Trend in Total Factor Productivity Growth in Indian Iron and Steel Industries Under a Liberalized Trade Regime: An Empirical Analysis with Adjustment for Capacity Utilization

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This study attempts to measure productivity performance in terms of partial factor productivity and total factor productivity growth and tries to relate and adjust economic capacity utilization with total factor productivity growth for the entire period, 1979-'80 to 2003-'04. The results on partial factor productivity of factors show improvement in productivity of material, labour and capital. The result on the overall productivity shows declining total factor productivity growth during post-reform period as compared to pre-reform period. Total output growth in Indian iron and steel industry is found to be mainly input-driven rather than productivity-driven. With adjustment for variations in capacity utilization, trend in total factor productivity growth remains declining but variations among sub-periods turn-out to be larger and sharper. Furthermore, our result reveals that total factor productivity growth is more sensitive to the extent of capital-deepening of the steel sector showing negative and statistically significant association between total factor productivity growth and capital-output ratio .The liberalization process is found to have its adverse impact on total factor productivity growth.

INTRODUCTION

Estimating productivity level and growth rate as well as analyzing productivity determinants gained a renewed interest both among growth economists and trade economists. Liberalization implies an increase in market force in the economy. With the introduction of economic reforms in 1991, Indian industries have been witnessing profound changes in the basic parameters governing its structure and functioning. Relaxing of licensing rule, reduction in tariff rates, removal of restriction on import of raw materials and technology, price decontrol, rationalization of customs and excise duty, enhancement of the limit of foreign equity participation etc are among those which have been introduced at early 90's. One major objective of trade liberalization in India has been to enhance industrial productivity and input-use efficiency. This has been made possible with the greater and cheaper access to imported know-how, capital goods, intermediate goods and global capital, relaxing constraints on various input use and technology choices, increased domestic and international competitive pressures by bringing in technological dynamism in industries and permitting more efficient firms to grow and competing out inefficient ones. With the introduction of economic policy reforms, Indian industries have been undergoing structural reforms and facing hard competition from external markets. Growth of a firm depends on the efficient and rational use of the scarce resources available to the firm. In other words, it is the level of productivity of the factors of production that determines the sustainability of the firm. It was recognized that output growth could not be enhanced by continuous input growth in the long-run due to the nature of diminishing returns for input use. For sustained output growth, TFP growth is essential and therefore, TFP growth became synonymous with long-term growth as it reflects the potential for growth (Mahadevan, 2004).

Linkage Between Trade Liberalization and TFPG

Although there exists voluminous empirical research work regarding nexus between trade liberalization and factor productivity growth, overviews on the link between liberalization and TFPG find inadequate evidence on this issue, it is as yet a controversial issue and debate is still unsettled. The controversy on the impact of liberalization on TFPG and diverse conclusions resulting from empirical investigations are probably due to differing interpretations of liberalization and openness. These varied empirical results initiate us to investigate further into the links between liberalization and productivity growth of Indian industry.

Grossman and Helpman (1991) argue that technological change can be influenced by a country's openness to trade. Openness to trade provides access to imported inputs which embody new technology and increases the size of the markets facing producers which in turn raises return to innovation and affects a countries research intensive production. Thus, a countries openness leads to improvement in domestic technology helping the production process and becomes more efficient, improves productivity growth.

Benefits from trade to a country's manufacturing sector arise from two sources: The first source is from greater efficiency in production through increased competition and specialization. The second source is from the opportunities that arise to exploit economies of scale in a large market. Reduction in average cost is possible with the access to a large market that encourage larger production runs in the industry .Trade expansion induces firms to increase in size and engage in more plant specialization. In an environment of increased trade, consumers' demand for variety of products can be fulfilled through imports. Access to the world market also means that more products can be produced profitably and this should generate gains from increased product diversity and improve customer welfare (Petersson, 2002:241).

Advocates of trade liberalization aspire to promote productivity gains with the exposure of industries to severe international competition and facilitating access to the international market. They argue that manufacturing units which face foreign competition are forced to adapt. In particular, plants are encouraged to produce closer to the production possibility frontier while the frontier itself will move out faster. Evidence indicates that manufacturing concerns exposed to trade pay higher wages, operate at a higher scale, produce with more capital and achieve higher productivity levels. (Van Biesebroeck, 2003). Productivity growth appears to be directly linked with production of tradable goods. This implies that the benefits from foreign activities are likely to be higher in two areas; firstly, in places where the domestic market is small and foreign sales are a precondition to fully exploit scale economies and secondly, where production technology lags best practice, providing ample scope for productivity improvements through imitation and adaptation of foreign technology. Trade liberalization enables cheaper and easier access to global capital and foreign technologies. Lowering of trade restrictions makes possible the import of capital and intermediate goods which embody superior technology that results cost reduction and also in turn increases productivity growth which uses this product.

On the other hand, critics argue that increase in foreign competition may be detrimental to domestic industries if it leads to a closure of factories (Van Biesbroek, 2003). Rodrik (1991) finds that lower protection or higher import competition reduces a firm's investment in productivity enhancing technological upgrading. This is specially the case when the incentive to invest depends on the firm's output or market share – yet trade liberalization reduces the market share. Deraniyagala and Fine (2000; 98) also argue that the magnitude of gains from trade liberalization could be fairly low. If trade reduces the domestic market shares of the unprotected domestic producers without expanding their international sales, their incentive to invest in improved technology will decrease as protection ceases. This effect reduces the benefits of tariff reductions that are supposed to lower the relative prices of imported capital goods and ease access to foreign technology for domestic firms (Pavcnik, 2000:37).It is also argued that liberalization does not facilitate acquisition of better technology by domestic plants because acquisition is dependent on the flexibility of the domestic labour force.

The principal reforms initiated in the year 1991 included relaxation of import tariffs on most of the goods, removal of quantitative restrictions and liberal terms of entry of foreign players, India's simple average tariff rates were reduced along with reduction of quotas and non tariff barriers. With the extensive relaxation of control over trade, the pace of reforms got momentum over the period 1991-'96. After that, the pace of reforms was slowed down. The uneven structure of tariff rates continues to be a cause of concern along with rapid falling trend in tariff rates in the early nineties. The 1991 reforms were much broader in scope and scale and initiated a departure from earlier control regime and permits towards a market oriented regime. The 1985 reforms were piecemeal because it did neither abolish the import licence in total nor did it reduce the level of import tariff. As a result of trade liberalization since eighties, Indian economy has become more outward looking with the increase in trade intensity and FDI inflow. Liberalization of foreign investment has increased competition through the entry of foreign firms into the domestic market. The improved performance ended abruptly when the economy slid into a recession in the early 1997 with weak and inefficient firms struggling to cope with increased competition from import and new firms trying to establish themselves in the altered competitive scenario. Rodrick and Subramanian (2004) distinguish the reforms in eighties and nineties by describing the former as 'pro-business' and the latter as 'pro-market'. The eighties' reforms focused on increasing profitability of the existing firms by easing capacity restriction and reducing corporate taxes among other things. The reforms of nineties allowed more competition and paved a way for entry of new domestic firms and MNCs in Indian industries.

Brief Overview of Literature

Empirical studies suggest that trade reforms promoted total factor productivity (TFP) in Indian manufacturing during eighties' (Goldar1986, Ahluwalia1991, and Chand and Sen2002). There is adequate reason to suppose that manufacturing sector responds to liberalization and the high growth rate during nineties' was 'due to continued structural reforms including trade liberalization, leading to efficiency gains'.(WTO,2001,p1). This view has been supported by Krishna and Mitra (1998) and Unel (2003) who found that growth of TFP was higher in nineties' compared to the period upto 1990-'91. Das (2003) reported that a positive impact of lowering of NTBs on manufacturing as well as intermediate goods sector promoted industrial productivity. Turning to the trends in productivity in the post-reform period, the evidence from empirical studies by researchers was ambiguous, though subjective evidence, especially of trends of recent years shows significant increases in productivity growth. Tata Service Ltd (TSL), 2003) has reported a faster growth rate in TFP in Indian manufacturing in post-reform period as compared to pre-reform period. Despite ambiguity regarding acceleration in TFPG, evidence suggests that trade liberalization since 1991 had a positive impact on the TFPG in India (Krishna and Mitra, 1998; Chand and Sen, 2002; Das, 2003; Topalova, 2004). At the sectoral level, there is evidence of improved TFPG in exporting sectors vis-à-vis the non-exporting ones (Dholakia and Kapur, 2001; Unel, 2003) Kathuria (2002) finds that productivity of foreign owned firms improved in the post-reform period and Indian owned firms which invested in R& D gained from productivity growth. Kato (2005) finds that smaller the market share of a firm, higher is the productivity growth.

Goldar and Kumari (2003) report a declining trend of TFP growth in Indian manufacturing in 90s resulting that gestation lag in investment projects and slower agricultural growth in the 90s had an adverse impact on productivity growth. Several studies (Das, 1999, 2003, Singh et .al 2000, Kumari, 2001, Srivastav, 2001) find TFP growth in Indian manufacturing deteriorated during nineties compared with that of eighties'. Balakrishnan et.al (2000) reports a significant decline in the growth rate of TFP since 1991-'92 in five manufacturing industries in India and they failed to find a link between trade reform and TFP growth in the nineties.' Rajan. S. S el.al(2008) find declining TFPG in Indian iron and steel industry probably due to inefficient utilization of factors of production particularly underutilization of labour input in accordance with changing demand, together with sluggish growth in technical progress. Most of the studies on productivity in India have focused on the growth in TFP in Indian manufacturing . These studies suggest a decline in total factor productivity growth till 1970s,with a turn-around taking place in mid 80s',pursuant to the reoriented trade and industrial policies and improved infrastructure performance (Brahmananda, 1982; Ahluwalia, 1991; Balakrishnan and Pushpangadan 1994; Majumder, 1996, Rao, 1996, Pradhan and Barik, 1999) . The proposition that the TFPG accelerated during the 80s' would be consistent with the recent debatable view associated with Rodrik and Subramanian (2004) who argued that transition to high growth phase occurred around 1980- a full decade before economic liberalization-that started being adopted during the 1980s. Given this ambiguity, the effect of trade reforms on total factor productivity growth is an empirical issue.

After reviewing the literature, it can be observed that most of the studies conducted so far are on aggregate manufacturing, the coverage of which is not till 2003-'04. Till now, existing studies focus on measurement of partial and total factor productivity and entry aspect of firms. The present study is a comprehensive analysis on specific energy intensive industry – iron and steel sector regarding inputs (material including energy, labour and capital) and output as well as partial and total factor productivity growth with adjustment for variations in economic capacity utilization for the period,1979-'80 to 2003-'04, dividing it into pre and post-reform period.

In this backdrop, this paper develops an analytical framework and tests empirically whether trade reforms improve productivity growth in Indian iron and steel industry -one of the largest energy intensive industries in India. Therefore, this study is an attempt to measure the total factor productivity growth with adjustment for capacity utilization and assesses the impact of liberalization on TFPG of the said industry in order to have a clear insight into whether liberalization has significantly contributed to TFPG. Previous findings for the contribution of total factor productivity growth to total output growth yielded contradictory result. Many developing countries grew via factor accumulation instead of improved technological change via total factor productivity growth and therefore, attempt has also been made to investigate into the fact whether output growth is input-driven or productivity-driven and to investigate factors influencing TFPG. The diverse empirical results suggest the need for further investigation into the link between trade liberalization and productivity growth in Indian iron and steel industry. An investigation of the issue on analytical front may insert to our knowledge of the issue and throw lights on the distinct set of results produced by the existing studies.

The rest of the paper is organized as follows: Section 2 depicts methodology and data base. Productivity growth estimates both partial and total are documented and presented in section 3. Section 4 presents and analyses the impact of liberalization on total factor productivity growth and determinants of total factor productivity growth. Section 5 shows how TFPG can be adjusted in a consistent manner with the variations in capacity utilization. Section 6 presents summary and conclusions.

METHODOLOGY

Description of Data and Measurement of Variables

The present study is based on industry-level time series data taken from several issues of Annual Survey of Industries, National Accounts Statistics, *CMIE* and Economic Survey, Statistical Abstracts (several issues), *RBI* bulletin on currency and finance, handbook of statistics on Indian economy, whole sale price in India prepared by the Index no of office of Economic Advisor, Ministry of Industry etc covering a period of 25 years commencing from 1979-'80 to 2003-'04. Selection of time period is largely guided by availability of data.[1]

In order to avoid over estimation due to ignoring contribution of material input on TFP, a third variable of intermediate inputs (material including energy input) [2]has been incorporated in the value-added function as such to obtain gross output. Pradhan and Barik (1999) argued that the gross output, instead of value added, appears to be the appropriate choice of TFPG estimation in India. Generally, TFP growth estimates based on value added terms are over estimated since they ignore the contribution of intermediate inputs on productivity growth (Sharma, 1999). Therefore, modified gross value of output so calculated has been used as a measure of output suitably deflated by wholesale price index of manufactured. Deflated cost of fuel (Appendix-A1) has been taken as measure of energy inputs. Deflated gross fixed capital stock at 1981-'82 prices is taken as the measure of capital input. The estimates are based on perpetual inventory method. (Appendix-A2). Following the same line as adopted in deflating energy input, the reported series on materials has been deflated to obtain material inputs at constant prices. Total number of persons engaged in Indian iron and steel sector is used as a measure of labor inputs as is reported in ASI, which includes production workers, and non-production workers like administrative, technical and clerical staff (Goldar et.al. 2004). For recent issues, it is reported in ASI under the head 'persons engaged', for earlier issues, it is reported as 'number of employees'.

This paper covers a period of 25 years from 1979-'80 to 2003-'04.The entire period is sub-divided into two phases as pre-reform period (1979-'80 to 1991-'92) and post-reform period (1991-'92 to 2003-'04), sub-division of period being taken logically as such to assess conveniently the impact of liberalization on TFPG.

Econometric Specification

Productivity is a marginal contribution of a factor to the output growth of a product. If productivity is increasing in an economy; it means that its factor of production and commodity inputs are manifesting an increase in their output efficiency. The productivity improvements along with the increase in quantities of factors will also be contributing an additional source of output increase (Brahmananda, 1982). Productivity increases when the growth in output is greater than the growth in input, or when the rate of growth of output minus the rate of growth of the composite input is positive. Economic growth can be obtained either by increasing inputs or by improving productivity factor. Productivity growth occurs when a higher output can be attained with a given amount of input, or a certain level of output can be attained with smaller amounts of factor input. This productivity growth is obviously preferable to growth due to increase in factor inputs, since the later might be subject to diminishing marginal return. Productivity growth is necessary not only to increase output but also to enhance competitiveness of a country. The estimation of factor productivity will be very useful to evaluate the variations in the performance of an industry over a period of time. The prosperity of a new developed nation has been attributed mainly to the sustained growth of their total factor productivity (Prescott 1997).

The partial factor productivity is calculated by dividing the total output by the quantity of an input. The main problem of using this measurement of productivity is that it ignores the fact that productivity of an input depends on level of other inputs used. The TFP approach overcomes this problem by taking into account the levels of all the inputs used in the production of output. Therefore, in this paper, along with partial productivity growth, TFPG is estimated under three input framework applying Tran slog[3] index of TFP as below:

$$\Delta \mathrm{LnTFP}(t) = \Delta \mathrm{LnQ}(t) - \left[\frac{S_L(t)+S_L(t-1)}{2} \,x\, \Delta \mathrm{LnL}(t)\right] -$$

$$\left[\frac{S_K(t)+S_K(t-1)}{2} \,x\, \Delta \mathrm{LnK}(t)\right] - \left[\frac{S_M(t)+S_M(t-1)}{2} \,x\, \Delta \mathrm{LnM}(t)\right]$$

Q denotes gross value added, L Labour, K Capital, M material including energy input.

$$\Delta \mathrm{Ln}\ Q(t) = \mathrm{Ln}\ Q(t) - \mathrm{Ln}\ Q(t-1)$$

$$\Delta \mathrm{Ln}\ L(t) = \mathrm{Ln}\ L(t) - \mathrm{Ln}\ L(t-1)$$

$$\Delta \mathrm{Ln}\ K(t) = \mathrm{Ln}\ M(t) - \mathrm{Ln}\ M(t-1)$$

$$\Delta \mathrm{Ln}\ M(t) = \mathrm{Ln}\ L(t) - \mathrm{Ln}\ L(t-1)$$

S_K, S_L and S_M being income share of capital, labor and material respectively and these factors add up to unity. TFP is the rate of technological change.

EMPIRICAL ESTIMATION OF TFP GROWTH

Estimation of annual TFP growth rate of Indian iron and steel industry at aggregate level are presented in Table -1:

TABLE 1
TREND IN GROWTH RATE OF TFP AT AGGREGATE LEVEL

Pre- reform Period (1979-'80to 1991-'92)			Post -reform Period (1991-'92 to 2003-'04)		
Year	TFP Indices	Growth rate in TFP (%)	Year	TFP Indices	Growth rate in TFP (%)
1979-80	1	-	1991-92	1.0423	10.54
80-81	0.9935	-0.65	92-93	0.9328	-10.51
81-82	1.0706	7.76	93-94	1.0054	7.78
82-83	1.0642	-0.60	94-95	1.181	5.73
83-84	0.9412	-11.56	95-96	0.9107	-14.33
84-85	1.0155	7.89	96-97	1.063	16.72
85-86	0.9858	-2.92	97-98	1.0635	0.05
86-87	1.0066	2.11	98-99	0.8931	-16.02
87-88	1.0793	7.22	99-'00	1.0562	18.26
88-89	0.9886	-8.40	00-01	1.0412	-1.42
89-90	0.9914	0.28	01-02	1.0178	-2.25
90-91	0.9429	-4.89	02-03	0.9495	-6.71
91-92	1.0423	10.54	03-04	0.9337	-1.66
Average		0.5650			0.4761

Source: estimated by authors

Labour productivity for the whole period shows a growth rate at an annual average of 5.81% per annum whereas capital productivity shows an annual average growth rate of 0.80%. Capital intensity for the entire period is 5.05 whereas an estimate for the sub-period shows difference in growth rates. After economic reforms took place in July, 1991, capital productivity and labour productivity shows increasing trend. Capital intensity increases at higher rate from 4.59% in pre-reform period to 5.5 % in post-reform period. Total factor productivity growth is declining associated with declining growth rate in capital, employment during post-reform period. In a nutshell, for iron and steel sector, post-reform era witnessed declining growth rate in total factor productivity but acceleration in capital intensity as well as capital, material and labour productivity.

TABLE 2
TREND IN PARTIAL PRODUCTIVITY GROWTH OF INDIAN IRON AND STEEL INDUSTRY AT AGGREGATE LEVEL, 1979-'80 TO 2003 –'04

Year	Material Prod	Capital Prod	Labor Prod	K/L	Rate of Investment	Year	Material Prod	Capital Prod	Labor Prod	K/L	Rate of Investment
79-80	1.22	0.34	15.2	44.6	0.048	91-92	1.41	0.35	24.5	70.9	0.047
80-81	1.23	0.32	15.0	46.4	0.068	92-93	1.50	0.38	34.8	92.5	0.090
81-82	1.34	0.34	15.9	47.0	0.062	93-94	1.61	0.33	26.7	80.8	0.076
82-83	1.50	0.33	15.8	48.4	0.054	94 - 95	1.59	0.32	29.9	92.1	0.080
83-84	1.39	0.33	16.7	51.0	0.070	95-96	1.61	0.36	37.1	102.2	0.077
84-85	1.46	0.35	18.3	52.8	0.022	96 –97	1.79	0.36	33.6	92.1	-0.028
85-86	1.40	0.34	15.5	46.2	0.027	97 – 98	1.99	0.39	42.4	109.7	0.033
86-87	1.42	0.35	19.2	55.0	0.030	98 – 99	1.78	0.35	44.6	128.9	0.221
87-88	1.43	0.36	19.4	53.8	0.040	99 – 00	1.81	0.39	40.3	103.7	0.007
88-89	1.43	0.37	20.2	54.9	0.039	00 – 01	2.04	0.39	40.3	103.0	0.003
89-90	1.48	0.40	23.5	58.8	0.236	01 – 02	2.12	0.39	46.5	118.3	0.015
90-91	1.42	0.36	28.3	79.3	0.048	02 - 03	1.87	0.41	53.5	129.4	0.057
91-92	1.41	0.35	24.5	70.9	0.047	03 –04	1.72	0.41	57.5	140.5	0.058
Avg. growth rate (%)	**1.39**	**0.26**	**4.7**	**4.59**	**0.39**		**1.76**	**1.33**	**7.06**	**5.50**	**0.63**

Source: estimated by authors Prod=Productivity
 # Rate of investment refers to investment in real terms as a percentage proportion of capital stock in previous year and real investment refers to the change in the capital stock measured in real terms.

Table 3 depicts that overall long-term growth of 6.76% in value added (output) in Indian iron and steel industry during 1979-'80 to 2003-'04 is associated with rapid growth of capital(6% per annum) and low growth of labour (0.82% per -annum). Comparing the annual growth rate of pre-reform period (1979-'80 to 1991-'92) with that of post-reform period, it is evident that there is an increase in the growth rate of value added from 6.29% in pre-reform period to 6.90% in post-reform period.

It is evident that the revival of growth in output in post 90s was not accompanied by adequate generation of employment in iron and steel sector. Several explanations have been cited for that. It is argued that capital-intensive techniques were adopted because of increase in real wage in 1980s and onward. According to Nagaraj (Cited in A.K.Ghosh.1994), the "overhang' of employment that existed in 1970s were intensively used in the 1980s, thus generating a only few additional employment opportunities in the latter decades. It has also been argued that labour retrenching technique was difficult after introduction of the job security regulation in the late1970s and this forced the employers to adopt capital-intensive production techniques (Goldar, 2000).

Productivity of capital increased from 0.26 to 1.33 along with that of labour productivity, which increased from 4.7 to 7.06 during these two time frames. These changes were reflective of an increase in the rate of growth of capital intensity. The growth in the rate of investment is negatively associated with the growth rate of TFP (Table2). This implies that the increase in the rate of investment of the industry has not led to any marked increase in the efficiency in the production. In other word, there is neither the supply shock related increase in efficiency, or the demand shock related increase in efficiency as the rate of investment in the industry is increased in response to policy initiatives in the time period considered. The data also shows that the increase in the growth rate of output as is evident from the table 2, though accompanied by an increase in the rate of investment, is not accompanied by an increase in the productivity.

TABLE 3
GROWTH RATE OF VALUE ADDED, CAPITAL, EMPLOYMENT AND TOTAL FACTOR PRODUCTIVITY IN INDIAN IRON AND STEEL INDUSTRY (%)

Growth rate	1979-'80 to 2003-'04	1979-'80 to 1991-'92	1991-'92 to2003-'04
Value added	6.76 **(7.78)**	6.29 **(6.67)**	6.90 **(4.38)**
Capital	6.00 **(6.05)**	6.18 **(4.34)**	5.67 **(4.63)**
Employment	0.82 **(0.65)**	0.93 **(0.23)**	0.59 **(-0.81)**
Material productivity	1.83 **(1.49)**	1.39 **(1.23)**	1.76 **(1.61)**
Capital productivity	0.80 **(1.64)**	0.26 **(2.23)**	1.33 **(-0.23)**
Labour Productivity	5.81 **(7.09)**	4.7 **(6.43)**	7.06 **(5.24)**
Capital intensity	5.05 **(5.36)**	4.59 **(4.11)**	5.50 **(5.48)**
Total factor Productivity growth	-0.13 **(1.24)**	0.5650 **(1.53)**	0.4761 **(0.44)**

 # Growth rates for the entire period are obtained from semi-log trend.
 # # Figures in the parenthesis indicate growth rates of respective parameters in aggregate manufacturing.

Output growth – either input accumulation or productivity driven:
Traditionally (owing to Solow), the sources of output growth are decomposed into two components: a component that is accounted for by the increase in factors of production and a component that is not accounted for by the increase in factors of production which is the residual after calculating the first component. The latter component actually represents the contribution of TFP growth.

Table 4 shows the relative contribution of TFP growth and factor input growth for the growth of output during 1979-'80 to 2003-'04. Observing the growth path, it is apparent that TFP growth contribution is either negative or insignificant across the entire time frame and TFP explains on an average less than 12% of the growth in output. Therefore, it is true that increase in factor input is responsible for observed output growth and TFP contribution plays negligible role in enhancing output growth. Therefore, growth in Indian iron and steel industry was fundamentally dominated by factor accumulation resulting input-driven growth.

TABLE 4
CONTRIBUTION OF TFPG TO OUTPUT GROWTH UNDER LIBERALIZED TRADE REGIME

Period	Output growth	Contribution of Input growth	Contribution of TFPG
Phase 1 (1979-‘80 to ‘85-‘86)	4.43	3.69(83.21%)	0.74 (16.79%)
Phase 2 (1986-‘87 to ‘91-‘92)	7.33	6.51(88.81%)	0.82(11.19%)
Phase 3 (1992-‘93 to ‘97-‘98)	7.79	7.09(90.98%)	0.70(9.02%)
Phase 4 (1998-‘99 to2003-04)	6.91	6.2(89.67%)	0.71(10.33%)
Entire Pre-reform period (1979-‘80 to 1991-‘92)	6.29	5.72(91.02%)	0.57(8.98%)
Entire Post-reform period (1991-‘92 to 2003-‘04)	6.9	6.42(93.1%)	0.48(6.90%)
Entire period (1979-‘80 to03-‘04)	6.76	6.89(101.92%)	-0.13(-1.92%)

***Figures in the parenthesis are contribution of factor inputs and productivity in percentage term to the respective phase.**

The iron and steel industry whose industrial structures depends heavily on traditional manufacturing activities and have higher capital-to-output ratios will generally tend to have lower rates of TFPG. Furthermore, it is noticed from our results that TFPG is more sensitive to the extent of capital deepening of the steel sector. TFPG is regressed on K /Y and GO (growth in GVA) and the relationship was as follows:

$$TFPG = 1.33 - \underset{(-2.28)}{2.58} K/Y - \underset{(-1.61)}{0.48} GO$$

$$R^2 = 0.12$$

Our result suggests a negative and statistically significant association between TFPG and K/Y which implies that the low TFPG rate is correlated with high capital-to-output ratio and vice versa and association between TFPG and GO is found to be statistically insignificant.

DETERMINANTS OF TOTAL FACTOR PRODUCTIVITY GROWTH

Econometric Modeling of Liberalization

The process of liberalization can be linked to the manufacturing productivity. The Indian government started to implement a wide range of economic reforms on various fronts to make domestic industries more efficient and internationally competitive. Indian firms were expected to respond positively these measures. The liberalization process was to expose firms to international competition and force them to introduce new methods of production, import quality inputs, capital equipment or technology and compel them to improve their efficiency. Trade liberalization is captured by either an explicit measure of liberalization or by a dummy variable capturing a change in the economic policies. The use of dummy variable to demarcate the post-reform period from pre-reform period (as had done earlier by Ahluwalia, 1991; Harrison, 1994; Krishna and Mitra, 1998) is subject to criticism. Dummy variable technique assumes that trade reform was one time phenomenon and it was complete and at the same time it fails to capture that reform has been gradual over time, rather an on-going process.

In order to understand the impact of liberalization on TFPG more precisely, we use a piecewise linear regression equation (popularly known as spline function) which is depicted as follows:

$$\text{Ln } Y_t = \alpha + \beta t + \beta'(t - t_0)\, Dt$$

Where Y_t is TFP.

Result of the regression equation is as follows:

$$\text{Ln } Y_t = 0.04837 - 0.00183t - 0.0033\, Dt$$

$$(1.152) \quad (-0.368) \quad (-2.41)$$

$$R^2 = 0.14, \text{ Durbin-Watson}=2.74$$

Figures in the parenthesis are t values. As the coefficient of the difference between two time periods is statistically significant at 0.05 level and negative (coefficient being – 0.0033), conclusive inference can be drawn in that liberalization has its significant negative impact on TFPG during post-reform period.
Theory and evidence suggest that several factors can contribute to TFP growth. Economic policies play a key role in increasing TFP as highlighted by endogenous growth literature.

Here, industry specific import or export penetration ratio as a measure of openness, effective exchange rate, inflation rate etc. are used as explicit measure of economic liberalization.

Factors determining TFP Growth

The basic empirical framework employed in this study is based on a simple model of TFP:

$$TFP_t = \alpha' + X_{it}\beta + \mu_t$$

Where TFP refers to total factor productivity growth.

X_i refers to the vector of determinants of TFP and μ is the error term.

In order to understand the impact of liberalization on TFPG more precisely, the above equation is elaborated as follows:

$$TFPG = \alpha' + \beta_1 EXPOR + \beta_2 IMPEN + \beta_3 GO + \beta_4 TAR + \beta_5 REER + \beta_6 TOT + \beta_7 INFL + \beta_8 CU + \beta_9 IFM + \beta_{10} GMUP + \beta_{11} EXPOR * REER + \beta_{12} EXPOR * INFL + \beta_{13} IMPEN * TAR + \beta_{14} IMPEN * INFL + \beta_{15} IFM * INFL + \beta_{16} IFM * REER + LIBDUM.$$

The export-output ratio is total exports divided by the gross total output values of the domestic industries while the import-penetration is equal to total import divided by total domestic demand. Tariff rate is the aggregate of customs payment divided by the value of imports. REER is the real effective exchange rate of Indian rupee with base year 1985=100 and inflation is defined as the change in the change in the consumer price index that are taken from the Hand Book of Statistics on Indian Economy,2005-'06.Terms of trade implies volume index of imports expressed as percentage of volume index of exports also collected from the Hand Book of Statistics on Indian Economy,2005-‘06.CU indicates economic measure of capacity utilization as estimated by ourselves following the methodology depicted in AppendixA-3. IFM is the ratio of recent investment in fixed machinery (used as proxy of technology acquisition) to the existing fixed capital stock and GMUP is the gross mark-up which is obtained from the gross value added minus total emolument divided by gross output. DUMLIB is the dummy variable of the post liberalization period (taking value one for 1991-‘92 and onward and zero for earlier years). Table 5 contains the descriptive statistics of the key variables used in the estimation procedure.

TABLE-5
DESCRIPTIVE STATISTICS FOR TFP VARIABLES

Variable	Definition	Mean	Standard deviation	Minimum	Maximum
EXPOR	Export-output ratio	0.0351	0.0292	.00	.10
IMPEN	Import-penetration	.1063	0.0391	.05	.20
GO	Growth-in output	6.52	6.56	-5.52	20.50
TAR	Tariff rate	53.85	17.27	31.04	98.89
REER	Real-effective exchange rate	78.90	16.31	57.08	104.48
TOT	Terms of trade	135.60	17.62	109.30	175.00
INFL	Inflation rate	8.54	3.50	2.70	15.50
CU	Capacity utilization	.744	.127	.49	.89
IFM	Investment in fixed assets	16.77	23.86	-12.60	104.50
GMUP	Gross-mark-up	14.81	3.95	9.75	28.44
N	Number of periods	25			

Table 6 presents the estimates of coefficients of the above equation for each of the models. Prior to estimation, we examined the correlation among trade variables and we find that different trade variables are strongly correlated with each other. The high correlation between trade variables causes multicollinearity. Therefore, to remove problem of multicollinearity, we do not simultaneously include the different trade variables in our estimate. Our empirical result from TFP growth equation suggests that export has an almost negative effect on TFP growth since coefficients in all the equations are negative implying that exports do not contribute significantly to TFP growth in Indian iron and steel industry. But, this may not probably be a generalized notion that exports are not beneficial for a developing economy like India because exploiting economies of scale, enhancing foreign exchange earnings, accelerated economic growth can be made possible through export. The coefficient of import-penetration ratio is negative and significant which implies that increase in import may slowdown TFP growth and more precisely, it can be said that productivity growth has opposed effect on imports and it reduces imports by increasing domestically produced import substitutes. A significant negative relationship between output growth and TFP growth is evident from our analysis which is beyond our expectation since all the coefficients are statistically significant and negative. It indicates that with the growing degree of output, productivity is gradually reduced. The tariff variables are significant in two equations and negative in all equation which is rightly signed indicating that increase in tariff would decrease TFP growth and one percentage point increase in tariff would decrease TFPG by 0.8%. Real effective exchange rate has a significant negative impact on productivity growth as is expected. It is indicative that decrease in real effective exchange rate should increase the demand for traded industries' output by stimulating export via-a vis enhance TFP growth. Role of inflation in growth is controversial among theorists and policy makers on several occasions which are beyond the scope of our study. We have used inflation as a regressor in the model to capture the stability of the economy which is hypothesized as necessary for TFP growth. Developing economies signal the impact of money illusion which is why inflation is needed to be included as macro-economic determinant of TFP growth. It is a fact that inflation adds to economic growth by generating employment in a sense that the positive relation of inflation and TFP can be expected. But, our result shows that it holds statistically insignificant results. A statistically significant positive relation is found between CU and TFP growth which implies that trade openness induces domestic manufacturers of iron and steel to utilize capacity to the fullest possible in order to enhance TFP. Significant positive association between GM and TFPG is noticed in our estimate implying that with the increase in TFPG, gross mark up enhances. Growth in investment in fixed machinery has significant positive impact total factor productivity growth. A one percentage point increase in the machinery and equipment expenditure would increase TFPG by more than 3 percent on an average.

A number of interaction terms are found to be significant for productivity. The interaction between export-output ratio and inflation has a significant and positive impact on total factor productivity growth. The other interaction between export-output ratio and real effective exchange rate has a positive but insignificant impact on TFPG. The interaction between import penetration and inflation has a significant negative impact on TFPG. Interaction between investment in fixed asset and real effective exchange rate impacted positively on productivity performances and interaction between import penetration and tariff has significant positive impact on TFPG. The coefficient of liberalization dummy is found to be negative and statistically significant in most of the equations .This variable, when incorporated into the equation along with other explanatory variables, captures the net effect of all factors connected with economic reforms other than those which are directly included in the equation. Therefore, trade liberalization has caused significant adverse impact on TFPG.

TABLE 6
ESTIMATION OF TFPG DETERMINANTS BY OLS TECHNIQUE
(DEPENDENT VARIABLE: TFP GROWTH RATE)

Explanatory Variable	Regression									
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
EXPOR	-545.27 (-0.531)	-678.24 (-1.21)	-734.4 (-3.2)	-851.83 (-1.66)	-1034.7 (-2.1)	-955.9 (-1.86)	-689.7 (-1.34)	-646.9 (-0.747)	-	-
IMPEN	-1430.2 (-3.22)	-1451.7 (-3.7)	-1530.2 (-1.36)	-1624.58 (-4.73)	-1499.4 (-4.55)	-1286.1 (-4.15)	-1246.6 (-3.8)	-1224.2 (-3.68)	-1282.34 (-4.02)	-1147.3 (-3.79)
GO	- 0.65 (-3.84)	-0.658 (-4.39)	-0.668 (-4.18)	-0.662 (-4.65)	-0.654 (-4.54)	-0.617 (-4.14)	-0.658 (-4.24)	-0.629 (-4.03)	-0.619 (-4.04)	-0.637 (-4.11)
TAR	-0.68 (-1.42)	-0.671 (-1.52)	-0.764 (-4.6)	-0.743 (-1.84)	-0.516 (-1.45)	-	-	-	-	-
REER	-1.52 (-2.9)	-1.54 (-3.22)	-1.589 (-1.86)	-1.72 (-4.07)	-1.80 (-4.26)	-1.72 (-3.92)	-1.73 (-3.71)	-1.6 (-3.46)	-1.67 (-3.74)	-1.47 (-3.49)

TOT	-.14 (-1.15)	-0.133 (-1.27)	-0.117 (-3.48)	-0.111 (-1.14)	-	-	-	-	-	-
INFL	0.46 (0.16)	-	-	-	-	-	-	-	-	-
CU	15.18 (2.02)	14.58 (3.09)	9.26 (4.84)	-	-	-	-	-	-	-
IFM	-3.67 (-5.40)	-3.65 (-5.84)	-3.43 (-6.44)	-3.54 (-6.99)	-3.75 (-7.85)	-3.4 (-7.86)	-3.15 (-7.4)	-3.14 (-7.23)	-3.12 (-7.31)	-3.06 (-7.12)
GMUP	1.09 (2.4)	1.13 (3.04)	1.15 (3.21)	1.25 (3.73)	1.09 (3.54)	1.09 (3.38)	0.98 (2.94)	0.873 (2.66)	0.864 (2.67)	0.817 (2.51)
EXPOR* REER	6.46 (0.62)	7.62 (1.09)	7.46 (1.10)	8.20 (1.24)	11.29 (1.84)	10.84 (1.69)	8.04 (1.23)	-	-	-
EXPOR* INFL	53.78 (2.09)	57.2 (4.26)	54.58 (4.34)	53.36 (4.34)	46.94 (4.24)	45.98 (3.96)	51.58 (4.41)	46.25 (4.18)	42.91 (4.31)	37.93 (4.12)
IMPEN* REER	10.13 (2.61)	10.07 (2.81)	10.45 (3.03)	11.55 (3.67)	11.22 (3.53)	11.09 (3.33)	10.53 (3.001)	10.43 (2.92)	10.93 (3.16)	9.09 (2.88)
IMPEN* TAR	14.48 (2.92)	14.37 (3.16)	15.05 (3.48)	15.14 (3.56)	12.98 (3.36)	7.71 (5.56)	6.82 (5.09)	6.73 (4.93)	7.24 (6.3)	6.66 (6.28)
IMPEN* INFL	-13.55 (-0.685)	-10.49 (-2.13)	-9.37 (-2.05)	-11.05 (-2.73)	-10.23 (-2.54)	-9.46 (-2.25)	-6.94 (-1.69)	-5.66 (-1.40)	-4.27 (-1.21)	
IFM * INFL	0.026 (0.676)	0.023 (0.738)	-	-	-	-	-0.042 (7.15)	-	-	-
IFM * REER	0.046 (5.26)	0.0465 (5.82)	0.046 (6.07)	0.049 (6.64)	0.0517 (7.43)	0.046 (7.53)	-	0.0423 (7.03)	.0042 (7.14)	0.041 (6.93)
DUMLIB	-9.99 (-0.73)	-10.98 (-0.97)	-14.23 (-2.43)	-17.73 (-1.99)	-19.4 (-2.12)	-13.41 (-2.57)	-	-	-	-
Constant	118.5 (2.09)	122.93 (2.68)	134.34 (3.20)	150.05 (4.05)	132.22 (3.88)	109.6 (3.45)	119.9 (3.65)	108.24 (3.32)	109.3 (3.47)	97.18 (3.2)
Adjusted R^2 D-W=2.73	0.76	0.80	0.80	0.81	0.81	0.79	0.76	0.75	0.76	0.75

TOTAL FACTOR PRODUCTIVITY GROWTH WITH ADJUSTMENT FOR CAPACITY UTILIZATION

Such adjustment to productivity measure is of crucial importance in order to capture the effect of variation in capacity utilization on TFPG. This section estimates how TFPG measure may be changed with the variation in capacity utilization .We regress the log difference of the measured productivity growth on the log difference of the capacity utilization rate, which is a proxy for business cycle. Subsequently, we have adjusted the average of the regression error term so that it equals the original productivity measure when the productivity measure is adjusted for cyclical factors.

$$\Delta \text{ Log } TFP_t = a + b\Delta \text{ Log } CU_t$$

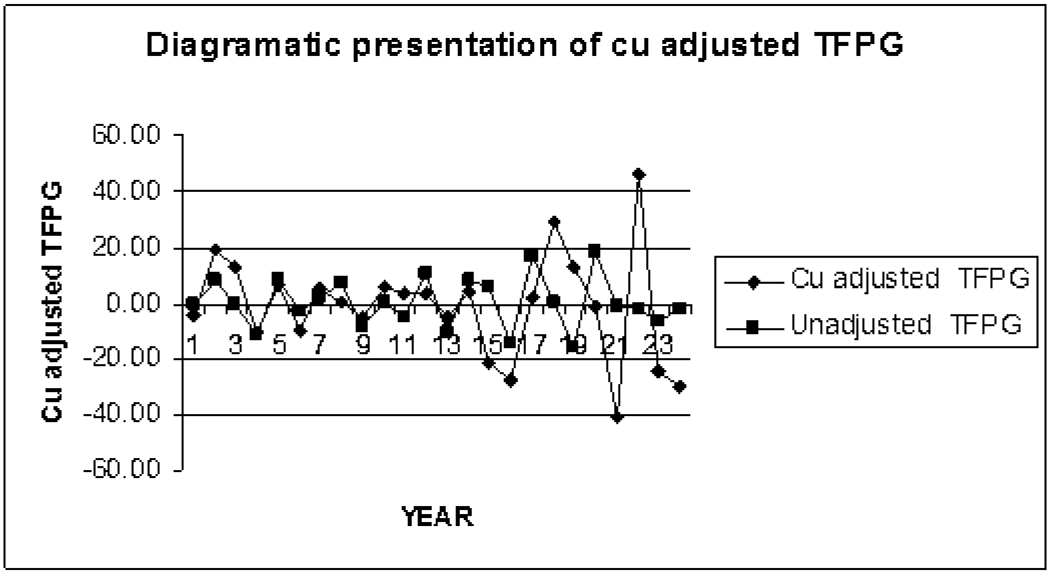
The result of the regression is as follows:

$$\Delta \text{ LogTFP} = -0.0019 + 0.089\Delta \text{ Log CU}_t$$
$$(2.87)$$

Where CU is economic capacity utilization (methodology for measuring CU is shown in Appendix-A3) and t statistics are given in the parenthesis. Durbin-Watson=3.03, $R^2 = 0.18$

Our regression result shows that effect of CU on measured productivity growth is significant at 0.05 level.

GRAPH 1



Rate of changes in CU are found to be positively correlated with TFP growth rate. This implies that among many other factors like growth in output, import of capital goods, advanced technology, trade policy etc. that affect TFPG, CU may have a resultant positive effect on TFPG rate. With the adjustment of capacity utilization, positive growth rate of TFP (0.565%) in 80's becomes larger and sharper and displays a very noticeable accelerated growth rate in TFP (2.32%) and in 90's, CU adjusted TFPG sharply declined.

TABLE 7

TFP GROWTH RATE AFTER ADJUSTING CAPACITY UTILIZATION, 1980-81 TO 2003-'04.

Time interval	TFP growth rate (% per annum).	
	Unadjusted TFPG	TFPG adjusted for capacity utilization
Pre-reform period i.e. 1980-'81 to 1991-'92	0.565	2.32
Post- reform period i.e. 1991-'92 to 2003-'04	0.476	-3.97
Entire period i.e. 1980-'81 to 2003-'04	-0.11	-1.14

 # Growth rates for the entire periods are obtained from the semi log trend.

Difference in average annual growth rate between pre-reform (1980-'81 to1991-'92) and post-reform period (1991-'92 to 2003-'04) is larger after incorporating effect of CU into TFP growth calculation; while unadjusted translog measure implies a slowdown of -0.09% (0.476% minus 0.565%), capacity adjusted TFPG measure suggest abrupt decline of -6.29% (-3.97 %minus 2.32%) following trade reform. In a nut shell, inspection of entries in table 7 reveals that removal of cyclical effect from the estimated TFP growth does not affect its overall movement but remarkably enhances its variation because variations between sub-periods are enlarged after adjusting capacity utilization as cyclical factors.

SUMMARY & CONCLUSION

This study attempts to measure productivity performance in terms of partial factor productivity and total factor productivity and tries to relate and adjust capacity utilization with total factor productivity growth for the entire period, 1979-'80 to 2003-'04. The results on partial factor productivity of factors show improvement in productivity of material, labour and capital. The result on the overall productivity displays that TFPG has declined in post-reform period as compared to pre-reform period. Total output growth in Indian iron and steel industry is found to be mainly input-driven. After adjusting capacity utilization, trend in adjusted TFPG remains declining but variations among sub-periods turn out to be larger and sharper. Furthermore, our result reveals that TFPG is more sensitive to the extent of capital deepening of the steel sector showing negative and statistically significant association between TFPG and capital-output ratio .The liberalization process is found to have its adverse impact on total factor productivity growth.

In conclusion, it is suggested that aggregate growth strategies through stimulation of domestic demand, access to global market, and investment in new emerging growth areas are required for propelling a higher growth rate. Consolidation is the urgent need to achieve higher scale of operation in order to compete efficiently in liberalized regime as well as to face global challenges. In terms of future applied research directions on Indian context, regional level study with plant level data sets would be more informative in decision-making process.

ENDNOTES

1. Till 1988-89, the classification of industries followed in ASI was based on the National Industrial classification 1970 (NIC 1970). The switch to the NIC-1987 from 1989-90 and also switch to NIC1998 requires some matching. Considering NIC1987 as base and further NIC 1998 as base, iron and steel industry has been merged accordingly. For price correction of variable, wholesale price indices taken from official publication of CMIE have been used to construct deflators.
2. Earlier studies that have not treated material including energy as separate factor of production, has failed to pick-up significant economies that are likely to generate in the use of such input. Jorgenson (1988) has observed that in a three input production framework, the contribution of intermediate inputs like material, energy etc. are significant sources of output growth.
3. The Translog index of TFP is a discrete approximation to the Divisia index of technical change. It has the advantage that it does not make rigid assumption about elasticity of substitution between factors of production (as done by Solow index). It allows for variable elasticity of substitution. Another advantage of Translog index is that it does not require technological progress to be Hicks- neutral. The Translog provides an estimate of the shift of the production function if the technological change is non-neutral.

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Appendix

Appendix A-1: Energy Inputs: Industry level time series data on cost of fuel of Indian iron &steel sector have been deflated by suitable deflator (base 1981-'82 = 100) to get real energy inputs. An input-output table provides the purchase made by manufacturing industry from input-output sectors. These transactions are used as the basis to construct weight and then weighted average of price index of different sectors is taken. Taking into consideration 115 sector input-output table (98-'99) prepared by CSO, the energy deflator is formed as a weighted average of price indices for various input-output sectors which considers the expenses incurred by manufacturing industries on coal, petroleum products and electricity as given in I-O table for 1998-'99. The WIP indices (based 1981-'82) of Coal, Petroleum and Electricity have been used for these three categories of energy inputs. The columns in the absorption matrix for 66 sectors belonging to manufacturing (33-98) have been added together and the sum so obtained is the price of energy made by the manufacturing industries from various sectors. The column for the relevant sector in the absorption matrix provides the weights used.

Appendix A-2: Capital Stock: The procedure for the arriving at capital stock series is depicted as follows:

First, an implicit deflator for capital stock is formed on NFCS at current and constant prices given in NAS. The base is shifted to 1981-'82 to be consistent with the price of inputs and output.

Second, an estimate of net fixed capital stock (NFCS) for the registered manufacturing sector for 1970-'71 (benchmark) is taken from National Accounts Statistics. It is multiplied by a gross-net factor to get an estimate of gross fixed capital stock (GFCS) for the year 1970-'71. The rate of gross to net fixed asset available from RBI bulletin was 1.86 in 1970-'71 for medium and large public Ltd. companies. Therefore, the NFCS for the registered manufacturing for the benchmark year (1970-'71) as reported in NAS is multiplied by 1.86 to get an estimate of GFCS which is deflated by implicit deflator at 1981-'82 price to get it in real figure. In order to obtain benchmark estimate of gross real fixed capital stock made for registered manufacturing, it is distributed among various two digit industries (in our study, Iron & Steel industry) in proportion of its fixed capital stock reported in ASI, 1970-'71)

Third, from ASI data, gross investment in fixed capital in Indian iron &steel industry is computed for each year by subtracting the book value of fixed asset in previous year from that in the current year and adding to that figure the reported depreciation on fixed asset in current year (Symbolically, $I_t = (\beta_t - \beta_{t-1} + D_t) / Pt$) and subsequently it is deflated by the implicit deflator to get real gross investment.

Appendix A-3:

Econometric Model for estimating capacity utilization and data description:

Considering a single output and three input framework (K, L, E) in estimating CU, we assume that firms produce output within the technological constraint of a well-behaved production function.

Y = f (K, L, E) where K, L and E are capital, labour and energy respectively. Since capacity output is a short-run notion, the basic concept behind it is that firm faces short-run constraints like stock of capital .Firms operate at full capacity where their existing capital stock is at long-run optimal level. Capacity output is that level of output which would make existing short-run capital stock optimal.

Rate of CU is given as

$$CU = Y/Y^* \ \ldots\ldots\ldots \ (1)$$

Y is actual output and Y* is capacity output.

In association with variable profit function, there exist a variable -cost function which can be expressed as

$$VC = f\ (P_L, P_E, K, Y)\ldots\ldots.(2)$$

Short run total cost function is expressed as

$$STC = f\ (P_L, P_E, K, Y) + P_K.K\ldots\ldots\ldots\ldots\ldots.(3)$$

P_K is the rental price of Capital.

Variable cost equation which is variant of general quadratic form for (2) that provide a closed form expression for Y* is specified as

$$\begin{aligned} VC = {} & \alpha_0 + K_{-1}\left(\alpha_K + \tfrac{1}{2}\beta_{KK}\left[\frac{K_{-1}}{Y}\right] + \beta_{KL}.P_L + \beta_{KE}.P_E\right) \\ & + P_L(\alpha_L + \tfrac{1}{2}\beta_{LL}.P_L + \beta_{LE}.P_E + \beta_{LY}.Y) \\ & + P_E(\alpha_E + \tfrac{1}{2}\beta_{EE}.P_E + \beta_{EY}.Y) + Y(\alpha_Y + \tfrac{1}{2}\beta_{YY}.Y) \ \ldots\ldots\ldots.\ (4) \end{aligned}$$

K_{-1} is the capital stock at the beginning of the year which implies that a firm makes output decisions constrained by the capital stock at the beginning of the year.

Capacity output (Y*) for a given level of quasi-fixed factor is defined as that level of output which minimizes STC. So, the optimal capacity output level, for a given level of quasi-fixed factors, is defined as that level of output which minimizes STC. So, at the optimal capacity output level, the envelop theorem implies that the following relation must exist.

$$\partial STC/\partial K = \partial VC/\partial K + P_K = 0 \qquad \ldots\ldots\ldots..\ (5)$$

In estimating Y*, we differentiate VC equation (4) w.r.t K_{-1} and substitute expression in equation (5)

$$Y^* = \frac{-\beta_{KK}.K_{-1}}{(\alpha_{K} + \beta_{KL}P_L + \beta_{KE}P_E + P_K)} \quad \text{………… (6)}$$

The estimates of CU can be obtained by combining equation (6) and (1).

Output is measured as real value added produced by manufacturers ($Y = P_LL + P_K.K_{-1} + P_E.E$) suitably deflated by WIP index for manufactured product (base 1981-'82 = 100) to offset the influence of price changes. In CU measurement, variable cost is sum of the expenditure on variable inputs ($VC = P_LL + P_E.E$).Total number of persons engaged in Iron and Steel sector are used as a measure of labour inputs. Price of labour (P_L) is the total emolument divided by number of labourers which includes both production and non-production workers. Deflated cost of fuel has been taken as measure of energy inputs. Due to unavailability of data regarding periodic price series of energy in India, some approximations become necessary. We have taken weighted aggregative average price index of fuel (considering coal, petroleum and electricity price index, suitably weighted, from statistical abstract) as proxy price of energy. Deflated gross fixed capital stock at 1981-'82 prices is taken as the measure of capital input. The estimates are based on perpetual inventory method. Rental price of capital is assumed to be the price of capital (P_K) which can be estimated following Jorgenson and Griliches (1967):

$P^t_K = r_t + d_t - \frac{P^{\bullet}_k}{P_k}$ where r_t is the rate of return on capital in year t ,d_t is the rate of depreciation of capital in the year t and $\frac{P^{\bullet}_k}{P_k}$ is the rate of appreciation of capital .Rate of return is taken as the rate of interest on long term government bonds and securities which is collected from RBI bulletin(various issues). The rate of depreciation is estimated from the reported figures on depreciation and fixed capital as available in ASI which Murty (1986) had done earlier. However, we have not tried corrections for the appreciation of value of capital in the estimates of price of capital services.

Fourth, the post benchmark real gross fixed capital stock is arrived at by the following procedure. Real gross fixed capital stock (t) = real gross fixed capital stock (t – 1) + real gross investment (t). The annual rate of discarding of capital stock (D_{st}) is assumed to be zero due to difficulty in obtaining data regarding D_{st}.

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