Growth and Productivity Performance in Indian Chemical Industry: An Empirical Investigation under New Trade Regime

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This paper tries to assess productivity performance in terms of partial factor productivity and total factor productivity growth and tries to depict true snapshot of total factor productivity growth after adjusting economic capacity utilization for the entire period, 1980-81 to 2003-04. The results of partial factor productivity show improvement in productivity of material, but labour and capital productivity are gradually declining. Using translog index, 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 chemical industry is found to be mainly input-driven rather than productivity-driven. After adjusting capacity utilization, TFP growth does not affect its overall movement but remarkably mitigates its variation because variations between sub-periods are smaller after adjusting capacity utilization as cyclical factors. The liberalization process is found to have its adverse impact on total factor productivity growth. Finally, analysis of the nature of competition shows that rigidity in the expansion of competition exists in the Indian chemical industry.

Keywords: Chemical industry, Competition, Productivity, Liberalization, Capacity utilization

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I. Introduction

Following the balance of payments crisis during 1990-91, Government of India has adopted several waves of far reaching trade reforms since 1991. The reforms include sharp reductions in the number of goods subject to licensing and other non-tariff barriers, reductions in export restrictions and tariff cuts across all industries. Trade liberalization has resulted in higher levels of competition within the Indian economy. There has been ongoing debate regarding impact of liberalization on productivity growth in Indian manufacturing industries. In majority of the Indian studies, it was found that post liberalized era witnessed a more declining growth rate in factor productivity. This may probably be due to declining utilization rate of capacity which was caused by massive expansion of capacity owing to abolition of licensing rule, consequent to reforms as well as unaccompanied by adequate generation of demand.

Based on the broad phases of varying level of output growth and capacity utilization, the analysis breaks-up the entire time frame into pre- and post-liberalization period. The 1990s reforms were taken up to make Indian industries efficient, technologically up to date and competitive. The enhancement of efficiency, upgradation of technology and enhancement of competition were expected to make Indian industries rapidly growing. There are several mechanisms through which competition influences productivity growth. Competition can place downward pressure on costs, force firms to be more focused on meeting customers need, lead to more efficient allocation of resources among firms, act as a spur to innovation. Competition places pressure on managers to push their firms closer to production possibility frontier. Individual firms increase their productivity through internal changes such as new technology, organizational change, and downsizing. The entry of a new firm into an industry and the subsequent threat to incumbents' market shares can triggers this process. Productivity growth, being an indicator of industries' competitiveness and better standard of living, is positively associated with capital productivity, labour productivity, and capital intensity. The chemical industry is included in the present study because of its increasing importance.

Its share of value added increased from 16.3 to 18.5%, placing it at the first rank, although in terms of employment it ranks only fourth. Its profitability was found to be above the industry average and increasing, whereas its international competitiveness was found to be nearly average but rising. Its ratio of exports to output has doubled from about 5 to 10%.

In this backdrop, this paper develops an analytical framework for assessing TFPG performance and tests empirically whether productivity growth has been improved in Indian chemical industry after path breaking economic reforms when effect of capacity utilization has been adjusted for. Previous findings for the contribution of total factor productivity growth to total output growth yielded contradictory result. Generally developing countries like India grew through 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. We have also endeavored to assess partial factor productivity growth and employment growth within this framework. Nature of competition is also analyzed in the study. An exploration of the theme on critical facade may insert to our knowledge into the issue.

The rest of the paper is organized as follows: Section 2 depicts brief overview of literature, section 3 describes methodology and data base. Productivity growth estimates both partial and total are documented and presented in section 4. Section 5 presents and analyses the impact of liberalization on total factor productivity growth and determinants of total factor productivity growth. Section 6 shows how TFPG can be adjusted in a consistent manner with the variations in capacity utilization and section 7 presents nature of competition in the industry. Section 8 presents summary and conclusions.

II. TFP and Output Growth in Indian Industries: Brief Overview

Empirical studies suggest that trade reforms promoted total factor productivity (TFP) in Indian manufacturing during eighties (Goldar 1986; Ahluwalia 1991; Chand and Sen 2002). 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, p. 1). 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 up to 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 1990s resulting 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; Srivastava 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. *et 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; Majumdar 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.

III. Methodology for Assessing TFPG

A. 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.* This study covers a period of 25 years from 1979-80 to 2003-04. Selection of time period is largely guided by availability of data.[1] This was partly because: though Indian economy was liberalized in 1991, with some tentativeness, it has been opened to the world economy during mid 80s and partly because of the non-availability of all types of data required for our study before 1979-80. The entire period is 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 and CU. Selection of time period is largely guided by availability of data.

TFPG study has been conducted in view of three inputs framework-namely material, labour, and capital. Gross output has been used as a measure of output suitably deflated by wholesale price index of manufactured. Similar study of Hyunbae Chun, Hak K. Pyo, and Keun Hee Rhee (2008) used gross output as real output in their MFP framework because they consider intermediate inputs like material and purchased services in their analysis. Deflated cost of fuel (Appendix A-2) 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 A-3). Following the

[1] Till 1988-89, the Classification of industries followed in ASI was based on the National Industrial Classification 1970 (NIC1970). The switch to the NIC1987 from 1989-90 and also switch to NIC1998 requires some matching. Considering NIC1987 as base and further NIC1998 as base, chemical 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.

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 chemical sector is used as a measure of labor inputs as is reported in Annual Survey of Industries (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.'

The entire period of study is sub-divided into two phases: 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.

B. Econometric Model for Measuring Productivity

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. However, the two most common approaches applied in case of Indian manufacturing are 'growth accounting' and 'econometric estimation.' Therefore, in this paper, along with partial productivity growth, TFPG is estimated under three input framework applying translog[2] index of TFP as below:

$$\Delta LnTFP(t) = \Delta LnQ(t) - \left[\frac{S_L(t)+S_L(t-1)}{2} x\Delta LnL(t)\right] - \left[\frac{S_K(t)+S_K(t-1)}{2} x\Delta LnK(t)\right] - \left[\frac{S_M(t)+S_M(t-1)}{2} x\Delta LnM(t)\right] \quad (1)$$

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

[2] 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.

$$\Delta Ln\ Q(t) = Ln\ Q(t) - Ln\ Q(t-1)$$
$$\Delta Ln\ L(t) = Ln\ L(t) - Ln\ L(t-1)$$
$$\Delta Ln\ K(t) = Ln\ K(t) - Ln\ K(t-1)$$
$$\Delta Ln\ M(t) = Ln\ M(t) - Ln\ M(t-1)$$

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

Using the above equation, growth rates of total factor productivity have been computed for each year. These have been used to obtain an index of TFP in the following way. Let Z denote the index of TFP. The index for the base year, $Z(0)$, is taken as 100. The index for the subsequent years is computed using the following equation:

$$Z(t)/Z(t-1) = \exp[\Delta Ln\, TFP(t)].$$

C. Sources of Output Growth in Indian Chemical Industry

Theoretically, sources of economic growth are composed of factor accumulation and productivity growth. The first source may lead to high growth rates, but only for a limited period of time. Thereafter, the law of diminishing returns inevitably occurs. Consequently, sustained growth can only be achieved through productivity growth, that is, the ability to produce more and more output with the same amount of input. Some researchers argued that the Soviet Union of the 1950s and the 1960s, and the growth of the Asian 'Tigers' are as examples of growth through factor accumulation (*e.g.*, Krugman 1994). On the other hand, growth in the industrialized countries appears to be as the result of improved productivity (*e.g.*, Fare *et al.* 1994).

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.

IV. Empirical Estimation of Growth of Total Factor Productivity and Partial Factor Productivity

Estimation of annual TFP growth rate of Indian chemical industry at

TABLE 1
TOTAL FACTOR PRODUCTIVITY GROWTH AT AGGREGATE AND DISAGGREGATE LEVEL (PRE-REFORM PERIOD)

	Organic & Inorganic chemicals	Plastic	Paint & Var-nishes	Drug & Medicine	Perfumes & Cosmetics	Man made fibre	Explosive chemi-cals	Photo-chemical films	Aggregate
1980-81	1.08	9.60	3.22	1.06	5.55	8.90	1.18	8.47	9.62
81-82	0.59	-27.00	-5.52	0.90	-9.65	-26.70	-2.31	-11.04	-5.62
82-83	-1.14	30.28	4.34	-5.07	4.28	29.48	1.13	23.92	-4.33
83-84	-7.39	-10.65	-3.98	-0.02	2.60	-10.12	0.71	-32.93	-2.43
84-85	12.16	37.38	2.84	11.55	-3.04	39.38	-0.27	23.43	4.89
85-86	-4.88	-39.82	-0.58	-9.74	2.96	-40.99	-1.23	14.42	-4.25
86-87	-0.04	35.79	-1.13	1.49	-2.11	36.47	0.90	-23.66	7.70
87-88	0.52	-19.49	-0.41	-1.16	0.68	-20.30	2.06	11.85	-4.49
88-89	-0.93	13.64	1.58	1.33	-1.38	13.53	-0.37	7.21	-0.26
89-90	-4.36	12.55	1.14	2.89	13.68	-7.92	0.52	-4.00	-5.63
90-91	10.84	-12.40	0.88	-1.70	-9.16	21.86	-1.54	6.46	7.25
91-92	-2.04	32.87	-2.23	3.54	-2.04	10.88	-1.88	-6.23	5.38
Average	0.368	5.229	0.013	0.423	0.198	4.539	-0.092	1.492	0.653
Standard deviation	5.66	26.53	2.94	5.07	6.39	25.82	1.39	17.66	5.86

Source: Own estimate.

aggregate as well as disaggregate level are presented in Table 1 & 2.

The disaggregated analysis of productivity growth shows that there exists considerable variations in TFP growth rate during both pre- and post-reforms period and aggregate variation enhanced during post-reforms periods (as aggregate standard deviations of both periods support this result). Productivity declined during post reforms period in all sub-sectors except Paint & Varnishes and Perfumes & Cosmetics. The aggregate analysis also displays declining TFP growth rate during post-reforms periods. The decline in measured productivity growth in the post-reforms period is mainly because of a steep fall in capacity utilization.

Due to heavy investment in the 1990s, the capacity of firms increased considerably, but production did not increase in the same proportion because growth in demand was sluggish. If it is possible to adjust and eliminate the effect of capacity utilization from gross productivity change, then economic reforms may have had a positive influence on productivity. A few studies, instead of directly blaming the reforms to the slowdown, have held deteriorating capacity utilization responsible. They argue that owing to the surge in investment activities in the post reforms period, unaccompanied by commensurate expansion of demand, capacity

TABLE 2
TOTAL FACTOR PRODUCTIVITY GROWTH AT AGGREGATE AND DISAGGREGATE LEVEL (POST-REFORM PERIOD)

	Organic & Inorganic chemicals	Plastic	Paint & Var-nishes	Drug & Medicine	Perfumes & Cosmetics	Man made fibre	Explosive chemicals	Photo-chemical films	Aggregate
1991-92	-2.04	32.87	-2.23	3.54	-2.04	10.88	-1.88	-6.23	5.38
92-93	-0.12	-33.49	1.22	-7.76	-11.62	-23.08	6.46	-0.18	-3.94
93-94	-6.45	26.28	-3.90	3.52	7.96	7.15	-9.32	-4.55	-1.43
94-95	0.72	-12.81	6.56	-1.90	1.84	-1.81	6.30	8.74	-6.13
95-96	4.28	0.19	-6.27	4.37	6.37	6.11	1.84	-2.33	-0.04
96-97	-0.84	18.07	4.48	-2.13	-4.32	-1.24	1.82	-1.20	14.43
97-98	-1.00	-14.56	-1.12	8.07	-5.90	3.40	-7.35	-1.39	-9.23
98-99	5.24	11.06	-7.36	-15.09	13.64	-2.06	-2.58	9.99	8.03
99-2000	-4.96	-2.30	5.43	14.43	-8.49	1.78	9.78	-14.15	0.49
2000-01	-3.74	-3.90	9.26	-6.35	-2.70	0.40	-7.07	21.35	3.42
2001-02	10.34	4.91	-10.35	1.73	3.29	-2.86	3.12	-16.55	-9.77
2002-03	-8.29	-1.13	7.80	-2.39	6.41	4.34	-3.03	7.70	1.44
2003-04	-0.54	-1.12	-7.13	1.93	-6.55	-22.09	2.18	-1.69	-6.85
average	-0.572	2.099	0.293	0.003	0.370	0.251	-0.159	0.100	0.221
Standard deviation	5.03	17.61	6.54	7.45	7.42	10.21	5.83	10.15	7.05

Source: Own estimate.

utilization went on worsening in the manufacturing industry, adversely affecting the productivity growth (Uchikawa 2001; Goldar and Kumari 2003).

Market reforms — trade and capital market liberalization, privatization, elimination of price control, liberalization of labour and other markets — have the vital instruments in increasing the rewards to all forms of capital. After liberalization initiated since 1991, investment-specific technological change resulted in the drastic reductions in the relative price of new capital goods in two distinct ways. First, the embodiment of new technologies in successive vintages of equipment permitted an increase in the efficiency of capital but without a proportional increase in its cost. Second, the higher rate of disembodied technological change in the sector allowed a reduction in the relative price of non quality-adjusted units of capital goods. As a result, real investment grew at a noticeably higher rate than real consumption.

New vintage of capital are often associated with the latest and best techniques of production. Productivity growth can be influenced by the quality of capital investment to which it embodies the latest technology.

New investment allows firms to replace ageing capital stock with new capital stock that embodies new technology and that is generally more efficient. This implies that factors such as capital obsolescence and ageing of capital stock which influence the efficiency of capital are important determinants of TFP growth.

The downturn of the economy initiated with the balance of payment crisis in 1990 adversely affecting the economy in 1991 and comparatively high cost of import of capital goods during initial phase of liberalization made capital replacement much more difficult. This led to a predominance of old inefficient capital stock in the capital structure mix of the industry. Another factor that affects capital obsolescence is due to the high rate of capital accumulation in the initial phase of liberalization with the expectation of enormous prospective earnings from the project. This was carried out without due consideration for productivity and the appropriateness of the acquired capital equipment of the industry. Anorther related factor is the low capacity utilization of the existing capital. Although it is true that there is no precise way of distinguishing the various factors that contributed to declining utilization rate, a shift from a restrictive trade regime to a more liberalized trade perhaps decelerates the utilization rate because it might be mainly due to gradually rapid and abrupt expansion of capacity but comparatively slow improvement in the growth rate of actual output as well as actual demand. Capacity has been expanded rapidly because licensing requirement for capacity creation has been abolished coupled with private players being come into operation for creation of additional capacity.

Therefore, dramatic import liberalization in forms of removal of quantitative restrictions on capital goods as well as consumer goods, gradual tariff reduction initiates certain type of capital obsolescence resulting deceleration of TFP growth during post 90s. This means that easier and cheaper access to improved foreign technology has led to adaptation and incorporation of improved technology from modern capital good sector abroad instead of domestic capital equipments which initiates one form of domestic capital obsolescence.

During the highly regulated environment, India was mainly a producer of Basic Chemicals. In the protected regime, licensing and import tariffs ensured that the firms did not face much competition from within as well outside India, the firms in India were small scale ones as compared to the world. However, after liberalization and advent of large-scale MNCs in Indian markets, the firms are now facing high degree of competitive pressure from within as well as outside India, persuading them to investment on newer and/or better technology so as to remain competitive. Though investing in in-house R&D to widen more efficient process technologies for production has been one of the technological strategies, in spite of encouragement given to firms in the form of tax reductions for R&D investments by the Indian government, the amount spent by Indian firms on R&D is hardly anything compared to the world players (Siddharthan and Pandit 1998). Moreover, Indian chemical industry is generally characterized by diversity of products and producers where technology diffusion may have been slower. Therefore, sluggish technology diffusion may lead to declining TFPG in Indian chemical industry. On the other hand, balance of payment crisis that initiated during early 90s may have impacted TFPG adversely in this sector.

The technical progress in developed nations is generally thought to be associated with capital accumulation rather than labour. Capital accumulation is considered to be the main ingredients of growth, but in a developing country like India, it suffers from paucity of capital, and their adaptation to newer technology becomes slower initially. This part tries to analyze the picture regarding capital, employment, and output growth in the context of Indian chemical industry.

Table 3 depicts that overall long-term growth of 7.61% in output in Indian chemical industry during 1980-81 to 2003-04 is associated with rapid growth of capital (7.33% per annum). Comparing the annual growth rate of pre-reform period (1979-80 to 1991-92) with that of post-reform period (1991-91 to 2003-04), it is evident that there is a decrease in the growth rate of output from 8.04% in pre-reform period to 6.85% in post-reform period.

It is evident that the revival of growth in output in post 90s was not possible by adequate generation of employment in this sector. Productivity of capital decreased from 1.07% to -0.05% along with that of labour productivity which shows slight decline from 6.57% to 5.10% during these two time frames. These changes were reflective of a slight decrease in the rate of growth of capital intensity. The growth in the rate of capital investment is negatively associated with the growth rate of TFP. This implies that increase in the rate of investment of the industry has led to marked decline in the efficiency in the production. The analysis also shows that the decrease in the growth rate of output as is evident from the Table 3 is also accompanied by a decrease in the productivity.

Table 4 shows the relative contribution of TFP growth and factor input growth for the growth of output during 1979-80 to 2003-04.

TABLE 3

GROWTH RATE OF VALUE ADDED, CAPITAL, EMPLOYMENT, PARTIAL AND TOTAL FACTOR PRODUCTIVITY IN INDIAN CHEMICAL INDUSTRY (%)

Growth rate	1980-81 to 2003-04	1980-81 to 1991-92	1991-92 to 2003-04
Output	7.61 (7.78)	8.04 (6.67)	6.85 (4.38)
Capital	7.33 (6.05)	6.94 (4.34)	7.84 (4.63)
Employment	1.81 (0.65)	1.47 (0.23)	2.39 (-0.81)
Material productivity	3.07 (1.49)	1.67 (1.23)	4.59 (1.61)
Capital productivity	0.34 (1.64)	1.07 (2.23)	-0.05 (-0.23)
Labour Productivity	5.71 (7.09)	6.57 (6.43)	5.10 (5.24)
Capital intensity	5.58 (5.36)	5.52 (4.11)	5.50 (5.48)
Total factor productivity growth	-0.07 (1.24)	0.65 (1.53)	-0.32 (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.

Observing the growth path, it is apparent that TFP growth contribution is either negative or insignificant across the entire time frame. 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 chemical industry was fundamentally dominated by factor accumulation resulting input-driven growth. With regard to the sources of output growth, it was found that much of the growth in output had come from material, capital followed by labour inputs, and productivity. The low contribution of productivity can be attributed mainly to the heavy decline in capacity utilization following the 1990s reforms as a result of a time lag between investment and output growth.

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

Period	Output growth	Contribution of Input growth	Contribution of TFPG
Phase 1 (1980-81 to 1985-86)	7.29	7.64 (104.80%)	-0.35 (-4.80%)
Phase 2 (1986-87 to 1991-92)	8.06	6.4 (79.40%)	1.66 (20.60%)
Phase 3 (1992-93 to 1997-98)	9.15	11.04 (111.59%)	-1.06 (-11.59%)
Phase 4 (1998-99 to 2003-04)	5.20	5.74 (110.38%)	-0.54 (-10.38%)
Entire pre-reform period (1980-81 to 1991-92)	8.04	7.39 (91.92%)	0.65 (8.08%)
Entire post-reform period (1991-92 to 2003-04)	7.68	8.0 (104.17%)	-0.32 (-4.17%)
Entire period (1980-81 to 2003-04)	7.61	7.68 (100.92%)	-0.07 (-0.92%)

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

V. Factors Affecting Total Factor Productivity

A. Econometric Modeling of Liberalization

The process of liberalization can be linked to the manufacturing productivity. With the initiation of a wide range of economic reforms by the India Government 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. Nevertheless, a dummy variable approach has been taken in the econometric framework to distinguish between the pre- and post-reform periods.

In order to understand the impact of liberalization on total factor productivity more precisely, we use a piecewise linear regression equation (popularly known as Spline function) where it is assumed that TFPG increases linearly with the passage of time until the threshold time period (t_0) [Here, t_0=1990-91 being last year of pre-reform period after which post-liberalization era begins] after which also it changes linearly with the passage of time but at a much steeper rate. Therefore, we have a piecewise linear regression consisting of two linear pieces or segments. The TFPG function changes it slope at the threshold value (t_0= 12). Given the data on TFPG, time period and the value of threshold level, the technique of dummy variables can be used to estimate the slopes of the two segments of the piece-wise linear regression. The piecewise linear regression equation is as follows:

$$Ln\ Z_t = a + b_1 t + b_2 (t - t_0) Dt \tag{3}$$

Where Z_t is TFP. Dt is the dummy variable with value equal to zero for the years up to 1990-91 and one thereafter.

Result of the regression equation is as follows:

$$Ln\ Z_t = -0.0084 - \underset{(-0.58)}{0.003t} - \underset{(-2.89)}{0.007(t - t_0)Dt}$$

$$R^2 = 0.54,$$

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 −0.007), 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. The study is different from the others in that the productivity is undertaken at the industry level rather than firm level. More significantly, an effort has been made in the econometric framework of our study to incorporate explicitly the variables that represent trade liberalization.

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.

B. Factors Determining TFP Growth

The basic empirical framework employed in this study is based on a simple model of TFPG.

$$\mathrm{TFPG}_t = \alpha' + X_{it}\beta + \mu_t$$

Where TFPG 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:

$$\begin{aligned}\mathrm{TFPG} = {} & \alpha' + \beta_1\mathrm{EXPOR} + \beta_2\mathrm{IMPEN} + \beta_3\mathrm{GO} + \beta_4\mathrm{TAR} + \beta_5\mathrm{TOT} + \beta_6\mathrm{INFL} \\ & + \beta_7\mathrm{CU} + \beta_8\mathrm{IFM} + \mu_t\end{aligned} \tag{4}$$

Since there exists correlation between error terms and explanatory variables, a simple OLS will lead to inconsistent estimate of the regression model. As is well known in the trade literature, every measure of openness raises the issue of endogeneity of variables. The running of Equation (4) with OLS would give us biased coefficient estimates which might be coming from endogeneity of the trade policy variables. As a result, total factor productivity growth might as well affect the trade policy variables. Another problem associated with the right-hand side variables may be measurement error which arises from correlation between right-hand side variables and error terms. Krishna and Mitra (1998) show that in the presence of correlation between right-hand side variables and error terms, the coefficient estimates will be biased upward. To remove the endogeneity problem, lack of good instrumental variables in the literature and in the data set used in the study leaves us running two stage least square technique (TSLS), with one period lagged variables of original trade policy variables as instruments.

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. Inflation is defined as the change in the change in the consumer price

TABLE 5
DESCRIPTIVE STATISTICS FOR TFP VARIABLES

Variable	Definition	Mean	Standard deviation	Minimum	Maximum
EXPOR	Export-output ratio	0.116	0.078	0.02	0.29
IMPEN	Import-penetration	0.151	0.030	0.09	0.22
GO	Growth-in output	7.61	8.38	-13.52	30.04
TAR	Tariff rate	27.08	10.43	11.62	49.19
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	1.063	0.186	0.66	1.49
IFM	Investment in fixed assets	12.55	9.97	-9.42	31.61
N	Number of periods	26			

TABLE 6
PEARSON CORRELATION

	EXOUT	IMPEN	GO	TARIFF	TOT	INFLATION	CU	IFM
EXOUT	1.000	0.557	-0.150	-0.699	-0.355	-0.449	-0.062	-0.355
IMPEN	0.557	1.000	0.024	-0.709	-0.294	-0.159	-0.477	-0.344
GO	-0.150	0.024	1.000	0.056	0.261	0.468	0.326	0.483
TARIFF	-0.699	-0.709	0.056	1.000	0.219	0.255	0.369	0.318
TOT	-0.355	-0.294	0.261	0.219	1.000	0.188	0.121	0.184
INFLATION	-0.449	-0.159	0.468	0.255	0.188	1.000	0.233	0.274
CU	-0.062	-0.477	0.326	0.369	0.121	0.233	1.000	0.415
IFM	-0.355	-0.344	0.483	0.318	0.184	0.274	0.415	1.000

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 as depicted in Appendix A-3. IFM is the ratio of recent investment in fixed machinery (used as proxy of technology acquisition) to the existing fixed capital stock. Table 5 contains the descriptive statistics of the key variables used in the estimation procedure.

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 weakly correlated with each other. Also, we have tested multicollinearity.

TABLE 7
COLLINEARITY STATISTICS

	Tolerance	VIF
EXOUT	0.289	3.462
IMPENTRA	0.351	2.851
GO	0.514	1.947
TARIFF	0.328	3.052
TOT	0.781	1.280
INFLATIO	0.592	1.688
CU	0.472	2.120
IFM	0.588	1.700

Dependent Variable: TFPG.

When independent variables are highly correlated in a multiple regression analysis, it is difficult to identify the unique contribution of each variable in predicting the dependent variable because the highly correlated variables are predicting the same variance in the dependent variable. Some statisticians says correlations above 0.70 indicate multicollinearity and others say that correlations above 0.90 indicate multicollinearity. Multicollinearity is assessed by examining tolerance and the Variance Inflation Factor (VIF) which are two collinearity diagnostic factors that can help to identify multicollinearity. If a low tolerance value is accompanied by large standard errors and no significance, multicollinearity may be an issue. The variable's tolerance is indicated by $1-R^2$. A small tolerance value indicates that the variable under consideration is almost a perfect linear combination of the independent variables already in the equation and that it should not be added to the regression equation. The Variance Inflation Factor (VIF) measures the impact of collinearity among the variables in a regression model. The Variance Inflation Factor (VIF) is 1/Tolerance, it is always greater than or equal to 1. There is no formal VIF value for determining presence of multicollinearity. A commonly given rule of thumb is that multicollinearity exists when Tolerance is below 0.1 and values of VIF that exceed 10 are often regarded as indicating multicollinearity. When those R^2 and VIF values are high for any of the variables in regression model, multicollinearity is probably an issue.

Sometimes, eigen values, condition index, and condition number will be referred to when examining multicollinearity. We take into consideration the condition number which is equal to condition index with highest value which is also equal to square root of the largest eigen value di-

TABLE 8
ESTIMATION OF TFPG DETERMINANTS BY
TWO STAGE LEAST SQUARE (TSL) TECHNIQUE

Explanatory variables	Regression result		
	coeffcient	SE	t ratios
EXPOR	1.26	0.610	2.066
IMPEN	-0.1995	0.066	-3.015
GO	0.960	0.396	2.425
TAR	0.797	0.368	2.164
TOT	-0.269	3.24	-0.083
INFL	4.41	1.39	3.168
CU	-0.159	0.156	-1.014
IFM	-3.04	1.28	-1.370
constant	-39.10	235.54	-0.166
Adjusted R^2	0.44		

Dependent Variable: TFP Growth Rate.

vided by lowest eigen value. An informal rule of thumb is that if the condition number is 15 or more, multicollinearity is a concern and if it is greater than 30, multicollinearity is very serious concern.

From our analysis to test whether there exists multicollinearity, it is found that correlations among independent variables are moderate which do not exceed the general rule of thumb. Moreover tolerance for these variables are moderately high which also are beyond the specified minimum ceiling (0.10) and VIFs do not exceed the specified rule of thumb of 10. The condition number is 13.964 which is also within the range. This indicates that multicollinearity is not at a issue of concern in this study.

Our empirical result from TFP growth equation (Table 8) suggests that export has a significant positive effect on TFP growth since coefficients in almost all the models are positive and significant implying that exports contribute significantly to TFP growth in Indian chemical industry. This may probably be a generalized notion that exports are beneficial for a developing economy like India because exploiting economies of scale, enhancing foreign exchange earning, accelerated economic growth can be made possible through export.

Import penetration ratios are expected to affect productivity positively if industries lower costs and become more efficient when import competition increases (Fernandez 2003). A negative correlation may arise because some import competing industrial sectors attract imports by being relatively less productive. 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 one percent increase in the import penetration ratio would decrease total factor productivity by 0.20 percent. A significant negative relationship between output growth and TFP growth is evident from our analysis which indicates that with the growing degree of output, productivity is gradually declined. The tariff variables are significant and positive in the equation suggesting that increase in tariff would increase TFP growth of domestically produced import substitutes. Role of inflation in growth is controversial among theorists and policy makers on several occasions which is 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.

Our result shows that it holds statistically significant and positive results. A negative relation is found between CU and TFP growth which implies that trade openness induces domestic manufacturers of chemical to utilize capacity to the fullest possible in order to enhance TFP but as a result productivity declines. Growth in investment in fixed machinery and equipment has insignificant negative impact total factor productivity growth.

VI. Total Factor Productivity Growth after Adjusting Capacity Utilization

Economic activity fluctuates over the business cycle, periods of high demand alternates with downturns in demand. Capital stocks are hard to adjust rapidly, so periods of low demand are typically periods of low capital utilization. A residual calculated using capital stock data thus fluctuates procyclically along with the rate of utilization. These fluctuations tend to obscure the movements in the longer run components of the residual and make it hard to distinguish significant break in trends. It has long been recognized that the existence of temporary equilibrium which is connected with the business cycle, can bias measured productivity growth away from its long run path. Earlier researchers have attempted to a variety of cyclical adjustments in order to take account of variations in the utilizations of stocks of factors of production. Some, like Norsworthy, Harper, and Kunze (1979), select time intervals for which the capacity utilization is widely believed to be nearly one which is called the 'peak to peak' adjustment method. Jorgenson and Griliches (1967) adjust for the variation in capital utilization using the relationship between electricity consumption and the horse power rating of electric motors. Denison (1979) in a number of studies uses variations in capital's share of income. These adjustment procedures have been controversial primarily because they have appeared to be ad hoc as well as not theoretically motivated. Unfortunately, the process that generates the data is unknown and it is difficult to assess the validity of such adjustments.

This section estimates how TFPG measure may be changed with the variation in capacity utilization. If measured productivities are influenced by cyclical movements like capacity utilization, it is desirable to control for cyclical bias in the productivity measure. To address this problem, we follow the method suggested by Basu and Kimball (1997) and Ball and Moffitt (2001). This first step in this method is to regress the log difference (natural log) of the measured productivity on the log difference of the capacity utilization rate, which is a proxy for business cycle. The next step is to adjust the average of the regression error term so that it equals the original productivity measure when the productivity measure is adjusted for cyclical factors. The purpose of adjusting TFP is to eliminate any error that may exist in the total factor productivity measure in order to represent original productivity (unadjusted total factor productivity minus error terms)

$$\Delta Ln\ \mathrm{TFP}_t = a + b\Delta\ Ln\ \mathrm{CU}_{t-1} + u \tag{5}$$

The result of the regression is as follows:

$$\Delta Ln\ \mathrm{TFP}_t = -0.00242 - 0.0276\Delta\ Ln\ \mathrm{CU}_{t-1} + u$$
$$(-2.34)$$

Where CU is economic capacity utilization (methodology for measuring CU is shown in Appendix A-3) and t statistics are given in the parenthesis. Durbin-Watson$=2.93$, $R^2=0.52$.

TABLE 9
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	0.653	-0.29
Post-reform period *i.e.*, 1991-92 to 2003-04	-0.323	-0.20
Entire period *i.e.*, 1980-81 to 2003-04	-0.073	-0.27

Note: Growth rates for the entire period are obtained from a semi-log trend and growth rates for the sub-periods are obtained by spline function.

While capacity utilization can affect measured productivity, productivity can also affect capacity utilization. To eliminate this endogeniety problem, we include lagged value of the capacity utilization rate as explanatory variable in the regression.

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

Rate of changes in CU are found to be negatively 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 negative effect on TFPG rate. With the adjustment of capacity utilization, negative growth rate of TFP (-0.29%) in 80s becomes smaller and displays a further noticeable deceleration in growth rate in TFP (-0.20%) in 90s, and CU adjusted TFPG sharply declined during the entire time frame on an average (-0.27).

On the contrary, it is found from the comparison between pre- and post-reform period that difference in average annual growth rate between pre-reform (1980-81 to 1991-92) and post-reform period (1991-92 to 2003-04) becomes smaller after incorporating effect of CU into TFP growth calculation; while unadjusted translog measure implies a abrupt slowdown of -0.976% (-0.323% minus 0.653%), capacity adjusted TFPG measure suggest decline of 0.09% (-0.20% minus -0.29%) following trade reform. In a nut shell, inspection of entries in Table 9 reveals that removal of cyclical effect from the estimated TFP growth does not affect its overall movement but remarkably mitigates its variation because variations between sub-periods are smaller after adjusting capacity utilization as cyclical factors.

VII. Nature of Competition

Despite competitiveness of a firm can be judged in view of concentration ratio a firm in an industry occupies during a particular period of time, it is not the reliable parameter in evaluating competitive scenario as because the position of the firms in the industry may have variations keeping concentration ratio same.

Ijiri and Simon (1977) elucidate that a frequent and sizeable change in the ranks of the firms in an industry would indicate vigorous competition in the industry. On the other hand, if the ranks do not change frequently, it is an indication of little competition. To understand the intensity of competition, in view of Baldwin, R. John (1998), frequent changes in relative firm's position in the industry explicitly indicates the prevalence of intense competition.

Ijiri and Simon suggest a measure of competition which is based on the relative ranks of firms at two different point of time. The initial and terminal period for the analysis of competition are considered. This measure is termed as the standard duration of $q_i = r_i / r_i^*$, where r_i is the rank at the end of a period and r_i^* is the rank at the beginning of the period. The standard deviation of q is an indicator of the average amount of shifting in rank[3] during the period. Within the post-liberalized time frame of 1991-92 to 2003-04, effort done by Ijiri and Simon (1977) has been adopted for 15 firms in chemical sector for the two consecutive years at the beginning, 1990-91 and 1991-92 as well as at the end, 2002-03 and 2003-04. Thereafter, standard deviations of relative ranks have been estimated using Ijiri-Simon Index method for the terminal points to have an insight into the mode of competition. It is evident from Table 4 that out of 15 firms in chemical industry, average shifting has come down in 8 firms which indicate that competition has declined. In two firms (soap, paint & varnishes), average shifting remains same between these two time periods and in remaining 5 firms, average shifting has increased implying increase in competition. Decline in competition varies from 14% to 132% where as increase in competition fluctuates from 14% to 316%. The highest decline in average shifting occurs

[3] Rank shifting has been judged in view of top 5 companies' sales performance within each and every firm of Indian chemical industry.

TABLE 10

IJIRI-SIMON INDEX OF COMPETITION

Industry's Sub-Sectors (1)	Standard Deviation of Relative Rank		% Change (4)
	1991-92/1990-91 (2)	2003-04/2002-03 (3)	
Soap	0.1428 (4.5)	0.1428 (6.5)	-
Printing Ink	0.5173 (10)	0.2657 (10.5)	-48.64
Paint & Varnishes	0 (2)	0 (3)	-
Dyes & Pigments	0.1444 (6)	0 (3)	-14.44
Pesticide	0.6755 (13)	0.5888 (13)	-12.83
Mixed Fertilizer	1.7309 (15)	0.4767 (12)	-72.46
Drug & Pharmaceuticals	0 (2)	0.1428 (6.5)	14.28
Benzene	0.3813 (8)	0 (3)	-38.13
Soda Ash	0 (2)	0.2657 (10.5)	-26.57
Urea	0.4766 (9)	0 (3)	-47.66
DAP	1.3178 (14)	0 (3)	-131.78
Phos. Fertilizer	0.5456 (12)	1.7257 (15)	316.29
Caustic Soda	0.3005 (7)	0.1845 (8)	-38.60
Calcium Carbide	0.5308 (11)	1.4577 (14)	174.62
Sulpheuric Acid	0.1428 (4.5)	0.2529 (9)	77.10
Average	0.4604	0.3669	

Source: Own estimate.

* Figures in the parenthesis indicate respective rank order. $r = 0.41$

in DAP and lowest decline in Dyes and Pigments. At the same time, highest increase in average shifting occurs in Phosphoric Fertilizer and lowest increase in Drug and Pharmaceuticals. The above analysis of competition compels us to conclude that pattern of increase/decrease in competition varies among firms within the said industry. We have a rank correlation of 0.41 between average shifting at the two end points which suggests that position of various firms in chemical industry with regard to competition seems to have no significant change.

This is because of the fact that this particular industry is operated with assured margins, protected against the emergence of competition from within India through licensing or from across the boarders through high import tariff which keep Indian chemical industry outside the purview of competition. Average rank shifting for the entire industry for the two terminal periods is declining (from 0.46 to 0.37).

VIII. Summary & Conclusion

The study analyses the performance of productivity growth (both in terms of partial as well as TFP) in both pre- and post-reforms periods covering a period of 1980-81 to 2003-04. The study reflects that productivity growth in the post-reform period of 1990s declined as compared to its level during 1980s at both aggregate as well as disaggregates level. Poor capacity utilization during the 1990s, balance of payment crisis as well as sluggish technology diffusion were attributed as the main reasons. However, even after correction for capacity utilization, the result did not find trace of productivity acceleration in the 1990s. Contribution of productivity to the output growth during entire study period is found to be negligible. The results on partial factor productivity growth are largely on expected lines. Result on partial factors productivity across industry showed an exceptional growth in productivity of material but capital, labour productivity growth declines sharply. Rank shifting measure suggested by Ijiri-Simon is applied for 15 firms in chemical industry for a period of 13 years after liberalization process started. It reveals that more than 50% of the firms in the industry have shown a declining trend in competition. Rank correlation of change in rank-shifting does not show significant shift in their relative position during post reform period indicating existence of rigidity in the expansion of competition in Indian chemical industry which is also contrary to common expectation.

There is still opportunity for improving efficiency by increasing the competitiveness of domestic enterprises. The exclusive set of factors that contributed to TFP growth is investment in knowledge. Therefore, strengthening of R&D, investment in human capital is highly desirable for strong and sustainable economic growth. The latter might also help to increase the technology transfer by initiating foreign direct investment in modern technologies demanding highly skilled labour force.

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Appendix

A-1 Energy Inputs

Industry level time series data on cost of fuel of Indian chemical 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.

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, chemical industry) in proportion of its fixed capital stock reported in ASI, 1970-71.

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

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}.

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

$$\mathrm{CU}=Y/Y^{*} \tag{1}$$

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

$$\mathrm{VC}=f(P_L,\ P_E,\ K,\ Y) \tag{2}$$

Short run total cost function is expressed as

$$\mathrm{STC}=f(P_L,\ P_E,\ K,\ Y)+P_K.K \tag{3}$$

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

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

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.

$$\partial\,\mathrm{STC}/\,\partial K = \partial\,\mathrm{VC}/\,\partial K + P_K = 0 \quad (5)$$

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

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

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

In CU measurement, output is measured as real value added produced by manufacturers ($Y = P_L L + P_K.K_{-1} + P_E.E$) suitably deflated by WIP index for manufactured product (base 1981-82=100) to offset the influence of price changes. variable cost is sum of the expenditure on variable inputs ($\mathrm{VC} = P_L L + P_E.E$). Total number of persons engaged in Indian chemical 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):

$P_K^t = r_t + d_t - (P_k^* / P_k)$ 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 (P_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.

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