Electronics industry vary considerably with respect to the size of firms and the location of firms. Age of the firm, considered to be a proxy for experience, is measured as the difference between the year for which TEC/TP is considered in period II and the year of incorporation of the firm. Assuming the rate of depreciation of capital to be 5%, the maximum age of a firm is 20 years, even for firms that exist for more than 20 years.

Most of the firms are found to be concentrated in a few cities of India, indicating unequal concentration of firms belonging to electronics industry. For the sake of convenience, these cities have been categorised as per their location in India. The four south Indian states, namely Andhra Pradesh, Karnataka, Tamil Nadu and Kerala are categorised as the southern region of India. States like Maharashtra, Gujarat, Rajasthan, Madhya Pradesh, Bengal, Orissa, Bihar and other north-eastern States are categorised as the Central region of India. The rest have been categorised as the northern region of India. Therefore, the location of firms is grouped into three categories based on geographical location of India, namely the northern region (L1), southern region (L2) and the central region (L3).

Another control factor is the size of firms that could have an impact on the components of TFPG of the sample firms. Firms are categorised into three groups based on the size (S_1, S_2, and S_3) measured by Gross Fixed Assets (GFA), net of revaluation reserves and work in progress of the firms at constant prices. Over the 12 years of time, some of the firms have changed their status from small to medium sized, some from medium to large sized firms while some from small to large. Therefore, the number of firms belonging to a particular category of size differs from one year to another. A firm has been categorised into one of the three groups based on its status at the year for which TEC/TP is considered in period II, $Size_{\tau+1}$.

The ownership of firms, private or public, may have an important influence on the performance of the firm. Most of the sample firms in the consumer sub-sector belonged to private ownership while in communication equipment sub-sector, 5 out of 13 firms were Public Sector Enterprises

(PSEs). Therefore, only for this sub-sector a dummy has been introduced to differentiate private enterprises (O1) from PSEs (O2).

Seven management related variables are explicitly considered to be the possible determinants influencing TFPG. However, there could be many other management and organisational factors that significantly influence on the TFPG components. It is very difficult to identify and measure all such factors that contribute to a firm's management efficiency. In order to overcome the problem of specification bias due to missing variables, it is rational to argue that the combined effects of all such factors, not specifically accounted in this study, can be modeled. It is assumed that an efficient manager/ management decision making will contribute more to TEC and TP.

This paper introduces a management decision model where TEC and TP are functions of variables defined above and a variable m_i that captures the unaccounted firm-specific management efficiency variables. The specifications of the variable m_i determine the nature of the management decision model. This gives flexibility in modeling differences in management decisions and efficiency in decision-making across the firms. First, to begin with, the specification of management efficiency variable (m_i) has been considered to be a random variable taking value of either zero or greater than zero. It is assumed to follow a truncated normal distribution with some mean and variance specifications. If it takes the value zero, it implies that the firm's manager is working with full management efficiency. On the other hand, if the variable takes any value greater than zero, there exists management deficiency at the firm level and therefore needs attention of the manager. The m_i specification is tested using generalized likelihood ratio test.

In case the first specification fails to hold, another specification is considered where $m_{i,}$ capturing only firm specific effects, could be fixed or random (in a panel set up) based on the assumption whether or not unobserved m_i is correlated with the other included explanatory variables. However, it is possible that there may be no firm specific variable m_i at all in the model. In such a case, a classical regression model is specified. Breusch Pagan Lagrangian Multiplier test is conducted to test classical model against the panel data model. In case of a panel data model, the nature of the firm specific management efficiency m_i has been tested using Hausman's specification test (Greene, 2005).

4.4. c. The Model

Separate analysis is carried out for the two sub-sectors of electronics industry using individual firm level data belonging to each sub-sector. The growth of all the variables has been measured for years in period II (τ+1) over the years in period 1 (τ), for e.g. growth in 1999 over 1993, 2000 over 1994 and so on. Thus, the data comprise cross-section and time series or panel data set up with i_h firms and 6 relative years between two periods, i_h being the number of firms belonging to sub-sector h. The management decision model for TEC or TP for i^{th} firm of a sub-sector h (h =1, 2) and for the 6 relative is given by equation 10. The equation specifies separate model for TEC and TP, both being a function of seven managerial variables, the control variables and the unaccounted firm specific management efficiency variable, m_i.

$$TEC_{\tau,\tau+1}(TP_{\tau,\tau+1}) = \alpha + \beta_1(Size)_{\tau+1} + \beta_2(Location) + \beta_3(Age) + \beta_4(Ownership)_{comm} + \\ + \sum_p \beta_{5p}(Managerial \quad Variables)_{p\tau,\tau+1} - m + \eta_{\tau+1}$$

[10]

Here, p represents the number of management variable, p= 1,2 …7.

τ & τ+1 denotes period I and period II. Here, i= 1, 2, ….i_h, and t= 1,2..6 are not specified but are common subscripts to all the variables.

Age = Measures the experience of a firm in an industry.

Age = the year for which TFPG is considered (t') – incorporation year (T'),

for t'- T' <=20

= 20 for t'- T' > 20

Location = India has been divided into three territories, North, South and Central

(Central includes both East and West) regions.

L_1 = 1 for North

= 0 otherwise

L_2 =1 for South

= 0 otherwise

Size = measured by the GFA of the firms at period II.

S_1 = 1 for GFA <= Rs 300 million

= 0 otherwise

S_2 = 1 for GFA >= Rs 1000 million

= 0 otherwise

Ownership = Ownership is categorised into private and public sector enterprises

This is used only for the communication equipment sub-sector.

O_1 = 1 for private firms or firms associated with big private enterprises.

= 0 otherwise

η is the random error term with normal distribution with mean and variance $\mu_{\eta,}\sigma_{\eta}^{2}$.

m denotes firm specific managerial activities and is positive with truncated-normal distribution with mean and variance, $\mu_{m,}\sigma_{m}^{2}$ in case of first specification. In case of the second specification, it may have a distribution if it is a random effect model.

α is the constant term accounting for all other factors not explicitly accounted in the model.

β's are the coefficient of the control variables and $\beta_p's$ are the coefficient for the p^{th} management decision making and efficiency variable.

5. Influence of Management Decision Variables on Technological Progress and Technical Efficiency: Results of Analysis

This section details the results with respect to the form of production functions, components of output growth and thereby TFPG followed by the results of the decision making model determining TEC and TP for the two sub-sectors over the two time periods.

Communication equipment followed a Cobb-Douglas production function while consumer electronics followed a translog production function (Table 1). The tests for presence of technical inefficiency in the model clearly indicate that technical inefficiencies did exist in both the sub-sectors of the electronics industry (Table 2). Therefore, there was every justification to carry out stochastic frontier production function analysis and subsequently make use of the production function for estimating TFPG and its components.

Table 1 and 2 may come here

The estimated production functions of the two sub-sectors are given in Table 3 a) and 3b). Results indicated a more significant contribution of labour to output compared to capital in these sub-sectors. An interesting finding was that the labour elasticity for communication equipment sub-sector was greater than unity and significant while that of capital elasticity was negative though insignificant in period 1. Therefore, the negative contribution of capital was more than compensated by the contribution of labour. However, elasticity of labour declined but remained significant in period 2. Negative elasticity of capital in period 1 is an indication of excess investment in more technologically advanced capital but poor utilisation of these invested resources. The between among labour and capital for the consumer electronics in period 2 was negative and significant implying that their interaction led to fall in the output. This suggests that

probably the input factors were substitutes in nature for this sub-sector. Simultaneous increase in both inputs adversely affected their marginal productivity, which in turn affected output adversely. None of the dummies was significant in communication equipment sub-sector indicating that the sub-sector remained more or less unaffected by external macro-economic policies/ shocks during this period of liberalisation. Consumer electronics sub-sector, on the other hand, was vulnerable to external shocks. The impact of dummy for 1997 (D4) on the production frontier and the dummy for 1997 and 1998 on labour contribution to output in period 1 (D4L and D5L) were significantly negative. This indicates that not only the potential production frontier but also the contribution of labour to output suffered during these years. On the other hand, the impacts of the years 1997 and 1998 on capital contribution to output in period 1 (D4K and D5K) were significantly positive. This could be attributed to South East Asian crisis in 1997-98, among others, that led to reduced demand for consumer electronics products. This would have forced the sample firms to withhold fresh investment or cut back on their existing investment with the objective of bringing down the level of output (to avoid the costly build-up of inventories). But, this could not be associated with labour retrenchment due to stringent and inflexible labour policies in India.

Table 3 a) and 3 b) may come here

The pattern of OG and factors that contribute to OG together with relative contribution of TEC and TP to TFPG has been estimated and are shown in Tables 4a) and 4b). TEC improved for the communication equipment sub-sector but fell in the later years of period 2 relative to period 1. On the other hand, TEC fluctuated from negative to positive initially but improved in the later

years for consumer electronics. TP remained more or less constant in the former and steadily declined for the latter sub-sector.

Table 4 a) and 4 b) may come here

The results in Table 5 clearly indicate that managerial inefficiency m_i, due to various other factors not explicitly accounted in the model, significantly influenced the two components of TFPG for the firms in both the sub-sectors. Likelihood Ratio (LR) test verifies that m_i follows one-sided truncated distribution in the model influencing TEC and TP for both the sub-sectors.

Table 5 may come here

Among the various managerial factors considered, the study found that Growth in Operating Margin (OMG), Growth in the Return on Capital Employed (ROCEG), Growth in the Technology Import Intensity (TIIG), second lag of R&D growth (R&DG (2)) and Growth in Vertical Integration (VIG) did significantly influence either TEC or TP or both simultaneously in the communication equipment sub-sector. In the consumer electronics sub-sector, R&D growth with two-year lag (R&DG (-2)) and Growth in the Return on Capital Employed (ROCEG) had a statistically significant influence on TEC. On the other hand, Growth in Operating Margin (OMG), Growth in the Raw Material Import Intensity (RMIG) and Growth in Vertical Integration (VIG) influenced TP of this sub-sector. The results are shown in Table 6 and Table 7.

Table 6 and Table 7 may come here

6. Inferences and Recommendations: How Significant are Management Variables?

Based on the above results, inferences have been drawn and recommendations made for each of the two sub-sectors.

6 a) Communication Sub-sector- Since liberalisation, communication industry has witnessed nothing short of a revolution that has profoundly changed the way of living in India. One of the biggest examples is the inclusive growth of telecommunication in India such as the introduction of mobile communications, internet/ broadband connections and other value added services in the last one and a half decade.

The analysis found a reinforcing impact of ROCEG on TEC for the sample firms. A positive impact of ROCEG is an indication of highly efficient and effective capacity utilization by the firms thus improving efficiency. However, it was found that though the sample firms did have positive ROCE, most of them experienced a declining growth in ROCE.

VIG had a positive impact on both the components of TFPG. The sample firms did benefit by identifying and specializing in their core areas for future growth and subcontract the rest of their manufacturing operations. For example, sample firms like Avaya Globalconnect Ltd, Alcatel India Ltd., Himachal communication Ltd among others, reported to have focused on improving technologies for their core production and were fully into manufacturing telecom services.

OMG had a positive influence on TEC for the sample firms. With greater margin over per unit of sales, the firms had greater resources at their discretion to spend on excellent skill sets, state-of-the-art infrastructure, exploring new avenues like technical support to Business Process Outsourcing (BPO), telecom software products, technical education programs and exploring strategic tie-ups with or without equity participation with MNC. However, competition among sample firms resulted in price cut for communication products. This was in conjunction with fall

in the market share of firms (Herfindahl index in Table 8) that resulted in fall in the growth of OM among sample firms.

Table 8 may come here

While TIIG and R&DG (-2) had a negative impact on TEC of the firms, R&DG (-2) positively influenced TP. With increasing income, customer demand for better and newer technological products increased rapidly. In order to cater to increasing demand, R&D initiatives primarily focused on technology upgradation without effectively absorbing or adapting such technologies. What could not be produced was imported without internally adapting them successfully.

Among the control variables, old firms were seen to have achieved TEC owing their experience for existing long in the industry. However old firms did not fare well in TP. This could be because their longevity led to a feeling of permanency that resulted in built-in inflexibility. Their resistance to change and unwillingness to bear the cost of unlearning old and obsolete technology had a damaging effect on TP. Also, new firms entered the industry with relatively better technology as compared to the older firms. Both large and small sized firms had successfully achieved TP. For large sized firms initiating expensive R&D was relatively easy owing to their huge capital investments and relatively better profits (Profits before Income and Taxes). However, small sized firms too did not fall behind in undertaking intensive R&D activities. This was because most of the small firms were either a subsidiary of large companies (eg. Bharti Telecom Ltd of Bharti Telecom groups and Raychem RPG Ltd of RPG Groups) or had foreign ownership/collaboration (eg. Krone Communications Ltd., Astra Microvwave

Products). Table 9 shows a rapid increase in allocation of resources for R&D among the sample firms.

Table 9 may come here

Private firms were found to be more willing to achieve TP. With increased autonomy and transparency among the management together with the pressure to survive competition in the market forced private sample firms to adopt best practices and techniques.

6 b) Consumer Sub-sector: One of the major segments of electronics industry was the consumer electronics before liberalisation in 1991 (World Bank Report, 1987). In fact, policy liberalisation was introduced for electronics sector in general and consumer electronics sub-sector in particular, in the early 1980s itself to make electronics more competitive by primarily liberalizing the domestic market. Thus, this sub-sector has perhaps one of the longest histories of operating in a liberalised market. Consumer electronics sub-sector has been essentially a customer-driven sector because the end products are designed keeping in mind the demand of the customers and commercial interests.

The firms benefited in terms of TP with VI. Growth in ROCE had a positive influence on TEC of the sample firms in the consumer electronics sub-sector. However, except for three firms, all the others experienced negative growth on returns to capital. OMG had a positive impact on TP for the sample firms in this sub-sector. That indicates that resources from positive margin were invested to achieve TP rather than TEC to cater to technologically dynamic market. But, similar to earlier experiences, sample firms in this sub-sector too experienced negative growth in operating margins. Falling growth of ROCE and OM may have been due to high turbulence in

the product market due to market expansion, shifting of market positions of brands by major players (predominantly MNCs), simultaneous increase in input prices but falling output prices and dumping of products by Chinese players in the market, beside others.

In the face of stiff competition, sample firms were expected to equip themselves rapidly with the technologies and/or licenses required for developing and manufacturing electronics products to meet new standards. Since the firms did not depend on imported capital or technology (as evident from insignificant influence of TIIG), it was expected of the firms to make huge investments in R&D to achieve TP. On the contrary, it was found that the impact of local R&DG (-2) on TP was insignificant and had a rather deteriorating impact on TEC instead. The sub-sector was seen to have cut down on R&D expenses in capital account lately (Table 9).

The negative impact of R&D could be for two primary reasons. Firstly, government had made provisions for tax incentives for the firms that were engaged in R&D activities. This might have motivated the firms to merely invest on R&D to derive tax benefits from the Government. Grossmann (2007) too argued in his paper that R&D subsidy might be detrimental to both productivity growth and welfare of an economy. Secondly, another possible reason for the deteriorating impact of R&D on TEC could be the shortage of skilled labour and expertise.

Except for three sample firms, rest of the sample firms reported more or less positive RMIG in this sub-sector. The positive influence of growth of RMI on TP in the face of declining R&D expenditure and an insignificant influence of TII implied that TP of these firms depended much more on import of raw materials and intermediates than import of core technology.

The consumer electronics sub-sector responded to the policy changes due to liberalisation impressively during the 1980s as well as after 1991. This is evident from the fact that the average age of sample firms was higher for this sub-sector relative to the rest of the industry, indicating that these firms survived policy changes and intense competition and continued to operate in the industry. The improvement in the market share (Herfindahl's index) amidst radical changes in policies and opening up of the sector to the global market is an indication that age would have had a positive influence on TFPG. The results in this study indicated precisely the same.

The study found the sample firms that were larger in size, were more adept and proficient to initiate rapid TP. This was because, in the face of falling R&D, OMG and ROCEG, only the large scale firms could have afforded to import of qualitatively superior raw materials and intermediates to improve TP. Also, large size helped firms benefited from VIG due to economies of scale.

Both consumer and communication sub-sectors appeared flourished in the Southern region, as seen from Table 6 and Table 7.

From the above results it is evident that sample firms of both the sub-sectors need to improve their operating margins amidst increasing competition from both domestic and foreign firms. One of the ways to arrest a decline in margin can be adoption of integrated Supply Chain Management (SCM) approach as this would enable cutting down of input costs. Increased profits should be reinvested to improve ROCE and productive R&D investments. Management should maneuver networking among electronics firms to learn from mutual experience and resort to

joint R&D on the one hand and joint technology imports on the other. However, while forming networking, the management should specially take care of the firm's needs.

Emphasis should be given to judicious investment of capital. Poor capital contribution to output together with declining ROCE is a cause of concern for both the sub-sectors. With more liberal policies being initiated by the Government like approval of an increase in the FDI cap in 2002 in the electronics industry (from 44% to 75%), sample firms should avail the opportunity to raise more funds from the international market (DoE, 2004). Import of technology should be encouraged where development of indigenous technology has higher opportunity cost. But, this should be followed with appropriate adaptation of the imported technology that suits Indian production process and environment to ensure optimal utilization.

Vertical Integration (VI) being a major contributor to both TEC and TP, it is necessary to promote VI through promotion of subcontracting between large enterprises on the one hand and Small and Medium Enterprises (SMEs) on the other. Particularly, subcontracting opportunities should be promoted between newly entered MNCs and local enterprises. In addition, international subcontracting opportunities between Indian SMEs and even large enterprises and global MNCs located elsewhere should be promoted for the benefit of domestic local firms. This is important because subcontracting can be a source of assistance transfer from MNCs to local firms as well as a source of innovation and productivity improvements for the latter.

7. Summary and Limitations

The paper focused on estimating relative contributions of TEC and TP to TFPG for the communication equipment and consumer electronics sub-sectors of electronics hardware industry. The results indicated that the two sub-sectors have strived and achieved steady TP in the period of economic liberalisation to cope with the intensifying competition. However, the same could not be said with respect to technical efficiency as these sub-sectors have hardly succeeded in achieving any modest degree of steady TEC.

The paper identified some of the management decision variables that can play an important role in influencing TEC and TP. R&D and prudent capital imports can play an important role in developing indigenous technology and fasten the process of adapting to better-suited technology. However, a negative influence of R&D and a positive influence of raw material imports on TFPG is an indication of higher dependence of a firm's production on imported inputs and complacency among the firms to put effort to improve or develop their own technology to substitute imported raw materials. Negative impact of technology imports on TFPG again points to the failure of management to direct R&D resources to tailor imported technology for better utilisation. The firms have managed to improve profits per unit of sales due to a growing domestic market and positive capital returns but declining growth of OM and ROCE is a cause of concern. This calls for imperative efforts from the management in terms of investing resources towards innovating activities, greater competency by acquiring specialization and improving labour skills/ productivity and adopting strategies to move up the value chain. The situation is an indication that for sustaining growth in the longer run, the firms have to expand their capacity of production to reap benefits from economies of scale and explore subcontracting opportunities.

The study also indicates a positive influence of private ownership on TFPG. Therefore, policy makers should promote infrastructure development by increasing public private partnerships and set up Special Economic Zones (SEZs) exclusive for hardware electronics industry.

The work has some limitations, most prominent one being not considering the impact of entry of MNCs as well as role of FDI and foreign investments in various other forms on productivity of the electronics firms. Limited data availability for only 26 firms restricted scope of the study. Finally, data were available for only 12 years during liberalization which prevented a comparative analysis of TFPG before and after liberalization.

Notes:

1. As per definition given by Prowess, value added is inclusive of salaries and wages, profit before depreciation, interest and tax, and rent income. The measurement of output and capital has been measured in gross values instead of net values. Gross-net value adjustment becomes a complicated problem as it depends very much on the age-structure of capital assets and the rate of depreciation. Reliable data on accounting and economic rate of depreciation are not available in India. Again, the adjustments by the firms for the decline of productive capacity are highly questionable (Hashim and Dadi, 1973 and Parkinson and Rustomji, 1978). Therefore, gross figures are more meaningful.Value added has been calculated as the gross output net of raw material inputs and energy inputs deflated by the wholesale price index for output and is availed directly from Prowess. Therefore, not accounting for changes in the relative prices of material inputs may not be a serious limitation of this study as pointed by Balakrishnan (1994). Also, in comparison with partial productivity (labour and capital) based on gross output, the productivity based on value added is less dependent on any change in the ratio between intermediate inputs and labour or capital (OECD, 2001). Therefore, gross value added has been considered a measure of output in the productivity analysis.

2. Labour hour has been calculated by dividing Salaries and Wages paid to the employees by wage rate per hour. Wage rate per hour is in turn estimated as the total emoluments paid to employees per mandays.

3. The VA has been deflated by the wholesale price index for the electronics industry while GFA has been deflated with the whole sale price index for machinery and machine tools with

base year 1993-94 =100 before estimating the value of capital stock at replacement cost. Deflationary Series for Electronics industry has been calculated.

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Figures

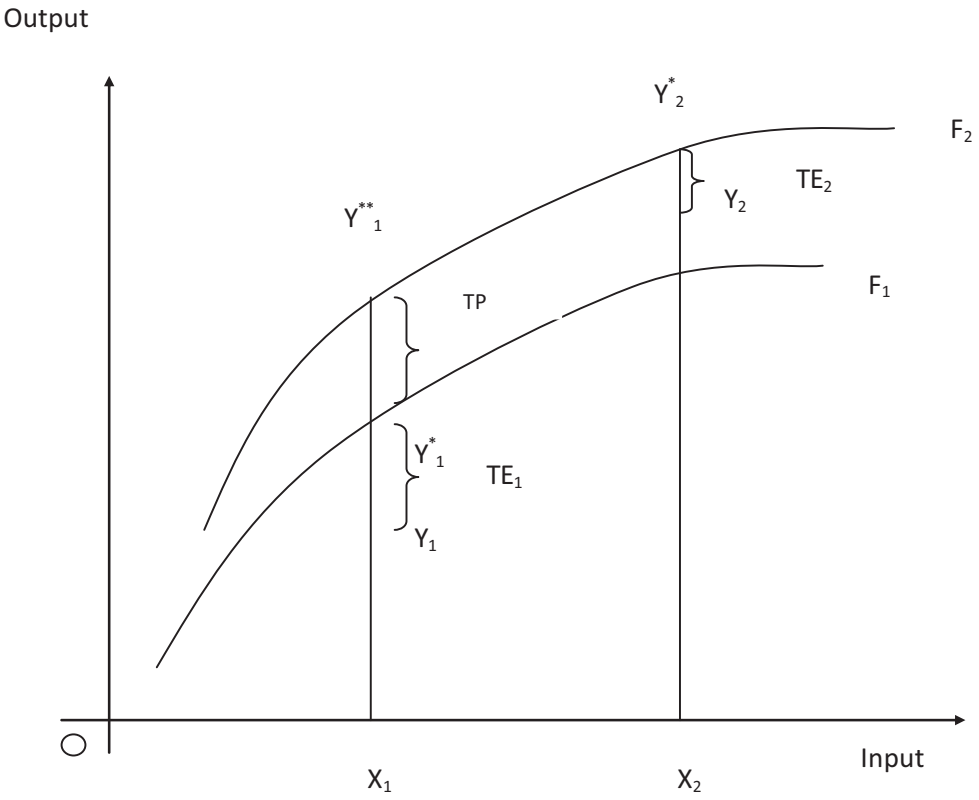

Figure I: Decomposition of TFPG in TEC and TP

Tables

Table 1. Test for the Form of Production Function

Null Hypothesis: C - D production function				
Test: lnll = lnkk= lnlk =D1lnl = D2lnl= D3lnl = D4lnl = D5lnl= D1lnk = D2lnk = D3lnk = D4lnk = D5lnk = 0				
Years	Communication		Consumer	
	LR chi2 (13)	P	LR chi2 (13)	P
1993-1998	19.35	0.11	59.63	0
1999-2004	18.40	0.07	28.71	0.01

Source: Estimated.

Table 2. Test for the Presence/Absence of Technical Inefficiency

Null hypothesis: There are no technical inefficiency effects (chi-$sq_{table\ (0.05)}$ = 2.71)*		
Years	Communication	Consumer
	LR Test for sigma_u_i- chi square	LR Test for sigma_u_i- chi square
1993-98	20.65	6.03
1999-04	16.4	26.6

*The calculated chi-square test statistics with one degree of freedom were compared with the table-value at 5% level of significance (chi-$sq_{table\ (0.05)}$ = 2.71).

Source: Estimated

Table 3 a) Communication Equipments Sub-Sector: Frontier Production Coefficients for the Two Periods

Period 1: 1993-98			
	Constant	LnL	LnK
Coef	6.96	1.01	-0.11
SE	4.6	0.13	0.23
P value	0.13	0	0.62
H_0: Constant Returns to Scale: One sided table-value z (0.05) = 1.96			
Returns to Scale($\hat{\beta}_k + \hat{\beta}_{k'} - 1$)		Z- Statistic	Conclusion
0.9		-2.32	H_0 Accepted: DRS
Period 2: 1999-2004			
	Constant	LnL	LnK
Coef	7.00	0.72	0.16
SE	3.39	0.16	0.21
P value	0.04	0	0.43
H_0: Constant Returns to Scale: One sided table-value z (0.05) = 1.96			

Source: Estimated

Table 3 b) Consumer Electronics Sub-Sector: Frontier Production Coefficients for Two Time Periods

Period 1: 1993-98												
	Cons	LnL	LnK	D4	D5	LnLL	lnKK	lnLK	D4LnL	D5LnL	D4LnK	D5LnK
Coef	3.96	0.71	0.23	-0.13	-6.92	-	-	-	-0.87	-0.47	1.16	0.63
SE	1.61	0.13	0.10	2.62	2.62				0.24	0.26	0.18	0.20
P value	0	0	0.01	0	0.01				0	0.07	0	0
Period 2: 1999-2004												
	Cons	LnL	LnK	D4	D5	LnLL	lnKK	lnLK	D4LnL	D5LnL	D4LnK	D5LnK
Coef	6.31	0.31	0.14	-	-	0.62	0.26	-0.80	-	0.62		-0.41
SE	11.8	1.85	1.24			0.19	0.11	0.29		0.27		0.17
P value	0.59	0.08	0.09			0	0.01	0.01		0.02		0.02

* LnLL means LnL* LnL, LnKK means LnK* LnK and LnLK means LnL* LnK in the above table

Source: Estimated

Table 4 a) Components of OG and TFPG in Communication Equipment Sub-Sector

Components Pd1 wrt Pd2	TEC	TP	TFPG	IG	OG
1999 relative to 1993	0.35	0.52	0.87	0.15	1.02
2000 relative to 1994	0.47	0.55	1.02	0.21	1.22
2001 relative to 1995	0.45	0.54	0.99	0.14	1.13
2002 relative to 1996	0.72	0.42	1.14	-0.12	1.02
2003 relative to 1997	0.14	0.56	0.70	-0.04	0.66
2004 relative to 1998	-0.02	0.52	0.51	-0.22	0.29

Source: Estimated

Table 4 b) Components of OG and TFPG in the Consumer Electronics Sub-Sector

Components Pd2 rel to Pd1	TEC	TP	TFPG	IG	OG
1999 relative to 1993	-0.14	1.61	1.47	-0.23	1.24
2000 relative to 1994	0.07	1.34	1.41	-0.05	1.35
2001 relative to 1995	-0.14	1.20	1.05	-0.04	1.01
2002 relative to 1996	0.02	1.19	1.21	0.19	1.03
2003 relative to 1997	1.26	0.10	1.36	-0.33	1.03
2004 relative to 1998	0.80	0.59	1.38	-0.93	0.45

Source: Estimated

Table 5. Test for the Presence/Absence of Entrepreneurial Inefficiency

Null hypothesis: There are no entrepreneurial inefficiency effects ($t_{table\ (0.05)}$ = 2.71) LR Test for sigma_u_i- chi square for Pd II over Pd I		
	Communication	**Consumer**
TEC	15.3	5.88
Model	Null rejected: **Frontier model**	Null rejected: **Frontier model**
TP	17.01	7.22
Model	Null rejected: **Frontier model**	Null rejected: **Frontier model**

Source: Estimated

Table 6. Factors Determining TEC/ TP of Communication Equipment Sub-Sector

Time-invariant inefficiency model for 13 groups: 78 observations				
	TEC	**P- Value**	**TP**	**P-Value**
AGE	0.036	0.001	-0.07	0
OMG	0.92	0		
ROCEG	0.08	0		
TIIG	-1.08	0.004		
R&DG (-2)	-3.92	0.04	1.76	0
VIG	3.75	0	0.35	0.06
R1 (North)			0.39	0
R2 (South)	0.60	0.024		
S3 (Small)			0.49	0
S1 (Large)			0.20	0.05
PRIVATE			0.14	0.05
Constant			1.57	0

Source: Estimated

Table 7. Factors Determining TEC/ TP in the Consumer Electronics Sub-Sector

Time-invariant inefficiency model for 13 groups: 78 observations				
	TEC	**P- Value**	**TP**	**P-Value**
AGE	0.06	0.01	0.1	0
OMG			0.39	0.04
ROCEG	0.43	0.07		
R&DG (-2)	-0.02	0.04		
RMIG			1.28	0.05
VIG			0.49	0.03
R2 (South)			-0.68	0.04
S1 (Large)			0.72	0.02

Source: Estimated

Table 8. Herfindahl Index Calculated for the Four Sub-Sectors in the Electronics Sectors with respect to the Firms in Each Sub-Sector during 1993-2004

Sectors Year	Communication	Consumer
1993	0.62	0.19
1994	0.59	0.14
1995	0.29	0.15
1996	0.15	0.13
1997	0.22	0.14
1998	0.22	0.18
1999	0.26	0.16
2000	0.20	0.17
2001	0.44	0.19
2002	0.27	0.23
2003	0.13	0.27
2004	0.11	0.31

Source: Estimated

Table 9. Total R&D Expenditure on Capital Account (Million Rs at Current Prices)

Years	**Communication**	**Consumer**
1993	3.8	2.8
1994	9.8	6.9
1995	7.4	74
1996	35.6	15.6
1997	80	49.9
1998	11.1	26
1999	29.8	46.3
2000	56	508.4
2001	151.6	34.9
2002	195.2	96
2003	57.9	3.9
2004	317.9	6.7

Source: PROWESS Data Base