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Contents

Focus

On the Spatial Concentration of Unorganized Manufacturing in India in the Post-Reform Period

DILIP SAIKIA

This article examines the spatial concentration of unorganized manufacturing in India before and after economic reforms. The findings suggest that the unorganized manufacturing has been concentrated in few advanced states and the situation has not changed even after economic reforms. Though spatial concentration has declined after reforms, but it takes place not because of improvement in the position of the lagging states, rather at the cost of the leading states, and hence, the decline can't be considered as took place in the desired direction for balanced regional development. At the disaggregated industry level, the high- and medium-high technology intensive industries are highly concentrated, whereas the resource-based low-technology industries are relatively diversified across states.

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Albeit various policies to address regional disparities in industrial development in the post-independence period, the issue of balanced regional industrial development still remains in India (Saikia, 2010). The issue has acquired renewed interest in the post-reform period as the regional (income) inequality has been widening; and many scholars have argued that it (increasing regional inequality) is mainly caused by the differential growth pattern between the more and less industrialized regions (Bhattacharya and Sakthivel, 2004). While such an argument is consistent with other country-level studies, which observe that spatial inequality in industrial development is one of the major causes of spatial income inequality in most of the developing countries (Kim, 2008; Fujita et al. 1999; and Kanbur and Vanables, 2005), but it is against the neoclassical principle, which suggests that in the long run divergence is followed by convergence. The neoclassical theory argues that spatial concentration increases during the early phases of industrial development, being concentrated in metropolitan areas, and then begins to decline at some later indeterminate point. Further, the new economic geography theory argues that the post-reform regional development is likely to be more evenly balanced (Elizondo and Krugman, 1992). In this context it is pertinent to inquire about what has happened to the spatial concentration of industries in India after economic reforms initiated since 1991.

The economic reforms in India, which was mostly directed towards the industrial sector, has made large scale de-licensing of industry and changes in industrial location policies, and thereby, curtailed government's monopoly as industrial owner and location regulator. Following these policy changes there has been increased concern about the impact of reforms on spatial concentration of industries. Extensive attempts have been made in the past to examine the regional pattern of industrialization and its impact on growth and development in India. However, the existing literature provides contradictory findings on the regional pattern of industrial development in India for the pre- and post-reform periods, and thus, rarely draws any generalized conclusion (Saikia, 2010, 2011). These studies observe that inter-state disparity in the distribution of manufacturing industries has declined during the 1980s (Awasthi, 1991 and Dholakia, 1994), whereas disparity has significantly increased in the post-reform period (Chakravorty, 2003 and Lall and Chakravorty, 2005). While all these findings are for the organized manufacturing sector, there is dearth of information about the regional pattern of unorganized manufacturing sector in India (Saikia, 2010). This paper is an attempt to address this issue.

The unorganized manufacturing sector represents an important part of India's manufacturing sector. The sector occupies a dominant position compared to the organized sector in terms of its contribution to employment, output and exports. The sector, with more than 99.2 percent of manufacturing enterprises, accounted for about 80.50 percent of manufacturing employment and contributed about 25 to 30 percent of manufacturing value added and 40 percent of manufacturing exports during 1994-95 to 2005-06 (Saikia, 2010). The Eleventh Five Year Plan and the Twelfth Five Year Plan document have recognized the sector as the most potential sector for rapid employment creation, and thus, a panacea to the burgeoning labour force. In spite of such importance of the sector no attempt has been made so far to examine the regional pattern of the sector. In this paper we make an attempt to analyze the regional pattern and the degree of spatial concentration of the unorganized manufacturing sector in India. The remaining of the paper is organized in the following sections. Section 2 briefly discusses the meaning and definition of unorganized manufacturing sector in the Indian context. Section 3 discusses the data set used in this paper. Section 4 analyzes the spatial distribution of unorganized manufacturing at the regional and state levels. Section 5 examines the spatial concentration of unorganized manufacturing, and finally, section 6 sums up the findings.

Unorganized Manufacturing: Definition

The concept of the unorganized/informal sector has been a much debated issue ever since the term has been coined by Hart in 1971 and subsequently used in the International Labour Organization's report of a comprehensive employment mission in Kenya in 1972. However, it was only in January 1993 during the 15th International Conference of Labour Statisticians at Geneva that the unorganized/informal sector acquired a proper definition. According to this definition unorganized/ informal sector enterprises are those which are not only unincorporated entities without separate complete accounts but are also units of production with specific characteristics such as operating in small scales, using obsolete technology with low level of organization, etc. (CUTS, 2009). This definition, along with some added recommendations from the UN Expert Group on Informal Sector Statistics (Delhi Group) such as the criteria of legal organization, type of accounts and product destination has been used as an internationally comparable definition. However, in practice, countries have adopted their own operational definition based on national circumstances.

In the Indian context, different organizations used different definitions of the unorganized/informal sector. The National Commission for Enterprises in the Unorganized Sector (NCEUS) 2008 defines unorganized enterprises as "all unincorporated private enterprises owned by individuals or households engaged in the sale or production of goods and services, operated on a proprietary or partnership basis and with less than ten total workers" (NCEUS, 2008). The National Sample Survey Organization (NSSO) defines the unorganized manufacturing enterprises as the manufacturing/repairing enterprises other than (a) those registered under sections 2m (i) & 2m (ii) of the Factories Act, 1948 and (b) Bidi and Cigar manufacturing enterprises registered under Bidi and Cigar Workers (Condition of Employment) Act, 1966, which are covered under the Annual Survey of Industries (NSSO, 1998, 2008).

Data Source

The paper is solely based on secondary data. The principle source of data for unorganized manufacturing industries in India is the National Sample Survey (NSS) quinquennial rounds on unorganized manufacturing sector. Since the NSS data are available quinquennially, we have faced problem in selecting a data-point to represent the pre-reform period, because the 45th round of NSS survey for the year 1989-90, which could be a better representation of the pre-reform period, is not comparable with the later rounds (51st, 56th and 62nd) of survey. With no other available reliable data on unorganized industries, we have no other alternative but to select the 51st round of survey (1994-95) to represent the pre-reform period.[1] Though the 51st round of survey was conducted after three years of the initiation of reforms in 1991, and hence, may not be a proper representation of the pre-reform period, yet it will give us a picture at a very closer point of reforms. The 62nd round of survey (2005-06) has been selected to represent the post-reform period. Henceforth, whenever we refer to the pre-reform and post-reform periods they will imply the years 1994-95 and 2005-06 respectively.

The 51st and 62nd rounds of NSS data used in this paper are derived from the household (or enterprise) level data available on CD-ROMs supplied by the NSSO, New Delhi. However, these two rounds differ from each other in terms of industrial classification and coverage, which leads to a few conceptual and methodological inconsistencies. For instance, the 51st round data are based on the National Industrial Classification (NIC) of 1987, while the 62nd round data are based on NIC 2004 classification. Therefore, we have to make necessary adjustments to the industry groups under the NIC 1987, to make the industry groups comparable with the industry groups under NIC 2004. Secondly, some industrial groups such as repair services, repair of capital services, etc. are included in 51st round, but excluded in 62nd round, and some industrial groups such as cotton ginning, cleaning and baling, recycling, etc. are included in 62nd round, but excluded in 51st round. Therefore, these industrial groups have been excluded from the analysis in order to make valid comparison between the two NSS rounds.

The NSSO has classified the unorganized manufacturing sector in three enterprise types, namely own account manufacturing enterprises (OAMEs), non-directory manufacturing establishments (NDMEs) and directory manufacturing establishments (DMEs). OAMEs are the enterprises run without a hired worker on a fairly regular basis. NDMEs are the establishments employing up to six workers, at least one of them being a hired worker employed on a fairly regular basis. DMEs are the establishments employing six or more (but less than ten) workers, at least one of them being a hired worker. In the present study analysis has been carried out for all the three enterprise types.

We have selected 25 states and divided them into five meta regions: eastern region (Bihar, Orissa and West Bengal), north-western region (Delhi, Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab and Uttar Pradesh), central region (Gujarat, Maharashtra, Madhya Pradesh and Rajasthan), southern region (Andhra Pradesh, Karnataka, Kerala and Tamil Nadu) and north-eastern region (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura).[2] To tackle the comparability problem arises because of the reorganization of state boundaries between the two time points; we have merged Jharkhand with Bihar, Chhattisgarh with Madhya Pradesh and Uttarkhand with Uttar Pradesh.

Spatial Distribution of Unorganized Manufacturing

At this juncture it is worthwhile to analyze the spatial distribution of unorganized manufacturing industries. This will provide a clear understanding about the location pattern of these industries across geographical units. We analyze the spatial distribution of unorganized manufacturing by looking at the share of the regions/states in total employment and gross value added at two geographical scales - region and state. We also consider per-capita gross value added to address the problem.

Inter-Regional Distribution

The distribution of unorganized manufacturing industries in terms of employment and gross value added across the five regions is reported in Table 1. It is apparent that while the eastern region is the leading region in terms of

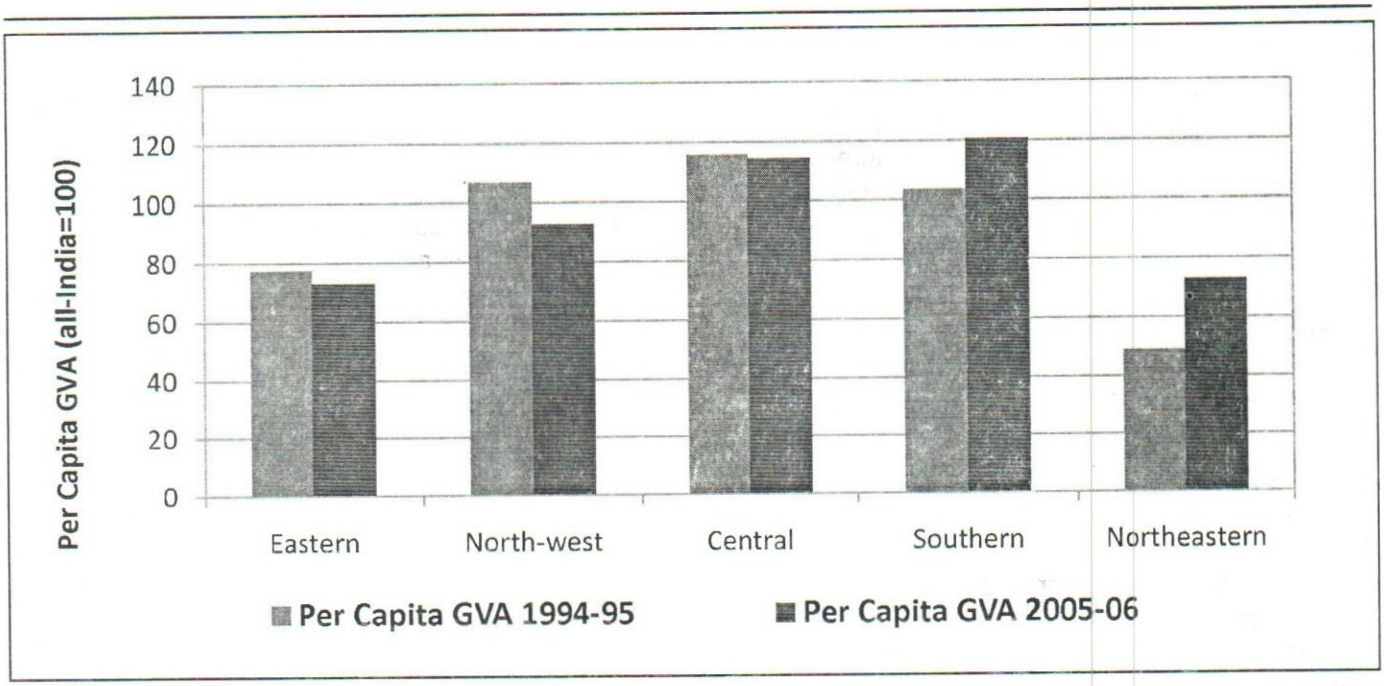
Table 1: Percentage Share of the Regions in Employment and Gross Value Added of Unorganized Manufacturing

Regions	Employment		Gross Value Added	
	1994-95	2005-06	1994-95	2005-06
Eastern Region	31.18	27.25	17.05	16.09
North-West Region	22.50	20.62	25.55	22.86
Central Region	19.01	22.63	31.80	31.93
Southern Region	24.36	26.56	23.16	25.67
North-Eastern Region	2.73	2.71	1.87	2.73
All-India	100.00	100.00	100.00	100.00

Source: Author's computation using NSS unit level data on Unorganized Manufacturing Sector.

[1] See Saikia (2010) for a discussion on the comparability issues of the 45th round of NSS survey and on the justification for selecting 51st rounds of NSS survey (1994-95) to represent the pre-reform period.

[2] These 25 states accounted for more than 99.50 percent of India's total population and geographical area as per 2001 Census. Further, they accounted for more than 99.5 percent of unorganized manufacturing enterprises, employment and gross value added in 2005-06. Thus, our sample is a better representation of the country as a whole.



Source: Same as Table 1.
Note: The per-capita gross value added (GVA) figures are relative to all-India=100.

Figure 1: Per-Capita Gross Value Added from Unorganized Manufacturing across Regions

employment, the region is lagging in terms of gross value added for both the periods. On the other hand, the central region, which accounted the least share in employment, is the leading region in terms of gross value added. The other two major regions- north-west and southern regions- have accounted around one-fifth and one-fourth of national total respectively in both the variables. Thus, a clear mismatch is apparent between the eastern and central regions' shares in employment and gross value added, which could probably be explained by productivity differentials between the two regions and the industrial structure in terms of types of enterprises and industry mix.

The decline of eastern region and rise of southern region in the post-reform period is appeared as one of the intrinsic patterns of change in location of unorganized manufacturing. The eastern region has experienced continuous decline in terms of both employment and gross value added after reforms. As we will see in the next section, the two eastern states Bihar and Orissa have individually contributed to this decline, whereas the share of West Bengal has increased in both the variables. On the other hand, the success of the southern region is accompanied by all the states but Karnataka's net gain in employment and all states but Tamil Nadu's net gain in gross value added as well as increases in the per-capita gross value added in the post-reform period. A similar situation is evident in terms of share of the regions in gross value added (Table 1) and per-capita gross value added (Figure 1).

Contrary to the distinct location patterns of these two regions, the other regions have experienced somewhat mixed result. For instance, the central region has gained in terms of both the variables, whereas the north-west region Delhi and Uttar Pradesh have lost significantly, whereas Haryana, Jammu & Kashmir and Punjab have marginally gained in terms of both the variables (Table 2).

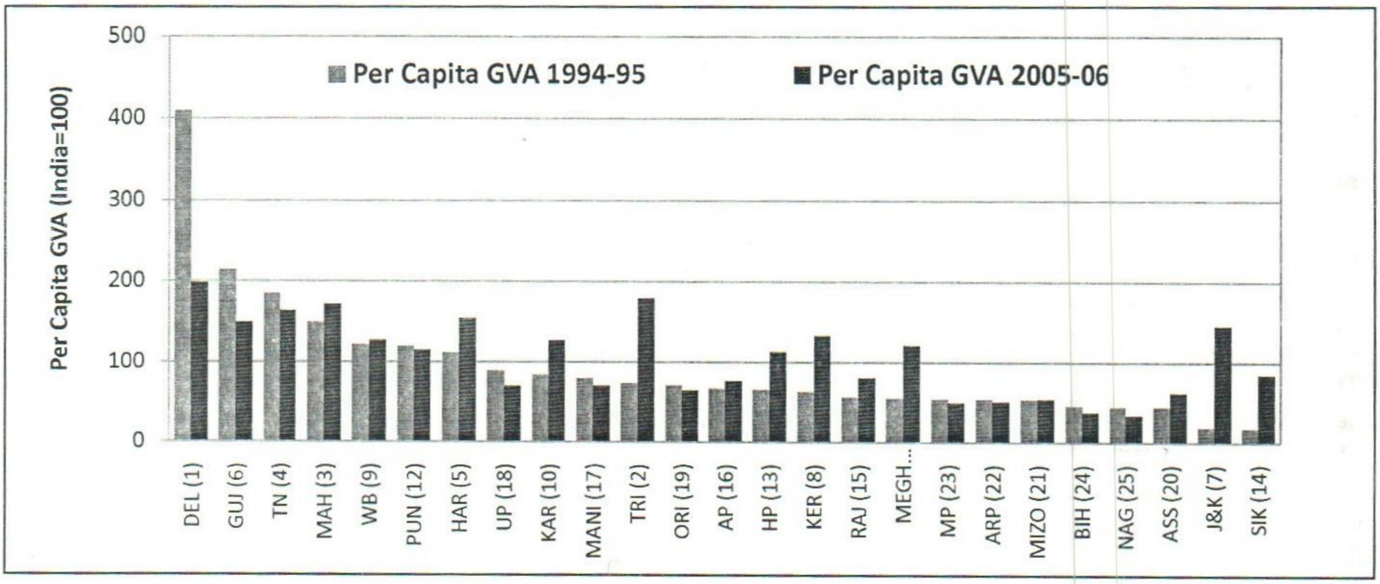
Inter-State Distribution

In India, states are considered as the standard unit of analysis for regional studies over the years. In this section we will analyze the distribution of unorganized manufacturing at the state level. It is apparent that Maharashtra, Gujarat, Tamil Nadu, Delhi and West Bengal have appeared as the leading states by registering considerably above the all-India average in terms of per-capita gross value added for both pre- and post-reform periods (Figure 2). Their combined share accounted for around 50 percent of gross value added and 38 percent of employment in 1994-95, which by 2005-06, drastically

Table 2: Percentage Share of the States in Employment and Gross Value Added of Unorganized Manufacturing

States	Employment		Gross Value Added	
	1994-95	2005-06	1994-95	2005-06
Eastern Region				
Bihar	7.41 (6)	6.60 (6)	4.78 (8)	4.04 (9)
Orissa	9.92 (3)	5.56 (8)	2.60 (13)	2.27 (15)
West Bengal	13.85 (2)	15.09 (1)	9.67 (5)	9.79 (3)
North-West Region				
Delhi	2.11 (12)	1.26 (16)	5.08 (7)	2.81 (13)
Haryana	0.88 (16)	1.49 (15)	2.23 (14)	3.22 (12)
Himachal Pradesh	0.46 (17)	0.45 (18)	0.39 (17)	0.66 (18)
Jammu & Kashmir	0.21 (20)	0.87 (17)	0.18 (19)	1.44 (17)
Punjab	1.39 (15)	1.65 (14)	2.84 (12)	2.70 (14)
Uttar Pradesh	17.45 (1)	14.9 (2)	14.83 (1)	12.03 (2)
Central Region				
Gujarat	5.75 (8)	5.08 (10)	10.51 (4)	7.37 (5)
Madhya Pradesh	3.72 (10)	6.03 (7)	4.26 (10)	3.96 (11)
Maharashtra	7.09 (7)	7.96 (5)	14.01 (2)	16.12 (1)
Rajasthan	2.45 (11)	3.56 (12)	3.02 (11)	4.48 (8)
Southern Region				
Andhra Pradesh	7.62 (5)	8.07 (4)	5.09 (6)	5.54 (7)
Karnataka	5.63 (9)	5.42 (9)	4.38 (9)	6.46 (6)
Kerala	2.10 (13)	3.82 (11)	2.04 (15)	4.02 (10)
Tamil Nadu	9.01 (4)	9.25 (3)	11.65 (3)	9.66 (4)
North-Eastern Region				
Arunachal Pradesh	0.03 (23)	0.01 (25)	0.06 (23)	0.05 (23)
Assam	1.86 (14)	1.74 (13)	1.16 (16)	1.61 (16)
Manipur	0.23 (19)	0.22 (21)	0.17 (20)	0.15 (21)
Meghalaya	0.13 (21)	0.25 (20)	0.15 (21)	0.37 (20)
Mizoram	0.03 (24)	0.03 (23)	0.04 (24)	0.05 (24)
Nagaland	0.06 (22)	0.04 (22)	0.08 (22)	0.06 (22)
Sikkim	0.00 (25)	0.02 (24)	0.01 (25)	0.04 (25)
Tripura	0.39 (18)	0.40 (19)	0.20 (18)	

Source: Same as Table 1.
Note: Figures in the parenthesis represent the relative rank of the states.



Source: Same as Table 1.

Notes:

1. The per-capita gross value added (GVA) figures are relative to all-India=100.
2. States are arranged according to their rank in 1994-95. Figures in the parenthesis with the name of the states represent the rank of the states in 2005-06.
3. The abbreviations used for the states are: AP-Andhra Pradesh, ARP-Arunachal Pradesh, ASS-Assam, BIH-Bihar, DEL-Delhi, GUJ-Gujarat, HAR-Haryana, HP-Himachal Pradesh, J&K-Jammu & Kashmir, KAR-Karnataka, KER-Kerala, MP-Madhya Pradesh, MAH-Maharashtra, MANI-Manipur, MEGH-Meghalaya, MIZO-Mizoram, NAG-Nagaland, ORI-Orissa, PUN-Punjab, RAJ-Rajasthan, SIK-Sikkim, TN-Tamil Nadu, TRI-Tripura, UP-Uttar Pradesh, WB-West Bengal.

Figure 2: Per-Capita Gross Value Added from Unorganized Manufacturing across States

declined in terms of gross value added (45.75 percent), while marginally increased in terms of employment (38.6 percent). Individually Gujarat and Delhi have significantly lost their share in both employment and gross value added, while Maharashtra and West Bengal have gained marginally in both the variables, and Tamil Nadu lost in gross value added and gained in employment. We can see more or less a similar story in terms of per-capita gross value added also.

The data presented in Table 2 and Figure 2 clearly discerns the states that have gained their share after reforms: West Bengal, Haryana, Jammu and Kashmir, Rajasthan, Andhra Pradesh, Karnataka, Kerala and Assam, and the states that have lost: Bihar, Orissa, Delhi, Uttar Pradesh and Gujarat. Despite such significant gains and losses of different states, there has been barely any change in their relative positions after reforms compared to pre-reform period.[3] To test this, we have computed the coefficients of rank correlation of shares of the states in unorganized manufacturing between 1994-95 and 2005-06. The coefficients are worked out to be fairly high at 0.966 in terms of employment and 0.958 in terms of gross value added, and they are significant at 1 percent level of significance, which implies that the relative ranks of the states remained unchanged before and after reforms.

Another interesting facet of the location pattern of unorganized manufacturing in India is the clustering of the backward states. There are at least two such clusters. The first one is the clustering of BIMARU states (Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh) together with Orissa. Though these states together accounted for 35 to 40 percent of employment and 25 to 30 percent of gross value added,[4] the per-capita gross value added from unorganized manufacturing of these states is far below

[3] It is easy to identify the states that have significantly improved their relative ranks: Madhya Pradesh in employment (from 10th to 7th) and Kerala in gross value added (from 15th to 10th); and the states which have lost their relative ranks: Orissa in employment (from 3rd to 8th) and Delhi in gross value added (from 7th to 13th).

[4] This high share is mainly because of large geographical size of these states. These states together accounted for 35 percent of country's total geographical area and 39.5 percent of total population as per 2001 census.

the national average. The other cluster is the group of eight north-eastern states. The north-eastern states with less than 3 percent share in total unorganized manufacturing employment and gross value added are out-performed over the years and the situation has not changed even after reforms. Further, excluding Assam the situation of the other north-eastern states is more pitiable for both the pre- and post-reform periods.

Spatial Concentration of Unorganized Manufacturing

The tabular data and graph presented in the previous section can't explain the degree of spatial concentration of these industries. Therefore, in this section we will employ spatial concentration measures to examine the degree of spatial concentration of unorganized manufacturing across the states. Let us start with a brief discussion on the concept and measures of spatial concentration.

Concept and Measures of Spatial Concentration

The term spatial concentration refers to the extent to which a given industry is concentrated in a few geographical units. Sometimes the terms spatial concentration, agglomeration and clustering are used synonymously, though they are fundamentally different. Agglomeration, in general, refers to the geographic concentration of economic activity as a whole (for instance industry, agriculture, etc.), whereas spatial concentration refers to the geographic concentration of economic activity in a particular industry, after controlling for the geographic concentration of overall economic activity (Brulhart, 1998). Clustering, on the other hand, is defined as a phenomenon in which economic activities are not randomly distributed over space, but tend to be organized into proximate groups (Chakravorty and Lall, 2007). These spatial concepts, however, are distinct from industrial concentration, which refers to the degree to which economic activity in a particular industry is concentrated in a small number of plants irrespective of their geographical location.

There are many standard statistical indices proposed in the literature to measure spatial concentration, such as coefficient of variation, concentration ratio, Herfindahl index, Gini index, Entropy index, Ellison-Glaeser index and Moran's I, etc. In the present paper we have employed the Herfindahl index for measuring spatial concentration. The Herfindahl index of an industry is defined as the sum squares of employment (or output) shares of all states in the industry. If E_{ik} is the employment (or output) of k^{th} state in i^{th} industry and E_i is the employment (or output) of all the states in i^{th} industry, then the Herfindahl index can be expressed as-

$$H_i^C = \sum_{k=1}^{n} (E_{ik}/E_i)^2$$

The value of Herfindahl index lies between one and $1/k$. The highest value is one when the industry is located in a single region and the lowest value is $1/k$ when all the regions have equal share.

Findings and Discussion

The Herfindahl index computed in terms of employment and gross value added of unorganized manufacturing by rural-urban sectors and enterprise types is reported in Table 3. It is obvious that concentration has declined in terms of employment and value added for the overall as well as all the three enterprise types and both rural and urban sectors after reforms compared to pre-reform period. It is not surprising that concentration is high for DME enterprise, which are more capital and technology intensive industries compared to OAME and NDME enterprises, which are basically household based tiny industries.

However, concentration is not uniform across different industry groups. Extending the scale of analysis to two-digit industries gives a better understanding of the degree of concentration and the variation in the direction of change in concentration across the industries. The result presented in Table 4 reveals that concentration is high for accounting and computing machinery; radio, TV and communication

Table 3: Herfindahl Index of Unorganized Manufacturing by Sector and Enterprise type

Variable	Year	OAME	NDME	DME	ALL	Rural	Urban
Employment	1994-95	0.107	0.095	0.106	0.094	0.108	0.103
	2005-06	0.096	0.086	0.096	0.087	0.097	0.091
Gross Value Added	1994-95	0.093	0.087	0.123	0.091	0.097	0.111
	2005-06	0.081	0.088	0.101	0.082	0.076	0.110

Source: Same as Table 1

Table 4: Herfindahl Index of Unorganized Manufacturing by two-digit Industry Groups

Industry Description (NIC-2004 Code)	Employment		Gross Value Added	
	1994-95	2005-06	1994-95	2005-06
Food Products & Beverages (15)	0.119	0.092	0.094	0.084
Tobacco Products (16)	0.186	0.141	0.158	0.121
Textiles (17)	0.143	0.128	0.127	0.111
Wearing Apparel; Dressing & Dyeing of Fur (18)	0.199	0.081	0.255	0.080
Leather & Leather products (19)	0.103	0.139	0.125	0.137
Wood & Wood Products (20)	0.088	0.109	0.097	0.076
Paper & Paper Products (21)	0.201	0.246	0.137	0.157
Printing & Recorded Media (22)	0.113	0.097	0.134	0.141
Coke, Refined Petroleum & Nuclear Fuel (23)	0.293	0.175	0.227	0.125
Chemicals & Chemical Products (24)	0.187	0.157	0.118	0.115
Rubber & Plastics Products (25)	0.173	0.110	0.227	0.122
Other Non-Metallic Mineral Products (26)	0.104	0.094	0.124	0.083
Basic Metals (27)	0.212	0.122	0.219	0.130
Fabricated Metal Products (28)	0.107	0.091	0.128	0.108
Machinery & Equipment, n.e.c. (29)	0.096	0.107	0.122	0.151
Office, Accounting & Computing Machinery (30)	0.832	0.706	0.864	0.767
Electrical Machinery & Apparatus, n.e.c. (31)	0.131	0.118	0.232	0.095
Radio, TV & Communication (32)	0.616	0.175	0.589	0.188
Medical, Optical Instruments & Watches (33)	0.172	0.152	0.219	0.127
Motor Vehicles, Trailers & Semi-Trailers (34)	0.136	0.282	0.167	0.218
Other Transport Equipment (35)	0.151	0.287	0.221	0.266
Furniture; Manufacturing n.e.c. (36)	0.122	0.101	0.160	0.153

Source: Same as Table 1

equipments; petroleum and nuclear fuel; and wearing apparel industries. Out of the 22 two-digit industries, concentration has declined in as many as 16 industries after reforms. Barely any significant increase in concentration is observed in any industry groups after reforms, except motor vehicle industries.

In fact, concentration mostly occurs at three-digit or even at more disaggregated industry levels. Therefore, we extend our analysis to 55 three-digit industry groups. Table 5 reports the Herfindahl index calculated in terms of gross value added for 15 most concentrated and 15 least concentrated industries. The most concentrated three-digit industries are manufacturing of aircraft and spacecraft followed by man-made fibers, watches & clocks, accounting & computing machinery, and manufacture of bodies for motor vehicles for both the pre- and post-reform periods. These are known to be high technology industries. On the other hand, resource based industries like food, beverages & tobacco products; textiles (except wearing apparel); leather & footwear; woods products; paper, printing & publishing; furniture products are the diversified industries. Industries like dressing & dyeing of fur, TV & radio receivers, recording & electrical equipment industries, which were highly concentrated before reforms have become less concentrated after reforms.

On the whole about one third out of 55 three-digit industries were highly concentrated in 1994-95, which declined to about one fifth in 2005-06. Concentration has

Table 5: Herfindahl Index of Unorganized Manufacturing by three-digit Industry Groups

1994-95		2005-06	
Industry Description (NIC-2004 code)	HHI	Industry Description (NIC-2004 code)	HHI
15 Most Concentrated Industries by three-digit industry			
Aircraft & spacecraft (353)	1.000	Aircraft & spacecraft (353)	1.000
Man-made fibers (243)	1.000	Watches & clocks (333)	0.923
Dressing & dyeing of fur (182)	0.889	Office, accounting & computing machinery (300)	0.767
Office, accounting & computing machinery (300)	0.864	TV & radio transmitters (322)	0.766
TV & radio receivers, recording apparatus (323)	0.772	Man-made fibers (243)	0.610
Watches & clocks (333)	0.732	Knitted & crocheted fabrics (173)	0.520
Other electrical equipment (319)	0.719	Motor vehicles (341)	0.418
Glass & glass products (261)	0.567	TV & radio receivers, recording apparatus (323)	0.412
Optical & photography equipment (332)	0.504	General purpose machinery (291)	0.350
Electric lamps & lighting equipment (315)	0.449	Publishing (221)	0.350
Insulated wire & cable (313)	0.442	Basic & non-ferrous metals (272)	0.346
Coke oven products (231)	0.424	Ships & boats (351)	0.338
Rubber products (251)	0.415	Refined petroleum products (232)	0.318
Basic & non-ferrous metals (272)	0.399	Glass & glass products (261)	0.306
Saw milling & planting of wood (201)	0.358	Transport equipment, n.e.c. (359)	0.305
15 Least Concentrated Industries by three-digit industry			
Paper & paper product (210)	0.137	Electric lamps & lighting equipment (315)	0.141
Other chemical products (242)	0.136	Other chemical products (242)	0.125
Footwear (192)	0.134	Tobacco products (160)	0.121
Casting of metals (273)	0.132	Plastic products (252)	0.120
Special purpose machinery (292)	0.131	Other food products (154)	0.112
Tanning & dressing of leather (191)	0.129	Footwear (192)	0.111
Dairy products (152)	0.124	Beverages (155)	0.096
Non-metallic mineral products (269)	0.115	Meat, fish, vegetables, oils, etc. (151)	0.091
Other food products (154)	0.110	Grain mill & animal feeds (153)	0.090
Structural metal products, etc. (281)	0.108	Structural metal products, etc. (281)	0.083
Publishing (221)	0.107	Manufacture of furniture (361)	0.082
Grain mill & animal feeds (153)	0.106	Non-metallic mineral products (269)	0.082
Meat, fish, vegetables, oils, etc. (151)	0.096	Wearing apparel (181)	0.080
Woods products (202)	0.085	Woods products (202)	0.079
Manufacture of furniture (361)	0.075	Saw milling & planting of wood (201)	0.071

Source: Same as Table 1.

Note: Herfindahl index is calculated using gross value added of Unorganized Manufacturing.

declined for all highly concentrated (except watches & clocks and aircraft & spacecraft industries) and moderately concentrated industries, while it has increased for some diversified industries. To consider the implications of such findings, let's look at the share wearing appeal industry. The significant decline in concentration is expected from the fact that the share of top four states in the industry (Delhi, Maharashtra, West Bengal and Tamil Nadu), which accounted for 80 percent of employment and 86.78 percent of gross value added in 1994-95, has declined to 45.86 percent and 43.12 percent respectively in 2005-06; whereas the share of some other states such as Andhra Pradesh, Uttar Pradesh, West Bengal and Tamil Nadu has increased. Similar explanations could be given to other industries also, where share of the top states has declined, and thereby, backward states have higher share in the post-reform period compared to the pre-reform period.

Conclusion

In this paper we have explored a new data set, the NSS unit level data on unorganized manufacturing sector, for analyzing spatial concentration of unorganized manufacturing industries in India before and after economic reforms. Since this data set is, thus far, not explored for regional studies, the analyses presented in this paper are fresh and a new contribution in the area of regional industrial studies in India. Despite the fact that the analyses presented in this paper are data exploratory, the findings are important in understanding the location pattern of unorganized manufacturing and its implication for regional development in India.

The findings of the paper suggest that the unorganized manufacturing in India has been concentrated in a few advanced states, and even after economic reforms the situation has not changed. Though spatial concentration has declined after reforms, but it takes place not because of improvements in the position of the lagging states, rather at the cost of the leading states, and hence, the decline can't be considered as took place in the desired direction for balanced regional development. We can see barely any significant improvement on the part of the backward states. In fact, the conditions of states like Bihar, Orissa, Uttar Pradesh and the group of north-eastern states have worsened after reforms. This indicates that although the centrifugal forces have been operating in the unorganized manufacturing sector of the advanced states, but the centripetal forces in the lagging regions are not strong enough to attract new industries. This is a serious problem faced by the poorer states as the business environment in these states are not investor friendly, because of a number of structural rigidities such as low level of economic development, poor socio-economic infrastructure (such as high incidence of poverty, low literacy rate, high infant mortality rate, low life expectancy, low human development, etc.), poor local governance, etc. Therefore, the local government of these states should provide special policy attention in order to development of socio-economic infrastructure that will improve local conditions such as connectivity with leading markets, human capital, electric power, easy finance, etc. and improvement of investment climate by removing restrictions and complex regulations, providing the necessary policy framework and supporting business environment to attract new investments.

Acknowledgement

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> *Productivity is being able to do things that you were never able to do before.*
>
> ***—Franz Kafka***

Simulation-based Layout Optimization of a Camshaft Manufacturing Plant for Productivity and Quality Improvement

ADITYA S. DHOBALE AND JAYDEEP S. BAGI

The work presented in this article is based on the study conducted at ABC industry which produces camshafts for automotive engines. The study is conducted with the objective to improve the utilization of available resources and quality dimensions of system like conformance of schedules and performance. There are many methods available for improving the utilization of resources, i.e., to improve productivity, but the time and cost involved in them is very important. One of the important methods for improvement of resource utilization is a plant layout. Proper analysis of plant layout design could improve the performance of production line such as decreased bottleneck rate, minimize material handling, reduced idle time, increase inefficiency and utilization of labour, equipment and space. The existing system was studied and current scenario was analyzed by using simulation modeling. Many problems in the existing layout were found like underutilized machines, excess material travels, improper layout adopted. A new layout is proposed which is prepared considering the data of the existing system and using the scientific method of layout planning.

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In the current era of globalization where competition is continuously increasing the effective utilization of available resources is very essential to survive in the market with the targeted profits. With rapidly increasing demand the industries must increase their productivity without affecting the quality and maintain lower costs to compete with their competitors. While striving for improvement in efficiency, the industries must maintain the cost performance balance. Hence the way of solving such problems and time spent on them becomes of critical importance. There are many ways like quality control, total quality management, standard time, plant layout to solve the problems related to productivity (Shewale et al., 2012, p. 259). According to many researchers the plant layout is one way to improve the resource utilization. Proper layout planning is very important in manufacturing process due to their effect in achieving an efficient product flow. Around 20–50% of the total costs within manufacturing are related to material handling and effective layout planning can reduce these costs 10–30%. Layout planning is concerned with the design, layout and accommodation of facilities in physical environment with the following objectives (Khusna et al., 2010):

- Minimization of overall production time
- Maximization of operational and arrangement flexibility
- Maximization of turnover of WIP
- Maximization of factory output in conformance with production schedules

It has a significant impact upon:

- Manufacturing costs
- Work in process

- Lead times
- Productivity

Discrete event simulation modeling is a very effective tool for handling the layout problems. Simulation is the dynamic representation of a real system by a computer model which behaves in the same manner as the system itself. In the manufacturing industry, simulation represents the dynamic manufacturing process in the computer model, and shows graphically and over simulated time the effects of a potential scenario to support the decision-making process. In the literature many researchers suggests proper layout planning as the tool for improved resource utilization and simulation is the best tool to evaluate different layout configurations (George, unpublished, p.1).

Factors Affecting Layout Planning

The production variety and volume, the material handling system chosen, the different possible flows allowed for parts, the number of floors on which the machines can be assigned, the facility shapes and the pickup and drop-off locations affect the planning. Due to their importance, these factors are detailed as follows (Drira, 2007, p. 255, 256, 258).

Products variety and volume

The layout design generally depends on the products variety and the production volumes. Four types of organization are referred to in this article, namely fixed product layout, process layout, product layout and cellular layout (refer to Figure 1: Types of layout).

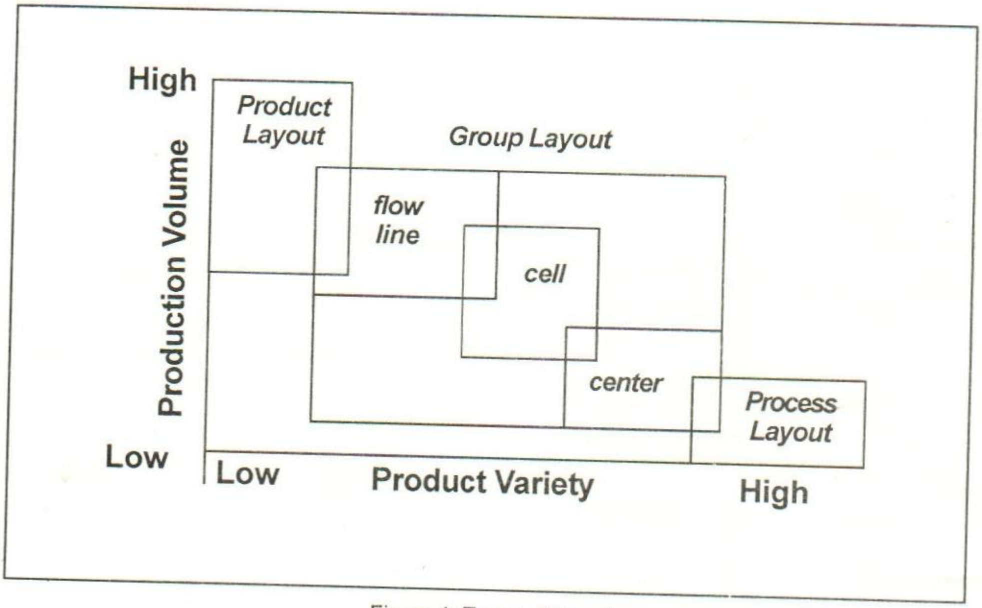

Figure 1: Types of layout

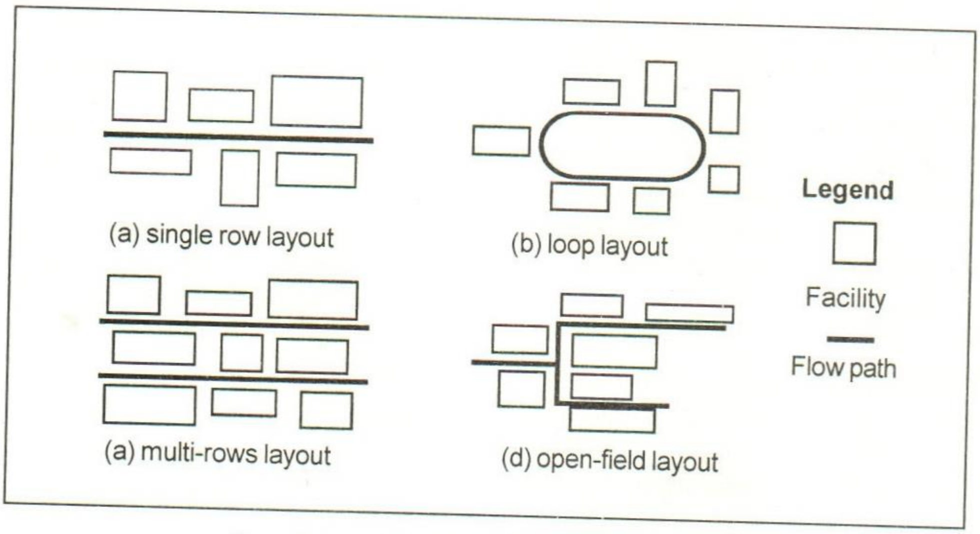

Figure 2: Layout Based on Material Handling Systems

Facility Shapes and Dimensions

Two different facility shapes are often distinguished: regular, i.e., generally rectangular and irregular, i.e., generally polygons a facility can have given dimensions, defined by a fixed length and a fixed width. In this case, the facilities are called fixed or rigid blocks.

Material Handling system

A material handling system ensures the delivery of material to the appropriate locations. (Refer to Figure 2: Layout based on material handling systems).

Backtracking and bypassing

Backtracking and bypassing are two particular movements that can occur in flow-line layouts, which impact the flow of the products. Backtracking is the movement of apart, from one facility to another preceding it in the sequence of facilities in the flow-line arrangement. (Refer to Figure 3: Backtracking and bypassing).

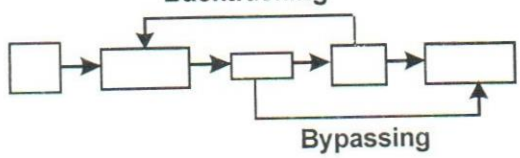

Figure 3: Backtracking & Bypassing

Company Background and Problem Definition

Company Background

The ABC industry under consideration manufactures camshafts for automotive engines. The line produces eight components. Each component is having same geometrical features but different orientations and passes through a sequence of operations. Time required for each operation is same for all components. The shop floor has functional layout where machines are arranged as per their purpose. In current scenario all eight components are scheduled and sent for machining as per the supervisors past experience.

Problem Definition

The objective of this research study is to evaluate the layout of current manufacturing system and suggest the improvements so as to improve the utilization of available resources, i.e., improve the productivity and quality dimensions like conformance to production schedules, performance of production line.

Work and Methodology

Companies are always trying to find ways of improving the utilization of available resources. But many times some methods of industrial engineering are time consuming and involve the ways that are difficult to implement. An example can be improved work procedures by method study and work study can be opposed by the workers. In such cases it requires lot of time to implement the changes. Plant layout is one the most important factor which if properly designed could improve the utilization of available resources without posing the problems of implementation.

There are various types of layouts such as product layout, process layout, and fixed layout. Product type of layout is generally appropriate for the facilities which produce one product or one type of a product. Therefore, the machines or departments are configured as in the order of operations of the product. In process type layout, the machines that perform similar operations are grouped together. The products visit these groups in the order of their operations. In case of fixed type layout, the products and their components are placed in a fixed location and the labor, equipment or tools are brought to this location.

Discrete event simulation is a very important tool in handling the layout problems. Manufacturing systems are very complex in nature and the components of manufacturing system have even more complex relationship between them. In such a case it becomes very difficult and time consuming to use the conventional analytical techniques to model these systems. Moreover due to continuously changing demand environment the product types are also changing so it again creates the problems to make the changes in the model with effective speed. Modeling and simulation enables designers to test whether design specifications are met by using virtual rather than physical experiments.

The use of virtual prototypes significantly shortens the design cycle and reduces the cost of design. It provides the designer with immediate feedback on design decisions which, in turn, promises a more comprehensive exploration of design alternatives and a better performing final design. Formulating the problem, collecting the data, building the simulation model, running the model, and analyzing the output are the basic steps in a simulation study.

Terms Used

For secrecy of data the component names are changed to C1, C2, C3, C4, C5, C6, C7, and C8. Operation names are changed to Operation No. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, *13, 14, 15, and 16. Machine names—M1, M2, M3, M4, M5,* M6, M7, M8, M9, M10, M11, M12, M13, M14.

Data Collection

Data collection is the very first step in a simulation study. In order to build the simulation model the data of the manufacturing system is required. Data like order schedule, raw material arrival schedule, operation cycle time, process sequence, number of shifts, working hours/shift, machine breakdown and maintenance time, breakdown frequency, is collected from the shop by conducting time study and interviewing the shop floor personnel. (Refer to Table 1: Operation sequence, Table 2: Machines used for operations.)

In the current system there is a functional layout in which the machines are arranged according to their type of operation. For material handling manually operated trailers are used. Raw material arrives as per fixed schedule. The source in simulation model is designed as per the arrival schedule. Drawings of all eight parts are studied and their process sequence is also analyzed.

Model Building

Refer Figure 4: Model of existing system using Flexsim 6 software package.

The processing times of each product on each operation, the demands of products, the arrival rate of the demands are calculated by fitting the appropriate distributions. The Expert Fit module of the Flexsim 6 is used for these calculations. Then the simulation model of the production line is built in Flexsim 6 software package.

Table 1: Operation Sequence

Operation No.	Component Name							
	C1	C2	C3	C4	C5	C6	C7	C8
1	Y	Y	Y	Y	Y	Y	Y	Y
2	Y	Y	Y	Y	Y	Y	Y	Y
3	Y	N	N	N	Y	N	N	N
4	N	N	N	Y	N	N	N	Y
5	Y	Y	Y	Y	Y	Y	Y	Y
6	Y	Y	Y	Y	Y	Y	Y	Y
7	Y	Y	Y	Y	Y	Y	Y	Y
8	Y	Y	Y	Y	Y	Y	Y	Y
9	Y	Y	Y	Y	Y	Y	Y	Y
10	Y	Y	Y	Y	Y	Y	Y	Y
11	Y	N	N	N	Y	N	N	N
12	N	N	N	Y	N	N	N	N
13	Y	Y	Y	Y	Y	Y	Y	Y
14	Y	Y	Y	N	N	Y	Y	Y
15	N	N	N	Y	N	N	N	Y
16	Y	Y	Y	Y	Y	Y	Y	Y

Y- Operation is required
N- Operation is not require

Table 2: Machines Used for operations

Operation No.	1	2	3	4	5	6	7	8
Machines Used	M9	M10	M9	M13	M7, M7	M14	M8, M6	M3
Operation No.	9	10	11	12	13	14	15	16
Machines Used	M4	M2, M4	M3	M2, M3	M2, M3, M4	M1	M1	M11, M12

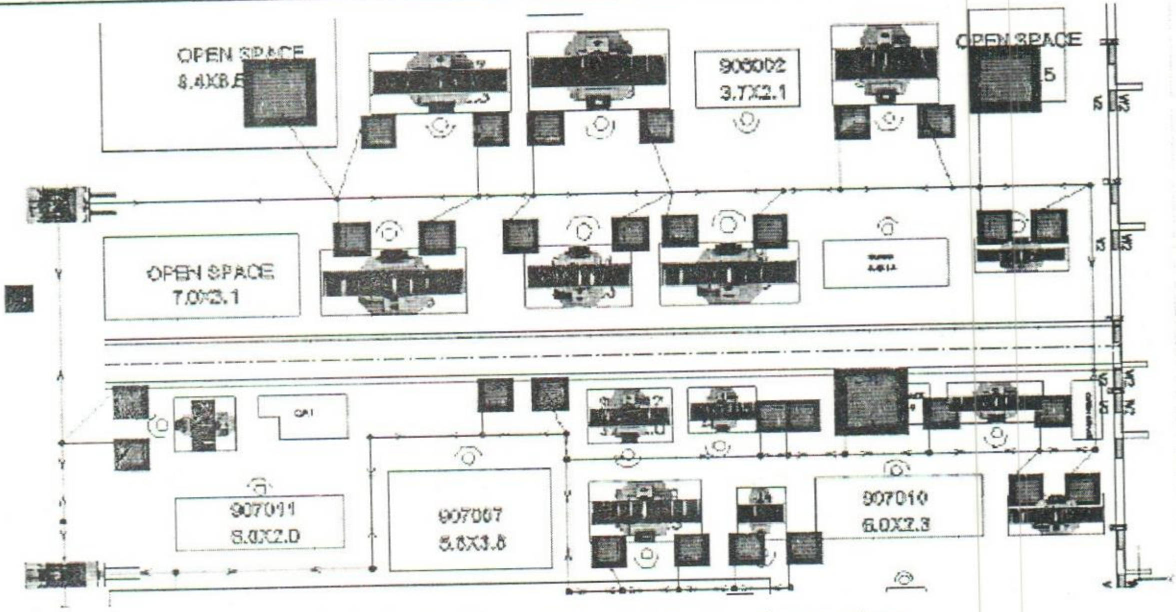

Figure 4: Model of existing system using Flexsim 6 software package

Model verification and validation

It is good practice to have an attitude like: "The results from a simulation are to be considered as being inherently inaccurate, unless there are good reasons to believe the opposite." In other words, one needs to be able to motivate why the simulation produces realistic results. Important steps are verification (checking the model for errors) and validation (checking whether the model produces realistic overall results) (Leo J De Vin et al., 2004, p. 159). The simulation model is thus verified by shop floor supervisors and it is validated by comparing the output, throughput and queue levels of the actual system and simulation model.

Evaluation of the existing system

Having validated model the existing system is analyzed for identifying areas of improvement. In existing system the production capacity of the line is locked up. Customer is offering still increased order but the company is not able accept it due to locked capacity. Also the incoming material is in the form of heavy bars which arrives daily in fixed quantity due to time required for cutting operation.

The result of simulation run showed that many machines are idle for most of the time and the line is underutilized. Study revealed that the layout used for these components was used as it is after change of previous order. Current order is going to continue for very long duration in years. (Exact data restricted by company). Thus it is clear that the layout revision can be made so as to improve the output.

The model is run for the period of one month period and the results are obtained. (Refer Table 3: Flexsim state report of existing system.) Results showed that machines M1, M3, M4, M13, and M14 are idle for more than 30% of the time. Also some machines are utilized up to 78% which means that if these machines fail the production will be seriously hampered.

Table 3: Flexsim state report of current system

Object	Class	idle	processing	breakdown
M1	Processor	45.68%	49.40%	0.02%
M2	Processor	29.64%	46.18%	0.00%
M3	Processor	34.98%	40.77%	6.54%
M4	Processor	48.65%	26.98%	9.75%
M5	Processor	22.28%	52.19%	7.69%
M6	Processor	19.57%	56.08%	10.14%
M7	Processor	20.50%	55.25%	5.16%
M8	Processor	26.02%	49.62%	5.86%
M9	Processor	14.58%	35.09%	7.73%
M10	Processor	26.19%	23.79%	0.00%
M11	Processor	26.88%	24.09%	11.23%
M12	Processor	21.40%	25.67%	0.00%
M13	Processor	62.77%	13.00%	0.00%
M14	Processor	44.12%	7.14%	0.00%

Proposed system

The evaluation showed that there is uneven distribution of work as well as poor utilization of available capacity. In proposed system the layout is revised to product type in which it is suggested to arrange the machines in the order of sequence of operations. The new layout is proposed considering all the points which affect the layout plan. The flow path of the material handling devices is also revised according to process sequence. Layout revision is one of the best ways to improve the utilization as it reduces the excess travel of material and queing of material becomes easy. Also it is checked whether the raw material supply could be increased. Vendor assures the supply of 5 more pieces per day which means that the raw material supply may be increased to 20 components per day. The source is redesigned as per new raw material arrival schedule and simulation model is run for one month period. The results when compared shows that the idle time of machines is reduced also overloaded machines are relieved for some percent of time. (Refer Figure 5: Proposed system after revision of layout, Table 4: Flexsim state report of proposed system.)

Table 4: Flexsim state report of proposed system

Object	Class	idle	processing	breakdown
M1	Processor	24.24%	60.02%	0.03%
M2	Processor	21.49%	54.34%	0.00%
M3	Processor	27.35%	48.45%	1.62%
M4	Processor	42.36%	33.34%	10.78%
M5	Processor	5.46%	69.20%	8.33%
M6	Processor	7.96%	67.77%	3.34%
M7	Processor	12.67%	63.07%	7.59%
M8	Processor	16.73%	58.80%	8.70%
M9	Processor	5.27%	43.54%	8.81%
M10	Processor	17.00%	32.23%	0.00%
M11	Processor	22.79%	28.02%	9.23%
M12	Processor	15.90%	31.17%	0.00%
M13	Processor	62.77%	13.00%	0.00%
M14	Processor	42.80%	8.47%	0.00%

Results obtained from the simulation run of proposed system showed that the idle time of almost all machines is reduced. Existing system gives the output of 320 components per month; by proposed system it would give the output of up to 370 components per month.

Comparative Statement

(Refer to Table 5- Comparison of existing and proposed system.)

The proposed layout streamlines the flow of material and significantly reduces the average time required per component.

Conclusion and Discussion

In this article, an attempt has been made to present the method of improving the resources utilization and reduce net

Table 5: Comparison of existing and proposed system

Description	Existing System	Proposed System
Average Time/ Component	135 Min	116.75 Min

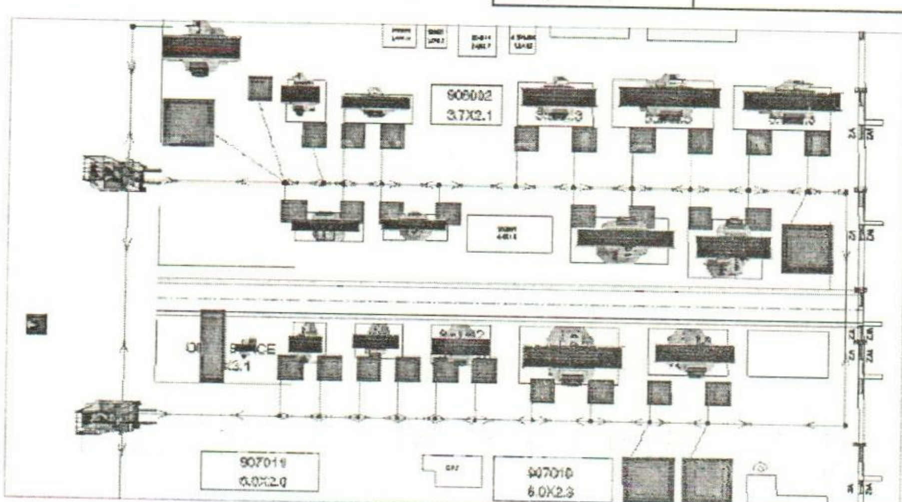

Figure 5: Proposed system after revision of layout

manufacturing cycle time by improving the productivity, quality and overall effectiveness of a camshaft manufacturing plant by its layout optimization using simulation technique.

To conclude for such a work which is responsible to teach and allow exploring the understanding of engineering hands on, is an altogether a different experience. Some of the points, which can be summarized as a conclusion, are

- Idle times of machines reduces considerably by the revision of layout
- Reduction in average time per component by 18.25 min.

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> *Quality is never an accident; it is always the result of high intention, sincere effort, intelligent direction and skillful execution, it represents the wise choice of many alternativies.*
>
> ***—Wiliam A. Foster***

Focus

An Analysis of Total Factor Productivity Growth of Automobile Industry in India 1985-86 to 2006-07

G. JIMMY CORTON

The present article analyses the factor intensities of automobile industry besides analyzing factor intensities of all industries in India for the period 1985-86-2006-07. This work also analyses total factor productivity growth of automobile industry. The analysis of this article relating to the automobile industry reveals that this industry is a capital intensive industry and the serious concern of this industry is low factor productivity growth which can be rectified by extensive use of labor and capital.

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Industrial development of the underdeveloped countries has become one of the great world crusades of our times. It is a campaign in which the advanced countries compete with each other to meet the rising claims of the non industrial countries for help in becoming industrialized. It is an effort in which the underdeveloped countries place a major hope of finding a solution to their problems of poverty, insecurity, over population and ending their newly realized backwardness in the modern world. The belief of the underdeveloped world was expressed by Nehru when he said "Real progress must ultimately depend on industrialization". Throughout the world industrialization has indeed become the magic word of the mid-twentieth century.

The reasons for this explosion of interest in industrialization are not hard to discover. The underdeveloped regions have long been mainly producers of raw materials, and they have observed that there is a strong and positive connection between the wealth and standard of living of a country and the extent of its industrialization. They also see that-as prices for raw materials fluctuate much more than prices for manufactured goods-an economy which is dependent on the export of one or a few basic commodities suffers from instability of the national income more than economies which are industrialized and more self-sufficient. Observing these facts, the people of the underdeveloped countries have naturally come to believe that, in order to achieve greater security, stability and higher standard of living their countries must become industrialized[1].

The transport sector is the backbone of countries economic growth and development. Transportation has made possible an unprecedented level of mobility across geographical boundaries and has given people many more options that they had years ago. It has broadened the base of business by introducing new markets and increasing the available pool of resources, thus the importance of this sector cannot be over looked. Trade facilitated by transportation has been a growing component of the National Income all over the world need less to say the transport sector is equally important for both developed and developing countries[2].

The Transport sector includes water transport, air transport and surface transport. Automobiles as a commodity which includes passenger cars, multi utility vehicles, commercial vehicles and two and three wheelers is a major constituent of road transportation.

The automobile industry is one of the largest industries with deep forward and backward linkages and hence has a strong multiplier effect among the forward linkages. The key generators of employment are the oil industry, distribution after sales service network and supply of spares and replacement by the auto component industry. It is estimated that 3 million persons are employed in the distribution and after sales industry.

The biggest impact is on the auto-component industry which today has become a key sector in the Indian Economy, the turn over being around Rs. 120 billion with exports close to Rs. 12 billion. As far the backward linkages the automobile industry is the largest consumer of raw material like CR/HR steel- Aluminium and Zinc Alloys and also of high value rubber and plastics. More over, the automobile industry is the most important drivers of machine tools industry, the bed-rock of industrial growth[3].

It is also important from the point of employment generation, revenue to the government in the form of taxes and duties and for national defence. Infact a healthy automobile industry is essential for the large scale industrialization. Development of automobile industry results in the growth of other associated industries like electronics, rubber, plastics, iron and steel, petro-chemicals, glass and textiles[4].

Methodology

This paper analyzed factor intensities and total factor productivity growth of automobile industry besides analyzing factor intensities of all industries. The period of study selected for the present work is from 1985-2007. The detailed methodology is given below.

Kendrick's Total Factor Productivity Index of Automobile Industry

To have an overall view of the productivity in an industry or in a firm there must be a single indicator which should naturally be the ratio of net output to the combination of all the relevant inputs. With this idea in view, Kendrik evolved the concept of total factor productivity index and defined it as follows[5].

Total Factor Productivity = $\frac{Q_0}{al + bc}$ Where

Q_0 is the index of net output,

l is the index of labour input,

c is the index of capital input,

a is the relative share of labour,

b is the relative share of capital.

Kendrick's total factor productivity growth is estimated by using annual growth rates and exponential growth rates. The methodology is explained as follows:

Annual Growth Rates of Total Factor Productivity

Annual percentage changes were estimated by computing annual growth rates. These growth rates give the changes over the year.

$$G_t = \frac{(Y_t - Y_{t-1})}{Y_{t-1}} \times 100$$

where,

G_t = growth rate of Kendrick's total factor productivity index for the year 't'

t = time (year)

Yt = t^{th} year total factor productivity index value

$Y_{(t-1)}$ = $(t-1)^{th}$ year total factor productivity index value

These annual growth rates were computed by taking Kendrick's total factor productivity index values in constant prices (i.e. 2003-04 prices for industry variables). Since the data is time series in nature, this method can be used for preliminary analysis and to find the year-to-year changes of the total factor productivity growth in the industry. Hence the change in total factor productivity growth is estimated per unit of time. If $G_i > 0$ it can be inferred that growth has taken place. In case, the $G_i < 0$ or negative, then the retardation in the total factor productivity activity is supposed to have happened. If there is no change in G_t, then there is stagnancy in the total factor productivity.

Exponential Growth Rate of Total Factor Productivity

The compound growth rates are estimated by using regression method. In this, the log-linear model applied with dummy variable. The model is

$$\text{Ln } Y_t = b_0 + b_1 t \quad (1)$$

$$\text{Ln } Y_t = b_0 + b_1 t + b_2 D \quad (2)$$

where,

Y_t is the value of Kendrick's total factor productivity index, t is time variable,

D is dummy variable (0=pre-liberalization, 1= post-liberalization),

b_0 is constant, and

b_1, b_2 are coefficients of time and Dummy variables respectively.

Here we drew growth rates of total period and pre and post liberalization changes from b1 by applying the following method.

G_t = (Antilog of b_1-1)*100

G_t is Growth rate of total time period.

It is hypothesized that there is no significant positive growth in total factor productivity in the automobile industry. To test this analysis is made on the basis of standard error, t-values and the significance of the coefficients b_1 and b_2 of the variables time and dummy. If the value of b_1 is significant, then it is concluded that there is a positive total factor productivity growth in automobile industry. All the estimations are made using the SPSS software.

However, this method (i.e. non-linear curve) is preferable over the average annual growth rates and linear curve one as this accepts that the change in the growth rate in this period is dependent on the change in output in the previous period. The regression statistics mentioned above are estimated in this case also to analyze the statistical reliability of the equation.

Factor Intensities of Automobile Industry

The factor intensities of automobile industry can be observed by analyzing the capital intensity (K/L), labour productivity (V/L) and capital productivity (V/K).

It can be observed from the data that the capital intensity (K/L) in the year 1985-86 is Rs.1,37,952 and has increased to Rs.1,47,536 in the year 1987-88. From the year 1988-89 to 2003-04 the capital intensity (K/L) has not exhibited much variation. From the year 2004-05 the capital intensity has decreased during the end of the study period. This indicates that the automobile industry is a capital-intensive industry, as a result the capital per labour is decreasing which is a interesting point in this analysis.

However, the labour productivity (V/L) and capital productivity (V/K) during the study period are showing an increasing trend which can be observed in the following table 1.

Table 1: Factor Intensities of Automobile Industry

Year	K/L in Rs	V/L in Rs	V/K
1985-86	137952	295726	2.14
1986-87	141234	338067	2.39
1987-88	147536	303143	2.05
1988-89	127183	316473	2.49
1989-90	133678	371504	2.78
1990-91	127681	424160	3.32
1991-92	130506	452402	3.47
1992-93	127715	456100	3.57
1993-94	129836	495653	3.82
1994-95	121106	552028	4.56
1995-96	110364	772877	7.00
1996-97	111696	704864	6.31
1997-98	108440	592733	5.47
1998-99	112633	427010	3.79
1999-00	116933	506176	4.33
2000-01	128899	415051	3.22
2001-02	132989	437152	3.29
2002-03	121585	450810	3.71
2003-04	114952	563548	4.90
2004-05	98575	631923	6.41
2005-06	92590	725086	7.83
2006-07	82501	536177	6.50

Source: Computed based on Annual Survey of Industries Data (Factory Sector, Central Statistical Organisation, Government of India, New Delhi).

In the year 1985-86 the labour productivity (V/L) is Rs. 2,95,726 and has increased to Rs. 7,72,877 in the year 1995-96. From the year 1996-97 onwards the labour productivity is decrased from Rs. 7,04,864 to Rs. 5,36,177 in the year 2006-07 with minor fluctuations. Hence we can see that the capital per labour is decreasing due to the decrease in labour productivity. However on the other hand the capital productivity in the year 1985-86 was 2.14 percent which has increased to 7 percent in the year 1995-96. However from the year 1996-97 the capital productivity has been decreasing from 6.31 percent to 4.9 percent in the year 2003-04. Again it has recovered in the year 2004-05 to 6.41 percent and increased to 7.83 percent in the year 2005-06 and and again declined to 6.5 percent in the year 2006-07.

Factor Intensities of All Industries

In the year 1985-86 capital intensities (K/L) of all industries is Rs.2,39,459 and has increased to Rs. 12,18,349 in the year 2005-06 with small fluctuations and reached to Rs. 11, 57,640 in the year 2006-07. On the other hand the labour productivity (V/L) of all industries in the year 1985-86 is Rs. 1,23,404 and has increased to Rs. 3,01,263 in the year 1999-00. From the year 2000-01 onwards the labour productivity (V/L) is Rs. 2,72,305 and increased to Rs. 4,84,084 in the year 2006-07. This can be observed from the following table 2.

Table 2: Factor Intensities of All Industries

Year	K/L in Rs	V/L in Rs	V/K
1985-86	239459	123404	0.52
1986-87	267220	51543	0.19
1987-88	289310	123195	0.43
1988-89	323919	139336	0.43
1989-90	344434	153087	0.44
1990-91	384247	168480	0.44
1991-92	430869	179326	0.42
1992-93	460653	214655	0.47
1993-94	520779	252021	0.48
1994-95	551084	269130	0.48
1995-96	557416	280006	0.50
1996-97	635276	279175	0.44
1997-98	683226	277857	0.41
1998-99	882629	297538	0.34
1999-00	962917	301263	0.31
2000-01	1053259	272305	0.26
2001-02	1164017	274135	0.24
2002-03	1204964	299398	0.25
2003-04	1293720	333422	0.26
2004-05	1256730	363504	0.29
2005-06	1218349	372924	0.31
2006-07	1157640	484084	0.42

If we look at the capital productivity (V/K) in the year 1985-86 it was 0.52 percent and has declined to 0.24 percent in the year 2001-02 with minor fluctuations in between these years. However, in the year 2003-04 the capital productivity (V/K) ratio is 0.26 percent and has increased to 0.42 percent in the year 2006-07.

The capital productivity (V/K) in the automobile industry is much higher compared to the capital productivity (V/K) of all industries during the study period. This clearly indicates that the automobile industry is more capital-intensive industry. The declining trend of the capital intensity (K/L) of the automobile industry reveals that the capital per labour employed is less than the capital per labour employed of all the industries. This indicates that the automobile industry is not a labour-intensive industry where capital per labour is high.

Total Factor Productivity

For calculating Kendrick's Total Factor Productivity index of automobile industry the year 1985-86 is taken as a base year with value 100. The index is showing an upward trend up to the year 1995-96 which is around 213.22 percent compared to the base year except with a small decline in the year 1987-88. However, from the year 1996-97 onwards the index is showing a declining trend with small up and downs till the year 2005-06 which is 227.43 percent and in the year 2006-07 it again declined to 170.93 percent.

Annual Growth Rates of Total Factor Productivity

To have a clear understanding of the trend of total factor productivity of automobile industry this study analyzed the annual growth rates of the total factor productivity. In the year 1986-87 the total factor productivity growth is 11.74 percent and has declined to -13 percent in the year 1987-88. Since then it has recovered to 17.11 percent in the year 1988-89. From the year 1991-92 the annual growth rates are showing declining trend up to the year 1993-94. In the year 1995-96 the total factor productivity growth rate is 50.59 percent as compared to 17.55 percent for the year 1994-95. Again with up and downs in the growth rates of total factor productivity, in the year 2003-04 it has increased to 30.93 percent from the previous year 11.43 percent. However, we can see the declining trend of total productivity growth with a negative growth rate of -17.25 percent in the year 2006-07. The Kendrick's total factor productivity annual growth rates can be seen from the following table 3.

Table 3: Growth Rate of Total Factor Productivity of Automobile Industry

Year	Kendrick's TFP	TFPG
1985-86	100	-
1986-87	111.74	11.74
1987-88	97.21	-13.0
1988-89	113.84	17.11
1989-90	127.76	12.22
1990-91	152.77	19.58
1991-92	159.43	4.36
1992-93	164.75	3.33
1993-94	176.94	7.40
1994-95	207.99	17.55
1995-96	313.22	50.59
1996-97	286.55	-8.52
1997-98	249.1	-13.07
1998-99	166.27	-33.25
1999-00	180.7	8.68
2000-01	140.26	-22.38
2001-02	141.95	1.21
2002-03	158.18	11.43
2003-04	207.09	30.93
2004-05	267.55	29.20
2005-06	327.43	22.38
2006-07	270.93	-17.25

Source: Computed based on Annual Survey of Industries Data (Factory Sector, Central Statistical Organisation, Government of India, New Delhi).

Exponential Growth Rate of Total Factor Productivity

The exponential growth rate of total factor productivity of automobile industry is computed in this section. Apart from growth rate the impact of reforms is also analyzed by using the dummy variable. The regression equation for this analysis is given below.

$\text{Ln } Y_t = b_0 + b_1 t$..................1

$\text{Ln } Y_t = b_0 + b_1 t + b_2 D$.........2

were,

Y_t is the value of Kendrick's total factor productivity index, t is time variable,

D is dummy variable (0=pre-liberalization, 1= post-liberalization),

b_0 is constant, and

b_1, b_2 are coefficients of time and Dummy variables respectively.

Here we drew growth rates of total period and pre and post liberalization changes from b1 by applying the following method.

$G_t = (\text{Antilog of } b_1 - 1) * 100$

G_t is Growth rate of total time period.

The detailed explanation of this model to prove the hypothesis is furnished in the methodology of this chapter.

The exponential growth rate of total factor productivity of automobile industry is 2 percent during the study period. The 74.8 percent R_2 value indicates that this model is a good fit. The slightly positive value of coefficient of time (b_1) variable reveals that the time has very less impact on the growth of total factor productivity which is clearly indicated by the insignificant *p*-value. The same can be observed in case of dummy variable which shows the low positive coefficient (b2) value of dummy variable and insignificant *p*-value indicates no impact of reforms on the growth of total factor productivity.

Table 4: Exponential Growth Rate of Total Factor Productivity

Predictor	Coefficient	SE Coefficient	t	*p*-value
Coefficient (b_0)	4.683	0.114	40.94	0.000
TIME (B_1)	0.0198	0.013	1.465	0.159
DUMMY (B_2)	0.356	0.192	1.849	0.080

Source: Computed based on Annual Survey of Industries Data (Factory Sector, Central Statistical Organisation, Government of India, New Delhi).

The very low positive value of exponential growth rate of total factor productivity is 2 percent and insignificant values of time and dummy variables indicate that there is no positive growth of total factor productivity of the automobile industry. Hence the null hypothesis can not be rejected.

$$\text{Log } Y_t = 4.683 + 0.0198t + 0.356D$$

(TFP) (time) (dummy)

R^2 = 0.748 or 74.8%, growth rate g_t = 2%

Inferences

From the foregoing analysis the following general inferences can be drawn.

1. Capital intensity (K/L) in the year 1985-86 is Rs.1,37,952 and has increased to Rs.1,47,536 in the year 1987-88. From the year 1988-89 to 2003-04 the capital intensity (K/L) has not exhibited much variation. From the year 2004-05 the capital intensity has decreased during the end of the study period. This indicates that the automobile industry is a capital-intensive industry; as a result the capital per labour is decreasing which is an interesting point in this analysis.
2. In the year 1985-86 the labour productivity (V/L) is Rs. 2,95,726 and has increased to Rs. 7,72,877 in the year 1995-96. From the year 1996-97 onwards the labour productivity is decrased from Rs. 7,04,864 to Rs. 5,36,177 in the year 2006-07 with minor fluctuations. Hence we can see that the capital per labour is decreasing due to the decrease in labour productivity.
3. The capital productivity (V/K) in the automobile industry is much higher compared to the capital productivity (V/K) of all industries during the study period. This clearly indicates that the automobile industry is more capital-intensive industry.
4. The very low positive value of exponential growth rate of total factor productivity is 2 percent and insignificant p-values of time and dummy variables indicate that there is no positive growth of total factor productivity of the automobile industry.

Conclusion

The capital productivity (V/K) in the automobile industry is much higher compared to the capital productivity (V/K) of all industries during the study period. This concludes that automobile industry is a capital intensive industry. One of the serious concerns in this industry is that the low factor productivity growth rate which can be rectified by extensive use of labour and capital in this industry.

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Manufacturing is more than just putting parts together. It's coming up with ideas, testing principles and perfecting the engineering, as well as final assembly.

—James Dyson

Focus

Total Factor Productivity Growth in the SMEs and Large Scale Industries of India: Estimation and Comparison

AVISHEK CHANDA

This article estimates and compares Total Factor Productivity Growth (TFPG) between the. Small Scale Industries. (SSIs)/ Micro, Small and Medium Enterprises (MSMEs) and the large scale industries sectors of India over the period 1973-74 to 2006-07 based on state level data. Using non-parametric Data Envelopment Analysis and Malmquist productivity index methodology, the article finds decline in TFPG for the SSIs/MSMEs sector over the period 1987-88 to 2001-02 mainly due to severe technological regress which also continued during 2001-02 to 2006-07. The article thus concludes with suggestions on technological up gradation of the SSIs/MSMEs sector for higher TFPG over time.

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The Small Scale Industries (SSIs)/ Micro, Small and Medium Enterprises (MSMEs) sector plays an important role in India's economic growth and development in terms of its contribution to manufacturing output, employment, and exports of the country. The total number of MSMEs in India during 2010-11 was 31.1 million that accounted for 44.86 percent of total industrial production, 8.72 percent of overall gross domestic product during 2008-09 at 1999-00 prices and generated employment of about 73.2 million during 2010-11, the second highest source of employment generation after agriculture (Annual Report, Ministry of MSMEs, 2011-12, pp. 21-26). During 2005-06, the SSIs contributed about 39 percent of the gross value of output of the manufacturing sector and almost 33 percent of exports of the country (Economic Survey, Government of India, 2007-08, pp. 199). Hence, growth and development of the SSIs/MSMEs sector have a direct impact on the growth of the manufacturing sector as well as overall growth of the national economy. The SSIs/ MSMEs in India are defined in terms of the original gross value of fixed investment on plant and machinery[1].

Given the smallness of size and scale, Total Factor Productivity Growth (TFPG) is important for sustained growth of output, employment, and exports and thereby long term economic growth of the MSMEs sector. TFP is the portion of output not explained by the amount of inputs used in production and is determined by the efficiency and intensity of input utilisation (Comin, 2006). TFPG is often regarded as an important determinant of competitiveness and long run growth. It also plays an

[1]The upper limits of investment on plant and machinery while defining SSIs/MSMEs have gone through changes over time. According to the Micro, Small and Medium Enterprise Development (MSMED) Act 2006, the MSMEs are defined as (i) Micro units where the investment in plant and machinery does not exceed Rs. 25 lakhs, (ii) Small units where the investment in plant and machinery is more than Rs. 25 lakhs but does not exceed Rs. 5 crore, (iii) Medium units where the investment in plant and machinery is more than Rs. 5 crore but does not exceed Rs. 10 crore.

important role in explaining differences in growth and per capita income. In this context, the main objective of this paper is to examine TFPG of the SSIs/MSMEs sector of India during pre and post liberalisation periods. This is because the liberalisation policies aimed at maintaining a sustained growth in productivity over time and attaining international competitiveness of the industrial sector of India. Furthermore, a comparison of TFPG between the SSIs/MSMEs sector and the large scale industries sector characterised mainly by the industries in the organised sector has been done. This is for examining whether and how TFPG of the SSIs/MSMEs sector during pre and post liberalisation periods has differed from the industries in the organised sector with much bigger per unit output, investment, and employment Vis-a-vis the industries in the SSIs/MSMEs sector. Using state level data over the period 1973-74 to 2006-07 from the reports of different Censuses of SSIs/MSMEs and Annual Survey of Industries (ASI), this paper examines and compares TFPG between the large scale (organized) sector and SSIs/MSMEs sector applying Malmquist TFPG index and the non-parametric Data Envelopment Analysis (DEA) methodology.

The article is organized as follows. Section II summarises the findings of the previous studies on estimation and comparison of TFPG between large scale small scale industrial sectors of India. Section III briefly discusses the DEA methodology and the Malmquist TFPG index for estimation of TFPG. Section IV gives description of data and measurement of variables. Section V analyses and compares the estimates of TFPG between large scale and SSIs/MSMEs sectors during pre and post liberalisation periods while Section VI concludes with the major findings and their implications.

Summary of findings of the earlier studies

In the available literature very few studies estimated and compared TFPG between large scale (organized) and small scale (SSIs/MSMEs) sectors. Majority of the earlier studies compared between large and small scale industries sectors of India in terms of the partial factor productivity estimates. Only three studies are found that compared TFPG between large and small scale industrial sectors. A brief summary of time periods, data sources, methodology and findings of these studies are presented in the following Table 1.

Table 1: Summary of earlier studies on estimation and comparison of TFPG between large and small scale industries sectors.

Studies using partial factor productivity ratios	*Time Period*	*Data Sources*	*Methodology*	*Findings*
1. Dhar and Lydall (1961)	1959	Census of Manufacturing Industries (CMI).	Output-capital ratios.	SSIs are more capital intensive than large scale.
2. Hajra (1965)	1955 and 1958	CMI data for 17 industry groups.	Ratios of labour productivity of small and large size groups. Capital-output ratios of small and large size groups.	Higher capital-output ratios for smaller units and conversely. Labour and capital productivity is low in small size groups relative to the large.
3.Sandesara (1969)	1953-1958	CMI data for 28 industries.	Capital-labour ratios. Output-capital ratios.	Small industries produce less output and generate less employment for a given capital size.
4. Mehta (1969)	1960-1963	ASI data for 32 industries.	Size class of factories by book value of fixed capital. Capital-labour ratios. Output-labour ratios. Output-capital ratios.	Increase in factory size leads increase in capital-labour ratios. Capital productivity declines with increase in size.
5.Bhavani (1980)	1973-1974	ASI and First Census of SSIs data for 46 3-digit industries.	Labour productivity ratios. Capital productivity ratios. Capital intensity ratios.	Both labour productivity and capital intensity is higher for large industries compared to small industries.Capital productivity is higher for majority of the large industries than the small counterparts.

Table 1 continued...

Table 1 continuation...

Studies using TFP/TFPG	*Time period*	*Data sources*	*Methodology*	*Findings*
1. Goldar (1988)	1976-1977	ASI and sample survey of small enterprises by Reserve Bank of India (RBI) data for 37 industries.	Relative TFP index.Relative labour productivity.Relative capital productivity.	Labour productivity and TFP of SSIs is less than large industries. Capital productivity of SSIs is higher than large industries.
2. Small Industries Development Bank of India (1999)	1981-1982 to 1994-1995	Aggregate time series data of ASI.	Same as Goldar (1988).	Labour productivity of SSIs is less than large industries. Capital productivity of SSIs is more than large scale sector.TFPG index is above one during the study period for the SSIs and thus SSIs are more productive than large industries.
3. Bala (2007)	1981-1982 to 1997-1998	ASI time series data.	DEA and Malmquist TFPG index.	In both pre and post liberalisation periods, TFPG has followed a declining trend for SSIs sector while the same has followed an upward rising trend for large scale sector.

Source: Author's compilation from different studies.

It follows from the survey of earlier studies that very few studies have empirically estimated and compared TFPG between small scale and large scale industrial sectors of India. Except, Bala (2007), the other two studies doing such estimation and comparison have not focused on comparison between pre and post liberalisation periods. However, the study by Bala (2007) has used data only from ASI and not from Census of SSIs/MSMEs. Moreover, the study period is restricted only up to 1997-1998. To full fill these gaps in the earlier studies, the present paper estimates and compares TFPG between large organised sector industries and SSIs/MSMEs using data over the period 1973-1974 to 2006-2007, and DEA and Malmquist TFPG index methodology.

Methodology

For estimating TFPG, the non-parametric mathematical linear programme Data Envelopment Analysis (DEA) and the Malmquist TFPG index has been used. DEA is a mathematical programming method for estimating the production frontiers which constructs a non-parametric piecewise frontier given the data on input and output. DEA was developed by Charnes et al. (1978) following the piecewise-linear convex hull approach of Farrell in 1957. The main advantage of using non-parametric DEA method is the non-requirement of explicitly specifying a mathematical form of the production frontier. The Malmquist TFPG index decomposes the estimate of TFPG into two components such as technical efficiency change and technological change. TFPG involves changes in technical efficiency in addition to technological changes in the presence of inefficiency of production and thereby use of Malmquist TFPG index is an advantage. Moreover, due to lack of information on market structures and prices, use of Malmquist index is also justified (Raj and Duraisamy, 2008, pp. 376). In this paper, DEA has been used to estimate Malmquist TFPG index with an output oriented measure of technical efficiency. Therefore, technical efficiency is defined as how much output can be proportionally increased without changing the input quantities relative to an efficient frontier.

An output oriented Malmquist productivity change index is briefly represented below following Coelli (1996, pp.27-28) and Raj and Duraisamy (2008, pp. 376-378).

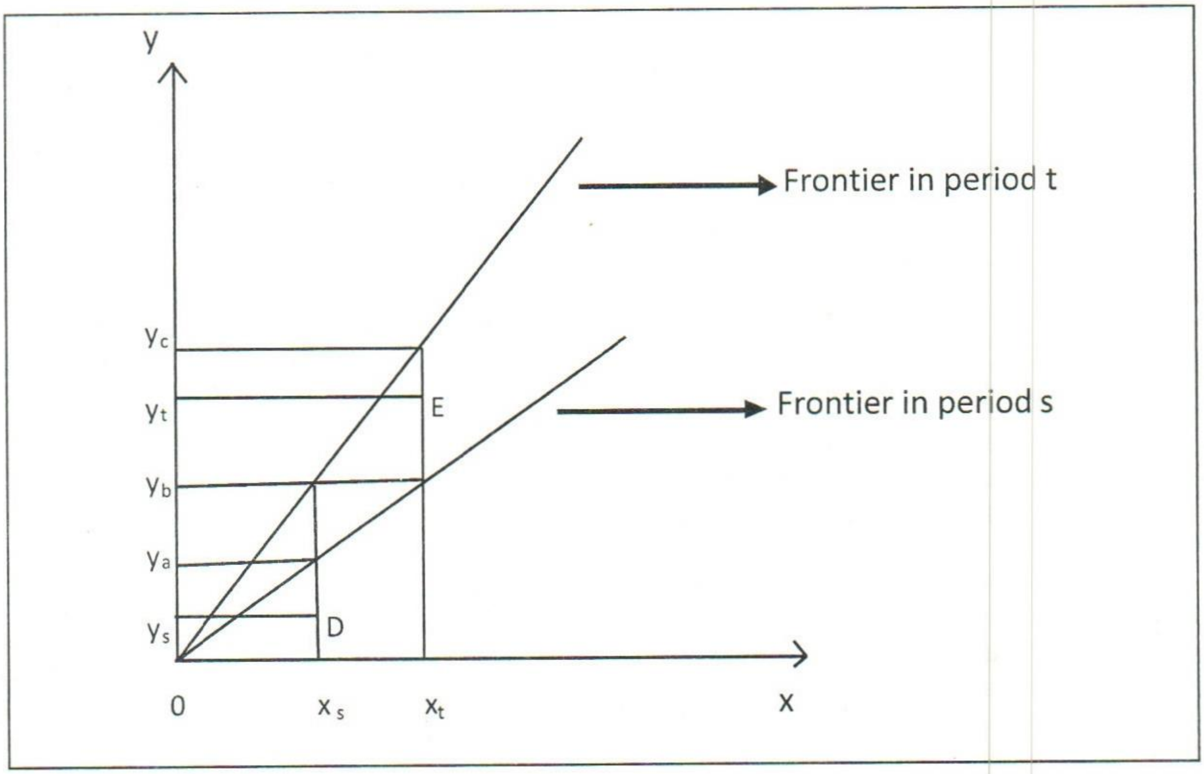
$$m_0(y_s, x_s, y_t, x_t) = \frac{d_o^s(y_t, x_t)}{d_o^s(y_s, x_s)} \left[\frac{d_o^s(y_t, x_t) d_o^s(y_s, x_s)}{d_o^s(y_s, x_s) d_o^t(y_s, x_s)} \right]^{1/2} \quad (1)$$

Equation (1) represents productivity of the production point (y_t, x_t) relative to the production point (y_s, x_s). The notation $d_s^0(y_t, x_t)$ is the distance from the period t observation to period s technology. A value of m_0 greater than one indicates positive TFPG while a value less than one indicates TFPG decline between period s and t. The index is the geometric mean of two output oriented Malmquist TFP indices. The advantage of using Malmquist index is the availability of decomposition of TFP change into technical efficiency change (catching up effect) and technological change (frontier effect). In equation (1) the term outside the third bracket is an output-oriented measure of technical efficiency while the term inside the bracket is a measure of technological change between period s and t. Hence, it is possible to write:

TFPG = [Technical efficiency change × Technological change] (2)

The following figure shows this decomposition for a single output and single input case under constant returns to scale technology:

The points D and E are production points of periods s and t respectively. Production in each period takes place below the technology and hence there is technical inefficiency. Therefore, it is possible to show from the above figure:



Source: Bala (2007, pp. 98)

Figure: Malmquist Productivity Indices

$$\text{Technical efficiency change} = \left(\frac{y_t/y_c}{y_s/y_a}\right) \quad (3)$$

$$\text{Technical change} = \left(\frac{y_s/y_b}{y_t/y_c} \times \frac{y_s/y_a}{y_s/y_b}\right)^{1/2} \quad (4)$$

The above equation (1) is calculated by DEA methodology which calculates the distance functions using non-parametric linear programming problems.

However, it is worth mentioning some of the limitations of using DEA method. These include: (1) sensitivity of the estimates of technical efficiency to measurement errors, (2) non-existence of statistical random error, and (3) non-permitting any statistical test of hypothesis.

Given, the theoretical part of the methodology, the empirical estimation has been done using the software Data Envelopment Analysis Programme (DEAP), version 2.1 from Coelli (1996).

Data and measurement of variables

Data

For the large scale sector, data on the required variables for estimation of TFPG such as output, labour, and capital has been taken from the reports of Annual Survey of

Industries (ASI) which is the main source of data on the organised sector of India. The organised sector is comprised of industries registering under the Sections 2 m (i) and 2 m (ii) of the Factories Act of 1948[2]. These industries are characterised by very large scale of production and having higher per unit output compared to the industries in the small scale sector. Except for 1972, the ASI is conducted annually in India since 1959 under the Collection of Statistics Act 1953 and the rules frame there-under in 1959.

Data on the required variables pertaining to the small scale sector has been taken from the reports of different Censuses of registered Small Scale Industries (SSIs)/Micro Small and Medium Enterprises (MSMEs) conducted by the Development Commissioner of SSIs/MSMEs[3]. Till now four Censuses are available and the most recent one is the Fourth Census of MSMEs during 2006-07. The previous three Censuses of registered SSIs were conducted during 1973-74, 1987-88, and 2001-02 respectively.

In this article, state level data on output, labour, and capital has been taken from the reports of four Censuses of registered SSIs/MSMEs for 1973-74, 1987-88, 2001-02, and 2006-07 respectively along with state level data on the same from the reports of ASI for the corresponding periods. The period (1973-74 to 1987-88) has been considered as the pre-liberalisation period while the periods (1987-88 to 2001-02) and (2001-02 to 2006-07) have been taken as the liberalisation period and the late liberalisation period respectively. Liberalisation actually started in 1990-1991 and thus pre-liberalisation period should include up to 1989-90. However, the Second Census of registered SSIs was conducted during 1987-88 and therefore 1989-90 could not be considered as the last year of pre-liberalisation period. Instead, 1987-88 has been taken as the last year. Moreover, the period (1987-88 to 2001-02) may be considered as the liberalisation period on the ground that some initial policy measures were taken up during the late 1980s.

Measurement of variables

Output has been measured by the gross value of output produced in the large and small scale sectors. The inputs such as labour and capital have been measure by the total number of workers employed and the market value of fixed assets/fixed capital respectively. In particular, state wise data on gross value of output, number of workers, and market value of fixed assets have been obtained from ASI and SSIs/MSMEs Censuses for 1973-74, 1987-88, 2001-02, and 2006-07. State wise gross output data for organised/ large scale and registered small scale sectors has been deflated at 2004-05 prices using state wise Net Domestic Product (NDP) data for registered manufacturing sector at 2004-05 prices from the report of Economic and Political Weekly Research Foundation (EPWRF, 2009) on Domestic Product of States of India: 1960-61 to 2006-07. State wise data on market value of total fixed assets has been deflated at 2004-05 prices using all India level data on Gross Fixed Capital Formation (GFCF) for the registered manufacturing sector at 2004-05 constant prices the back series of National Accounts Statistics 2011(http://mospi.nic.in/Mospi_New/upload/back_series_2011.htm). Due to unavailability of state wise GFCF data, national level GFCF data has been used for deflating state wise fixed assets. All the variables have been expressed in per unit basis using state wise data on number of units from ASI and Census of registered SSIs/MSMEs.

Analysis of results

Table 2 in the following shows the estimates of average TFPG and its decomposition into technical efficiency change and technological change across different states by large scale and SSIs/MSMEs sectors over the period 1973-1974 to 2006-2007:

Analysis by different Phases

Phase-I (1973-74 to 1987-88)

Table 3 indicates positive TFPG during the period 1973-74 to 1987-88 i.e. prior to liberalisation in both the large scale and the SSIs/MSMEs sectors. On an average TFPG is higher in MSMEs sector (1.971) compared to the large scale industries (1.204) during this period. The growth rate of TFP per annum during the pre-liberalisation period (1973-74 to 1987-88) is about 1.46 percent and 6.94 percent in the large scale and MSMEs sectors respectively[4]. For

[2]Section 2 m (i) includes all industries whereon 10 or more workers are working, or were working on any day of the preceding 12 months, and in any part of which a manufacturing process is being carried on with the aid of power. Section 2 m (ii) includes all industries whereon 20 or more workers are working, or were working on any day of the preceding 12 months, and in any part of which a manufacturing process is being carried on without the aid of power.

[3]There have been changes in the definition of small scale sector of India over time. Prior to the enactment of the MSMED Act in 2006, the sector was known as SSIs sector. At present, this sector is known as MSMEs sector. Accordingly, the definition of small scale sector differs across different Censuses.

[4]Perannum growth rates of TFP are obtained as (g-1)X1, where g is the average TFPG for the entire period.

Table 2: TFPG and its decomposition across different states by large and SSIs/MSMEs sectors over 1973-74 to 2006-07

States	Technical Efficiency Change		Technological Change		TFPG	
	Large Scale	MSMEs	Large Scale	MSMEs	Large Scale	MSMEs
Phase-I: TFPG of large scale industries and SSIs/MSMEs sector between 1973-74 to1987-88						
Andhra Pradesh	1.035	0.449	1.137	6.549	1.177	2.939
Gujarat	1.000	0.323	1.323	5.265	1.323	1.700
Karnataka	1.086	0.371	1.296	5.772	1.408	2.143
Kerala	1.109	0.109	1.173	6.631	1.301	0.720
Madhya Pradesh	0.597	0.224	1.560	5.265	0.932	1.577
Maharashtra	0.997	0.475	1.324	7.030	1.321	2.501
Orissa	1.024	0.272	1.554	6.675	1.591	1.818
Punjab	0.686	0.219	1.536	5.793	1.054	1.271
Rajasthan	0.649	0.249	1.554	6.112	1.009	1.521
Tamilnadu	0.832	1.319	1.262	7.031	1.049	9.270
Uttar Pradesh	1.220	0.367	1.569	6.170	1.913	2.263
West Bengal	0.668	0.218	1.163	7.030	0.777	1.530
Average o All States	0.885	0.316	1.361	6.245	1.204	1.971
Phase-II: TFPG of large scale industries and SSIs/MSMEs sector between 1987-88 to 2001-02						
Andhra Pradesh	0.850	1.397	0.245	0.083	0.208	0.115
Gujarat	1.000	0.838	0.416	0.098	0.416	0.082
Karnataka	1.000	1.902	0.360	0.081	0.360	0.154
Kerala	2.780	3.246	0.216	0.071	0.601	0.231
Madhya Pradesh	1.986	3.886	0.526	0.103	1.044	0.237
Maharashtra	1.237	2.656	0.387	0.061	0.478	0.274
Orissa	1.225	4.902	0.591	0.082	0.724	0.404
Punjab	1.741	2.580	0.236	0.091	0.412	0.235
Rajasthan	0.910	2.707	0.421	0.095	0.383	0.256
Tamilnadu	1.755	0.335	0.245	0.065	0.430	0.022
Uttar Pradesh	1.236	2.004	0.379	0.092	0.468	0.184
West Bengal	4.390	15.563	0.294	0.064	1.290	1.001
Average of All States	1.476	2.338	0.342	0.081	0.505	0.190
Phase-III: TFPG of large scale industries and SSIs/MSMEs sector between 2001-02 to 2006-07						
Andhra Pradesh	0.931	1.475	1.127	0.793	1.048	1.169
Gujarat	1.000	0.744	1.042	0.881	1.042	0.655
Karnataka	0.781	1.182	0.982	0.581	0.766	0.687
Kerala	1.351	2.409	1.363	0.674	1.842	1.623
Madhya Pradesh	1.204	1.063	1.028	1.124	1.238	1.195
Maharashtra	1.361	2.057	1.032	0.642	1.404	1.321
Orissa	0.770	0.840	1.049	0.695	0.808	0.584
Punjab	0.865	1.766	1.228	1.078	1.062	1.903
Rajasthan	1.349	1.252	1.002	1.004	1.352	1.257
Tamilnadu	0.932	1.359	1.140	0.691	1.063	0.939
Uttar Pradesh	1.194	1.776	0.996	0.792	1.189	1.406
West Bengal	1.185	0.834	1.055	0.698	1.249	0.583
Average of All States	1.055	1.310	1.082	0.787	1.142	1.031

Source: Author's calculations based on ASI and SSIs/MSMEs Census data, and DEA methodology.

the large scale industries all the states except Madhya Pradesh and West Bengal experienced positive TFPG during the period 1973-74 to 1987-88. For the MSMEs sector it is only Kerala where TFPG has declined. All states except Kerala show higher growth in TFP for the MSMEs compared to the large industries over this period. Among the twelve states, TFPG is observed to be maximum for Uttar Pradesh and Tamilnadu in large scale and MSMEs sectors respectively. Tamilnadu has significantly higher growth of TFP during this period compared other states in the MSMEs sector. Average technical efficiency change of all twelve states for the large scale industries sector during the period 1973-94 to 1987-88 is 0.885 which is greater than the same for the MSMEs sector (0.316). On the contrary, average technological change of the MSMEs over the same period (6.245) is much higher than that of the large industries (1.361). These two results also hold across all the states. It is observed that during this period technological progress is the major contributor of TFPG for both the large scale and MSMEs sectors. For the MSMEs, all the states experienced technical progress while except Tamilnadu all other states experienced decline in technical efficiency. For the large scale sector all states have positive technological change or technological progress. States such as Andhra Pradesh, Gujarat, Karnataka, Kerala, Orissa and Uttar Pradesh registered improvement in technical efficiency while the rest registered decline in the same. In general, the Phase 1973-74 to 1987-88 is characterised by decline in average technical efficiency and improvement in technology i.e. technological progress for large scale and MSMEs sector which is also found to be the main contributor of TFPG.

Phase-II (1987-88 to 2001-02)

The TFPG rates measured in terms of Malmquist productivity index indicate decline during the period 1987-88 to 2001-02 for both the large scale and MSMEs sectors. It may be noted that while liberalisation actually started in 1991, some initial policy measures were taken in the late 1980s.Therefore, the results further indicate decline in TFPG in the liberalisation period. Contrary to Phase-I, on an average TFPG is higher for the large scale industries sector (0.505) compared to the MSMEs sector (0.190). All states have greater TFPG in the large scale sector compared to the MSMEs sector over this period. The rate of decline in TFP per annum during the period 1987-88 to 2001-02 is about 3.54 percent and 5.79 percent in the large scale and MSMEs sectors respectively. However, all states except Madhya Pradesh and West Bengal in the large scale sector experienced decline in TFPG. Except West Bengal, the rest of the states in the MSMEs sector show declining TFPG. Among the states, West Bengal experienced growth in TFP during 1987-88 to 2001-02 for both the large scale and MSMEs sectors. West Bengal also exhibits the highest growth in TFP over this period among all the states for both the large scale and the MSMEs. Like Phase-I, technological change is found to be the main explanation behind TFP changes in Phase-II for both the sectors. On an average in Phase-II, technical efficiency has improved for both large scale and MSMEs sectors. However, during the same Phase significant technical regress is observed in both large scale and MSMEs sectors. Hence, technological regress is the main contributor of declining TFPG in Phase-II. Technical efficiency improvement is greater in the MSMEs sector compared to the large scale sector for the majority of the states while technical regress is much higher for all the states in the MSMEs sector compared to the large scale sector. Within the MSMEs sector technical efficiency has improved for all the states except for Gujarat and Tamilnadu in Phase-II while within the large scale sector Andhra Pradesh and Rajasthan exhibit declining technical efficiency of industries. Technical efficiency of large scale industries has remained the same in Gujarat and Karnataka in Phase-II. West Bengal registered the maximum improvement in technical efficiency in Phase-II within both large scale and MSMEs sectors. All states experienced technical regress in Phase-II within both sectors. The technological regress during Phase-II has outweighed the improvement in technical efficiency for all the states so that all of them registered declining TFPG.

Phase-III (2001-02 to 2006-07)

During the third Phase i.e. during the period 2001-02 to 2006-07, growth in TFP is positive for both the large scale and the MSMEs sectors. Therefore, the results indicate both the sectors experienced positive TFPG during the late liberalisation period. On an average TFP grew at a higher rate in the large scale industries sector (1.142) compared to the MSMEs sector (1.031) during this period. TFPG per annum during Phase-III in the large scale and MSMEs sectors is 14.20 percent and 3.10 percent respectively. The analysis by different states shows that Andhra Pradesh, Punjab and Uttar Pradesh registered higher TFPG in the MSMEs sector compared to the large scale sector. However, TFPG for the rest of the nine states is higher in large scale sector compared to the MSMEs sector. Karnataka and Orissa exhibited negative TFPG during 2001-02 to 2006-07 in the large scale sector while Gujarat, Karnataka, Orissa, Tamilnadu and West Bengal exhibited negative TFPG in the MSMEs sector during the same period. Thus, TFPG is negative for almost 50 percent of the states in the MSMEs sector. TFPG is negative in both large scale and MSMEs sectors for the states Karnataka and Orissa during the third Phase. Among the states growth of TFP is relatively high for Kerala during the third Phase in both the sectors. The decomposition of the TFPG in Phase-III between technical efficiency change and technological change shows the former is the main contributor of TFPG in the MSMEs sector. In contrast, both technical efficiency change and technological change play almost similar role in explaining TFPG in the large scale sector during Phase-III. All the states except Gujarat, Orissa and West Bengal have shown technical efficiency improvement between 2001-02 to 2006-07 in the MSMEs sector. However, except Madhya Pradesh, Punjab, and Rajasthan all the states in the MSMEs sector show technological regress. For Karnataka and Tamilnadu the technological regress has more than off sated the technical efficiency improvement of the MSMEs between 2001-02 to 2006-07 resulting in declining TFPG. The large scale industrial sector on the other hand shows both technical efficiency improvement and technological progress during the same period. Although five states in the large scale sector exhibit decline in technical efficiency, except Karnataka and Uttar Pradesh the rest exhibit technological growth. For Karnataka technical efficiency decline and technical regress took place together. In general, Phase-III is characterised by improvement in TFPG in both the large scale and MSMEs sector with technical efficiency improvement in both sectors and technological regress in the later.

The Malmquist TFPG index further permits the decomposition of the technical efficiency change component into pure efficiency change and scale efficiency change. The following Table 3 summarises the decomposition of technical efficiency change (improvement) during Phase-III into pure efficiency change and scale efficiency change by large scale industries and MSMEs sectors respectively:

It follows from Table 3 that technical efficiency improvement during the period 2001-02 to 2006-07 is largely contributed by scale efficiency change compared to pure efficiency change in the MSMEs sector. In the large scale sector on the other hand the improvement of technical efficiency is contributed by both scale efficiency and pure efficiency change in almost similar manner. On an average the growth of scale efficiency per annum during Phase-III of the MSMEs is about 29 percent while the growth of pure efficiency change per annum is only 1.40 percent. All states except Orissa show positive scale efficiency

Table 3: Decomposition of technical efficiency change into pure efficiency change and scale efficiency change during Phase-III (2001-02 to 2006-07)

States	Pure Efficiency Change		Scale Efficiency Change		Technical Efficiency Change	
	Large Scale	MSMEs	Large Scale	MSMEs	Large Scale	MSMEs
Andhra Pradesh	1.019	0.919	0.913	1.605	0.930	1.475
Gujarat	1.000	0.596	1.000	1.247	1.000	0.743
Karnataka	0.782	0.921	0.998	1.283	0.780	1.182
Kerala	1.000	1.722	1.351	1.399	1.351	2.409
Madhya Pradesh	1.000	1.000	1.361	1.063	1.361	1.063
Maharashtra	1.134	1.767	1.062	1.164	1.204	2.057
Orissa	1.000	1.000	0.770	0.840	0.770	0.840
Punjab	0.882	1.188	0.980	1.486	0.864	1.765
Rajasthan	1.225	0.932	1.101	1.344	1.349	1.253
Tamilnadu	1.012	0.936	0.921	1.452	0.932	1.359
Uttar Pradesh	1.197	1.022	0.997	1.737	1.193	1.775
West Bengal	1.196	0.730	0.990	1.142	1.184	0.834
Average of All States	1.029	1.014	1.025	1.291	1.055	1.310

Source: Author's calculations based on ASI and SSIs/MSMEs Census data, and DEA methodology.

change in the MSMEs sector. This implies that the advantages of growth in size in the MSMEs sector during the period 2001-02 to 206-07 have been realised positively. Scale efficiency increase of MSMEs is higher than that of the large industries. Moreover, except Madhya Pradesh all states in the MSMEs sector have higher growth of scale efficiency compared to the states in the large scale sector. In contrast to the MSMEs sector, there is decline in scale efficiency growth and increase in pure efficiency growth in majority of the states in the large scale sector. Moreover, majority of the states in the large scale industries sector show a higher growth of pure efficiency than the states in the MSMEs sector.

Conclusions and implications

TFPG is important for long run economic growth of income, output, employment, and other important economic indicators. Using data for twelve states, this paper estimated TFPG of the SSIs/MSMEs of India during pre and post liberalisation periods for examining how liberalisation impacted TFPG of the SSIs/MSMEs sector. Furthermore, a comparison of TFPG between large scale and SSIs/MSMEs sectors has been done to reveal whether and how TFPG has differed between these two sectors during pre and post liberalisation. The results indicate positive TFPG of the SSIs/MSMEs sector during pre-liberalisation period (1973-74 to 1987-88) and that it remained greater than that of the large scale industries which also experienced positive TFPG. The positive TFPG during this period was contributed by technological growth which remained much higher for the SSIs/MSMEs sector than that of the large industries. In contrast, TFPG of both the large scale and the SSIs/MSMEs declined during the liberalisation period (1987-88 to 2001-02). The decline is more for the MSMEs compared to the large industries during this period. Moreover, in spite of positive technical efficiency change, there was evidence of severe technological regress in the SSIs/MSMEs sector which is also the main factor behind TFPG decline. However, TFP improved and registered positive growth rates in the SSIs/MSMEs sector during the late liberalisation period (2001-02 to 2006-07) but remained less than that of the large scale industries. Although, MSMEs experienced positive TFPG in the late liberalisation period, it was mainly on account of increasing technical efficiency. Like the period (1987-88 to 2001-02), there was also technological regress in the MSMEs sector during (2001-02 to 2006-07) while large industries during the same period experienced technological growth.

These results have some important policy implications for long term growth of the SSIs/MSMEs sector of India. Lack of technological growth remained a major constraint for TFPG of the SSIs/MSMEs during the post-liberalisation period Vis-a-vis the large scale sector. Therefore, recent government policies for the SSIs/MSMEs sector should be focused on technology upgradation. Some of the important factors restraining technological growth of this sector are lack of technological information, non-availability of skilled labour force, entrepreneurship problems, lack of managerial skills, high cost of production due to lack of capital resources, etc. Hence, policy efforts are needed to enable SSIs/MSMEs overcoming these constraints. In this context, the policy measures and schemes of the Ministry of MSMEs and the government of India for technology up gradation and productivity enhancement under the National Manufacturing Competitiveness Programme (NMCP) during 2008 would be very crucial for ensuring technological growth and thereby long term economic growth of the SSIs/MSMEs sector of India.

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Vision is not enough, it must be combined with venture. It is not enough to stare up the steps. We must step up the stairs.

—Václav Havel

Focus

A Perspective on the Need of Quality and Productivity Management in Indian and Global Sponge Iron Industry

R.L. SHRIVASTAVA AND V.S. GORANTIWAR

Sponge iron industry is relatively new & hence facing many teething problems. The literature survey indicates that the quality & productivity is always neglected for the want of higher & higher production. This article makes an attempt to identify the facts & figures of iron & steel industry of which the sponge iron is an integral part. Gap analysis, SWOT analysis, growth factors & problems are also discussed to understand overall scenarion of steel & sponge iron in the world & in particular in India. Overall, it highlights the need of framework development of quality-productivity improvement for sponge iron industry.

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One of the most useful and versatile material, steel is considered to be the backbone of human civilization (Vadde & Srinivas, 2012). As the steel industry has tremendous forward & backward linkages in terms of material flow, income & employment generation, the growth of an economy is closely related to the quantity of steel used by it (Burange & Yamini, 2010). Sponge iron is the nerve for steel making (Steelworld.com). Since the turn of millenium, the world steel industry has experienced significant changes. First, global crude steel production per annum increased to around 120 million tonns by 2006, after having fluctuated at around 80 million tonnes for nearly three decades from the early 1970s to around 2000 (SATO, 2009).

Although direct reduction was the first iron making method and has been practiced for thousands of years, the economic conditions required for commercialization did not occur until the late 1950s. Since then, annual production of DRI has grown to over twenty million metric tons. It has now become a key component in keeping steelmakers competitive. Availability of raw materials, economical scenario, skilled manpower with good knowledge of present process, pollution free environment, local people acceptance are few important criteria for overall growth of SI industry.

In the editorial, Bhatnagar (2009) stated that in the past years, the Indian as well as global economy have witnessed a very high degree of uncertainty and volatility. The Indian sponge Iron Industry also felt the cascading effects of economic slowdown. However, the industry feels squeezed, but with its fundamentals still intact, it has the strength to utilize its full potential and grow at double-digit rates when backed by the Government in terms of raw material inputs. The key growth drivers being infrastructure development and high level urbanization, escalating demand from housing, automobile, white goods and rural/ agricultural development sectors. To achieve the production target of 124 MT till the year 2020, the steel Industry has to heavily depend on the secondary route, using Sponge Iron as a major source of quality metallic. The Sponge Iron Industry is fully geared up for the future but policy initiatives from the Government on availability and prices of raw materials have become a pressing need of the manufacturers. There is confidence about helps for this sunrise industry and await all steps with optimism.

According to Annual report 2011-12; Ministry of Steel; India continues to maintain its lead position as the world's largest producer of direct reduced iron (DRI) or sponge iron since 2004-05. To retain this spot, it is necessary to concentrate on strength and weakness. As stated in the report on 'Sponge Iron Industry', by Central Pollution Control Board, Ministry of Environment & Forest (2007); the SI production from a meager 1.31 million tons in 1991-92; it jumped to 10 million tons in 2004-05 and India emerged as the largest producer of coal based sponge iron in the world since 2004. The production has reached to 26.71 MT in the year 2010-11.

During literature review, it is noticed that the data reporting is different in different sources. Few authors have reported data for calendar year, while some reported in financial year. Also data collection process may be different for different sources. Hence, some differences were noticed in the reported figures. However, attempts are made to report the data from authentic sources such as –

a) World Steel Organization, (www.worldsteel.org)

b) Ministry of Steel, Government of India (www.steel.gov.in)

c) Ministry of Environment & Forest, Govt. of India.

d) Joint Plant Committee, the only institution in India, which is officially empowered by the ministry of steel / Government of India to collect data on the Indian iron and steel industry.

e) Sponge Iron Manufacturer's Association of India (SIMA); A national level association of DRI industry in India, established in 1991, to promote and protect the interest of the Indian sponge iron industry.

f) Technology developers of international repute, such as Midrex.

g) Few authors who are working in sponge ion field since very long & published many articles in technical & trade journals of national & international repute.

History of sponge iron

The recycling of the scrap after second world war was great work done to find out the way to clear all war debries during 60's. The contribution of arc furnace to meet such challenges was also established in the recovery of the steel. The process was widely accepted by almost all developing countries where generation of scrap was less in comparision to requirement. Steel produced by recycling process found much cheaper than the steel produced by blast furnace process. The scrap vanished gradually causing threat to arc furnaces where BF-BOF process continued its predominance as age old process in the world. During 70's the reduction of iron ore in small way was carried out in USA and birth of DRI / sponge iron was brought in to the existence (Sahu, 2001). Sponge iron industry entered in to Indian market way back in 1980, as an alternate route of steel making. India having good quality iron ore & non-coking coal, sponge iron process got stabilized with time. Pilot plant of 100 tpd at Andhra pradesh was set up for testing Indian raw materials. This small size became a viable model. Some old cement kilns were modified to sponge iron units at a much lower cost. Then started mushrooming of sponge iron units all over India. It is either nearer to iron ore source or coal source (Khattoi, 2011). The reason for the tremendous growth of the sponge iron industry world over could be attributed to the advantages of using sponge iron in electric arc furnace, partly substituting scrap (Sen, 2011).

Indian Scenario – Steel

The Indian iron and steel industry is nearly a century old, with Tata iron and steel company as the first integrated steel plant set up in 1907 (http://www.cci.in/pdf/surveys_report/iron-steel-industry.pdf). However, a humble beginning of the modern steel industry was reached in India at Kulti in West Bengal in the year 1870 (Vadde & Srinivas, 2012). Steel is the first core sector, completely freed from licencing, pricing & distribution control in India in the year 1990-91. The economic modernization processes are driving the sharp rise in demand for steel. The new industrial policy adopted by the government of India has opened up the Iron & steel sector for private investment. While the existing units are being modernized/ expanded, a large number of new / Greenfield steel plants have also come up based on modern, cost effective, state of the art technologies. India's steel production during 2009 – 10 was 64.88 million tons (MT), up 11% from a year ago. India has emerged as the fifth largest producer of steel in the world and is likely to become the second largest producer of crude steel by 2015-16. Notably, Tata Steel, the second largest steel producer in India, has been the world/s lowest cost steel producer since 2001. The comparative advantage of India's Iron & Steel industry is the ready domestic availability of significant reserves of high quality iron ore. The state of Orissa contains 25% of India's Iron ore reserves and 20% of India's coal reserves.

According to Sen (2011), emergence of India as one of the very strong economy is to a great extent led by the overall growth of the steel segment. He also felt that the future of steel in India awaits to unfold yet another phase of growth and prosperity. Sponge iron industry totally depends on the steel industry as it is the raw material for the production of steel through electric arc furnace route. Hence, any discussion on scenario of sponge iron industry will be incomplete without discussion on steel. Govt. of India through various ministries such as steel ministry; commerce & industry ministry etc. publishes related information for the various purposes. Given below is the brief account of Indian steel scenario.

Schumacher & Sathaye (1998) stated that the iron & steel industry presents one of the most intensive sectors within the Indian economy and is therefore of particular interest in the context of both global and local discussion. India has acquired a central position on the global steel map with the ever increasing demand from sectors like infrastructure, real estate and automobiles, at home and abroad, besides continuous modernisation, and improvement in energy efficiency. India was world's fourth largest crude steel producer in 2011-12 and is expected to become the second largest producer by 2015-16. The per capita steel consumption went up to 59 kg in 2011-12, from 34 kg in 2004-05. (IBEF, http://www.ibef.org/artdispviewcampaign.aspx?cat_id=487&art_id=32689&in=69). India's steel making capacity is estimated to exceed 100 million tonnes (MT) by 2013 and the production is expected to reach 275 MT by 2020.

Market Size

The consumption of iron & steel is primarily driven by the manufacturing, construction and infrastructure sectors, which have witnessed impresive growth in India in the past few years (SATO, 2010). The major players in the Indian market are Tata steel, Steel Authority of India Limited (SAIL), Bhushan Power & Steel Ltd, Jindal Steel & Power Ltd (JSPL), ESSAR Steel. Indian crude steel production is estimated to grow at a compound annual growth rate (CAGR) of around 10 per cent during 2010-2013, whereas the finished steel consumption is estimated to grow at a CAGR of around 12 per cent during FY 2012-14. During 2011-12, the real consumption of finished steel in the country was 70.92 MT as against production of 73.42 MT.

Challenges to Indian steel industry

1. High cost of power – Steel industry is power intensive. Power has major share in the cost of steel. The cost of power is high in India, making the steel production uncompetitive as compared to many countries in the world.
2. Non-availability of metallurgical coke – High quality coke is required for better quality steel production. Import of metallurgical coke increases the production cost of steel.
3. Unremunerative prices – Stagnating demand, domestic oversupply and falling prices in the last four years have hit Indian steel makers.
4. Endemic deficiencies – These are inherent in the quality and availability of some of the essential raw materials available in India.
5. High cost of capital – The interest rate on capital is exorbitantly high in India as compared to Japan & USA.
6. Low labour productivity – Though the labour is cheap but the labour productivity is extremely poor. For e.g. the labour productivity of SAIL & TISCO are 75 t/ man year & 100 t / man year. The same figure for POSCO, Korea & NIPPON, Japan are 345 t / man year & 980 t / man year.
7. Other systemic deficiencies – Poor quality of basic infrastructure like road, port etc; lack of funding in R & D; delay is absorption of latest technology by existing units; non-availability of good quality of iron ore; high level of taxation etc

Opportunities before Indian steel industry

The biggest opportunity is the enormous scope for increasing consumption of steel in almost all sectors in India. Even to reach the comparable developing and lately developed economies like China and few Europian countries, a quantum jump in steel consumption will be required. India has fourth largest iron ore reserves in the world. It has abundance of coal & other raw materials required for iron & steel making. India has third largest pool of technical manpower. The labour cost in India is low. All this is reflected in the lower production cost of steel in India as compared to many advanced countries. Unexplored rural market is identified as potential area.

Government Initiatives

Initiatives taken by the Government of India, include the following:

- 100 per cent foreign direct investment (FDI) is allowed in the sector
- Large infrastructure projects in Public-Private Partnership (PPP) mode are being formed
- The Government is encouraging research and development (R&D) activities in the sector
- Reduced custom duty and other favourable measures
- The Government of India has framed the National Steel Policy (NSP) to encourage the steel industry to reach global benchmarks in terms of quality, cost and efficiency.

Road Ahead

Indian steel production has grown strongly in recent decades and is likely to continue to expand as domestic producers increase their capacity to meet anticipated demand. The biggest opportunity before Indian steel sector is that there is enormous scope for increasing consumption of steel in almost all sectors, including the rural sector which remains fairly unexposed to the multi-faceted use of steel.

Steel making companies in India have launched massive expansion/ modernization programs with a view to adopt modern technology which is energy efficient, cost effective and environment friendly. They have also shown keenness to adopt latest technologies to make existing steel manufacturing processes more efficient and productive. With the present emphasis on creating physical infrastructure, massive investment is planned. The low per capita consumption as compaired to developed countries suggests that there is a tremendous potential for greater demand of steel.

Indian Scenario – Sponge Iron

India accounted for major share of global sponge iron production and has occupied the top slot from 2004, for being the largest producer of sponge iron across the globe. The Indian sponge iron industry has come a long way but instead of resting on its laurels it is looking steady and subsequently focusing on broadening its scope of growth. With the country's strong economic environment poised for an upturn, the industry prospects are certainly bright in time to come. There has been an inspiring track record of growth of sponge iron industry in India during the last decade. Table 1 shows the data from the ministry of steel about production of gas based & coal based sponge iron in India from 2006-07 to 2011-12. While table 2 shows segment wise production and capacity utilization for year 2010-11-12. Reduced growth rate in the year 2012 demands something to do for improvement in quality & productivity

Table 1: Production of SI in India

Year	Production of Sponge Iron (in Million Tons)		Total (Gas + Coal) Based (in Million Tons)
	Gas based	Coal based	
2006-07	5.26	13.08	18.34
2007-08	5.84	14.53	20.37
2008-09	5.52	15.57	21.09
2009-10	6.15	18.18	24.33
2010-11	5.79	20.92	26.71
2011-12(Apr –Dec)	5.79*	20.92*	21.22*

(Ref : www.steel.gov.in Annual Report 2011-12, Ministry of Steel)

Table 2 : Segment Wise Production and Capacity Utilization in India

	2010-11	2011-12	% Growth
A. Gas Based Units - Production (Tons)	6189917	5150018	(-) 0.83%
Annual Installed Capacity (Lakh Tons)	96	96	
Capacity Utilisation (%)	64.47	53.64	
B. Coal Based Units - Production (Tons)	17065432	15407645	(-) 0.90%
Annual Installed Capacity (Lakh Tons)	253.35	257.9	
Capacity Utilisation (%)	67.35	59.93	
Grand Total (A+B)	23255349	20557663	(-) 0.88%
Total Capacity (Lakh Tons)	349.35	353.09	
Overall Capacity Utilisation	66.56	58.22	

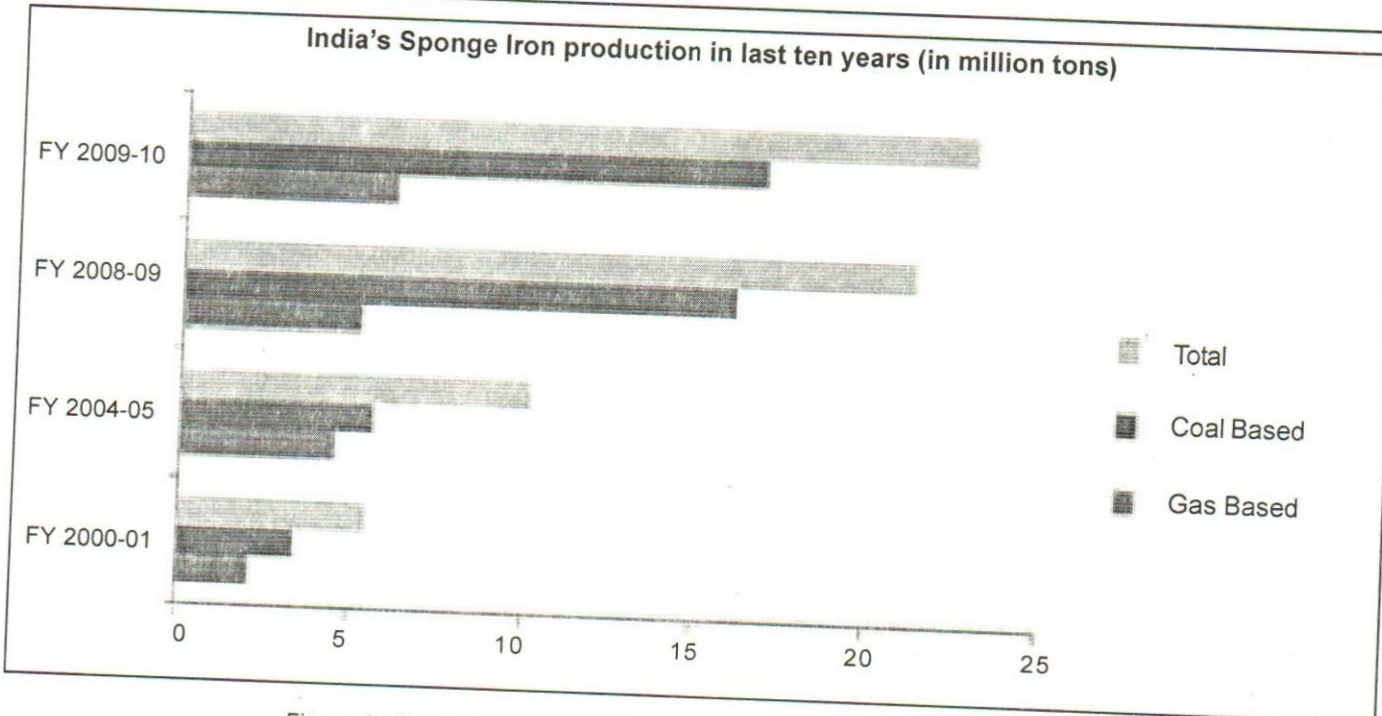

Figure 1 : Graph showing india's sponge iron production in last 10 years in India
(Ref : Ore team research, 2011)

in SI industry. Fig.1 shows the graph of production of sponge iron in last 10 years. Table 3 shows the production, installed capacity & capacity utilization of gas & coal based sponge iron.

The year 2011 – 12 was the year of political turmoil in India. Lot of policy changes have occurred which affected the sponge iron industry, directly or indirectly. Availability of iron ore & coal reduced drastically. Many units could not operate to its full capacity. Efforts for quality & productivity improvement were totally at bay. However, few companies (e.g. Tata Sponge Iron Ltd) still managed to earn the profit, resulting from their efforts for quality & productivity improvement through Total Quality Management (TQM) proving the importance & necessity of implementation of TQM in SI industry in India.(www.spongeironindia.in/presentations/PCTATASPONGE SIMAPresentation100912.pdf, www.tatasponge.com/investor/annualreports/annualreport2010-11.pdf, www.tata sponge.com/investor/annualreports/annualreport2011-12.pdf).

Table 3 : Production, installed capacity & capacity utilization of gas & coal based sponge iron in India

PARTICULARS	2009 – 10	2010 - 11
Production of Gas Based Sponge Iron (Tons)	61,72,213	61,89,917
Installed Capacity of Gas Based Sponge Iron per year (Tons)	96,00,000	96,00,000
Capacity Utilization of Gas Based Sponge Iron Production	64.29 %	64.47 %
Production of Coal Based Sponge Iron (Tons)	168,21,369	170,65,432
Installed Capacity of Coal Based Sponge Iron per year (Tons)	238,14,000	253,35,000
Capacity Utilization of Coal Based Sponge Iron Production	70.63 %	67.35 %
Production of Gas + Coal Based Sponge Iron	229,93,572	232,55,349
Installed Capacity of Gas + Coal Based Sponge Iron per year (Tons)	334,14,000	349,35,000
Capacity Utilization of Gas + Coal Based Sponge Iron Production	68.81 %	66.56 %

India has only three gas based sponge iron plants, i.e. Essar steel, Vikram ispat and Ispat industries – all in the western regions (Joint Plant Committee, 2005-06). Rest of the plants are coal based and are 500 + in number. Coal based DRI plants often experience problems with respect to formation of accretio resulting in reduced production rate & shorter campaign life, fluctuation in product quality, high coal consumption etc. The problem is compounded with deteriorating quality of coal & iron ore particularly for manufacturers compelled to use multipe sources of raw materials with deteriorating & varying quality (DRI Updates, 2011, p.25). In view of Khattoi (2011), due to significantly high level of production, sponge iron has become now a key ingredient for secondary steel making. While enhancing the production of sponge iron, the mainstay would be coal based sponge iron as gas based route is quite restricted owing to limited availability of gas in India. Indian production of sponge iron has continued its steady increase in recent years. Approximately 70% of this is via coal-based DR units and 30% via gas-based.

Scarnati (2008), observed that there have been historical reasons in India for the prosperity of coal-based DRI production over gas-based: India does not have ample reserves of natural gas, and what is currently available is mainly on the west coast. Coal, on the other hand, is abundant and lower grade coals can be used without difficulty. In terms of capital cost, a coal based DR unit is generally small in capacity and can be installed and operated with a much smaller investment.

Bhatnagar (2009), opined his 'Editorial' by stating that, in the past years, the Indian as well as global economy have witnessed a very high degree of uncertainty and volatility. The Indian sponge iron industry also felt the cascading effects of economic slowdown. However, the industry feels squeezed, but with its fundamentals still intact, it has the strength to utilize its full potential and grow at double-digit rates when backed by the government in terms of raw material inputs. The key growth drivers being infrastructure development and high level urbanization, escalating demand from housing, automobile, white goods and rural/ agricultural development sectors.

During eighties, there was a great demand for sponge iron due to shortage of scrap. Moreover, many new sponge iron plants were established after 1985. Thus, during eighties quality of sponge iron was not an important factor as there was a huge demand due to the shortage of scrap. Very little attention was paid to the quality & productivity of sponge iron. But as the competition grew, there was a need to focus on the quality and productivity improvement to survive. After the formation of SIMA i.e. Sponge Iron Manufacturing Association, in 1992, the sponge iron manufacturers had to set standards of quality of sponge iron. Thus quality of sponge iron gradually began a point of concern in the past. According to Ministry of Steel, Govt. of India (2010-11), India has to achieve 11% annual growth in steel industry to meet the present GDP growth and the target production of 124 MT up to 2020. India has huge resources of raw material like iron ore and coal to meet any type of challenges but we shall review our weakness, strength, policies and technologies to retain the number one spot in world for sponge iron manufacturing.

Healthy demand growth in steel sector & declined availability of steel melting scrap, resulted in to increase in sponge iron demand considerably and is likely to continue.

Targeted vs Achieved SI production in India

The data collected from the e-book by Chatterjee (2010), given in Table 4. It shows the data for targeted production & achieved production for gas based & coal based sponge iron manufacturing in India for the 2004-05 to 2009-10.

The graph drawn from the data from table No. 4 is

Table 4: Targeted vs. achieved production for gas & coal based SI in India

Year	Production, (Mt)					
	Targeted production			Achieved production		
	Gas based	Coal based	Total	Gas based	Coal based	Total
2004-05	6.1	6.0	12.1	4.6	5.5	10.1
2005-06	6.1	8.5	14.6	5.7	6.5	12.2
2006-07	7.1	11.0	18.1	7.0	8.5	15.5
2007-08	7.1	13.0	20.1	7.0	10.0	17.0
2008-09	7.1	17.0	24.1	7.0	15.3	22.3
2009-10	7.1	18.0	25.1	7.0	14.0	21.0

(Ref : Chatterjee, 2010)

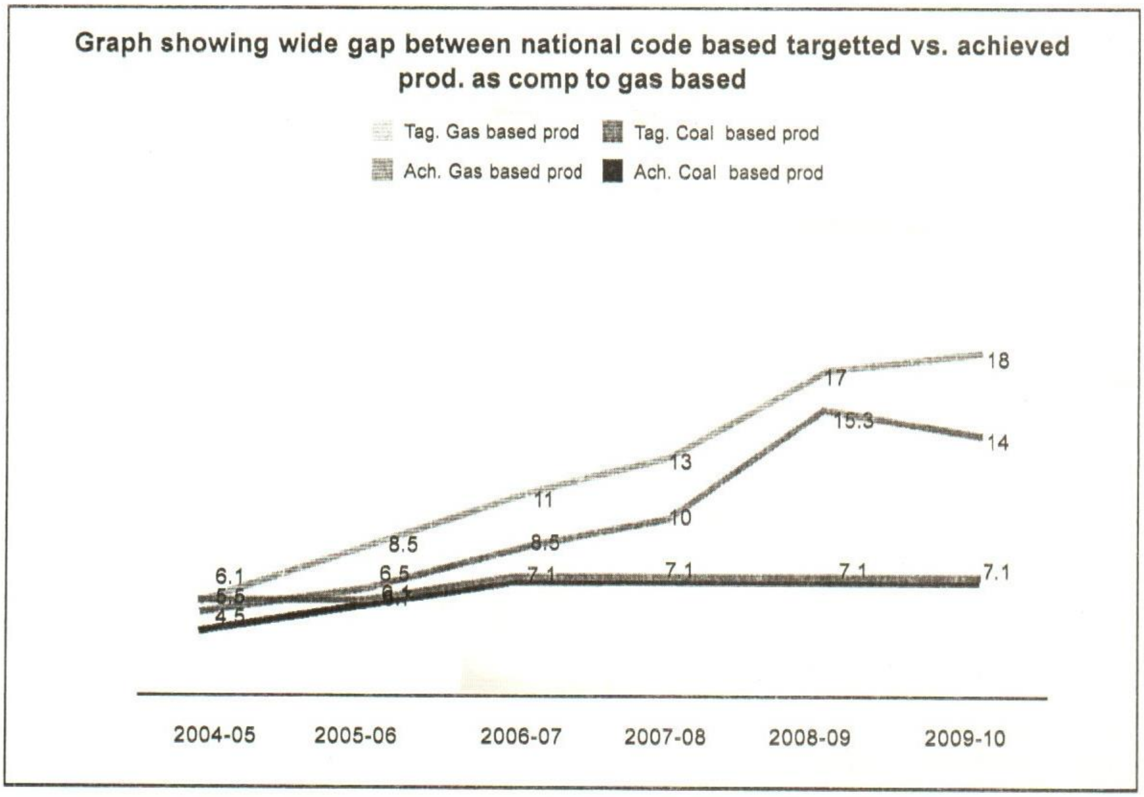

Figure 2: Gas based and coal based targeted vs. achieved production of SI in India (Ref : Chatterjee, 2010)

shown in Fig. 2. From Fig.2, it is clear that the achieved production is always less than the targeted production in coal based sponge iron plants. This fact, demands the need for identification & validation of critical factors affecting quality and productivity in coal based sponge iron industry. Sustaining continuous improvement and retaining number one position in the world in SI manufacturing should also be an objective in the mind.

Highlights of steel sector in India

Few highlights of steel sector in India are as follows –

- The steel sector contributes to nearly 2% of the GDP and employs over 5 lakh people.
- The per capita steel consumption has risen from 38 kg in 2005-06 to 55 kg in 2010-11.
- Capacity for crude steel production expanded from 51.17 million tons per annum (mtpa) in 2005-06 to 78 mtpa in 2010-11.
- Crude steel production grew at 8% annually [Compounded Annual Growth Rate (CAGR)] from 46.46 million tones in 2005-06 to 69.57 million tons in 2010-11.
- Production of finished steel stood at 66.01 million tons during 2010-11 as against 46.57 million tons in 2005-06, an average annual (CAGR) growth of 7%.
- Consumption of finished steel has grown at a CAGR of 9.6 % during the last six years.
- Export of finished steel during 2010-11 stood at 3.46 million tons while imports during 2010-11 stood at 6.79 million tones.

(www.steel.gov.in Annual Report 2011-12, Ministry of steel, Govt. of India)

GAP Analysis for Indian SI industry

Strength, Weakness, Opportunity & Threat analysis of any industry is the prime requirement to understand it thoroughly. It provides insight of the industry and therefore is must, before the start of study. Visits to various plants, discussion with top level officer, literature review (Dangayach & Deshmukh, 2001) were carried out for more accurate GAP analysis & SWOT analysis of Indian SI industry. Table 5 below highlights the GAP analysis.

Table 5: Various gap for sponge iron industry in India

GAP I : VISION GAP	
Successful sponge iron industry: It has core ideology i.e. they have ethical It has core ideology i.e. they have ethical It has ideology for quality product at any cost. Customer satisfaction is the core concept. Follow the govt. rules for pollution control & worker welfare. It has clear understanding of limited resources. It is able to define – Who is our customer ? What is the need of our customer? How the need of customer can be fulfilled?	**Unsuccessful sponge iron industry:** They run the business at ad –hoc basis or half heartedly. They are unaware of resources and capabilities of their employees which can be used to build business.
GAP II : CORPORATE PARENTING GAP	
Successful entrepreneur of sponge iron manufacturers. They run the industry by heart. They have interest to run the industry	**Unsuccessful entrepreneur of sponge iron manufacturers.** They run the business half heartedly. They are unaware of resources and capabilities which can be used to build business.
GAP III : ASPIRATION GAP	
Successful entrepreneur of sponge iron They have strong obsession to be successful.	**Unsuccessful entrepreneur of sponge iron** Except entrepreneur, no one has obsession to run industry. They are satisfied with conventional past performance. No opportunities for growth is exploited. Entrepreneur has fear of loss.
GAP IV : STRATEGIC GAP	
Successful entrepreneur of sponge iron Well defined planning which may provides the competitive edge over competitors. Well implemented strategies .	**Unsuccessful entrepreneur of sponge iron** No strategic planning. They have planning that fail to implement
GAP V : TECHNOLOGICAL GAP	
Successful entrepreneur of sponge iron They continuously upgrading production technologies, in such a way to achieve quality production in available resources.	**Unsuccessful entrepreneur of sponge iron** They have ignoring the up gradation of technologies for the fear of extra investment .
GAP VI : SOURCE GAP	
Successful entrepreneur of sponge iron The raw material availability for the production should be accessible	**Unsuccessful entrepreneur** The raw material availability for the production is not accessible

(Ref : Dangayach & Deshmukh, 2001; Industrial visits; Discussion with sponge iron employees)

SWOT Analysis for Indian SI industry

Strength

a) Abundant resources of iron ore
b) Availability of non-coking coal on large scale
c) Low cost and efficient labour force
d) Strong managerial capability
e) Establishment of technology
f) Strongly globalised industry and emerging global competitiveness
g) Modern new plants & modernized old plants

Weakness

a) High cost of energy
b) Higher duties and taxes
c) Lack of Infrastructure
d) Poor Quality of coal
e) Stringent Labor laws
f) Labour unions & frequent unrest
g) Depend on import of equipments & technology
h) Slow statutory clearances for development of mines

Opportunity

a) Huge infrastructure demand
b) Rapid urbanization
c) Increasing demand for consumer durables
d) Untapped rural demand
e) Increasing interest of foreign steel producers in India
f) Growing population
g) Increasing per capita consumption
h) Power generation through waste heat recovery

Threat

a) Slow growth in infrastructure development
b) Market fluctuations and China's export possibilities
c) Global economic slow down
d) Rapid changes in govt. policies
e) Changing interest rates

Growth Factors for Indian SI industry

The growth factors are the promises for SI industry for their overall development. They help executives in decision making during start or expansion of industry. Timely review of growth factors is necessary to understand the viability. Growth factors depends on nation & international environment touching almost every aspects. Hence, for their identification, overall knowledge of business environment is needed. Literature survey also supports the findings. Identified growth factors for Indian SI industry are as follows –

Huge Potential for Demand

a) High GDP growth rate at around 7%
b) 1.25 billion & growing population
c) Low per capita steel consumption of 55kg in 2010-11
d) Increased overseas demand

Government Policy

a) Mostly stable currency
b) Easing of regulations
c) Strong banking & infrastructure building

Skilled Human Resource

a) Large pool of technical manpower.
b) Largest young population in world.

Abundant Minerals

a) Reserves of 23 billion tons of iron ore
b) Huge reservoir of non coking coal
c) Indigenous availability of dolomite.

Technology Availability

a) Indian steel producers are one of the lowest cost producers in the world.
b) The technology is developed to its fullest extent. Lots of successful experiments are being carried out for further development.
c) Conversion of waste heat in to power

Advantage India

Equitymaster.com (2009), Steel Sector Analysis Report (2011), Invest India (2012), have discussed few points favoring India, as follows –

- A viable alternate route to steel making through the coal based sponge iron route using power generated from waste energy recovery and electric furnace stands established and is India's contribution to the world of steel making. Share of steel production in the country following this route is bound to grow with the growth in steel demand.
- Being a core sector, steel industry tracks the overall economic growth in the long-term. Also, steel demand, being derived from other sectors like automobiles, consumer durables and infrastructure, its fortune is dependent on the growth of these user industries.
- The Indian steel sector enjoys advantages of domestic availability of raw materials and cheap labour. Iron ore is also available in abundant quantities. This provides major cost advantage to

the domestic steel industry, with companies like TISCO being one of the lowest cost producers in the world.

- However, Indian steel companies have to bear additional costs pertaining to capital equipment, power and inefficiencies (low per employee productivity). This has resulted in the erosion of the edge they would have otherwise enjoyed due to availability of cheap labour and raw materials. Now with the focus on improving efficiency the industry is positioned to witness higher profitability.
- The basic import duty on steel has been consistently brought down. This has made the industry vulnerable to international competition. On the positive side, domestic prices now track the global prices more closely.

Problems of SI Industry in India

A panoramic view through the review of Equitymaster (2009), Infocus (2011), Steel Sector Analysis Report (2011), Invest India (2012), Scribe (2012), etc show an industry with investments of over Rs 5000 crore contributing more than Rs 450 crore per annum by way of taxes to the national exchequer, saving substantial foreign exchange, employing directly and indirectly nearly 1,25,000 people. On the other hand, it is also an industry, which is under tremendous viability pressure, due to raw material availability and pricing constraints. Selling prices are determined by market forces whereas all input costs are controlled by the Government. The problems of the Sponge Iron Industry can be discerned only on further scrutiny.

- The cost of basic inputs like iron ore, coal & gas has steeply gone up.
- All input costs (administered pricing) are higher in India than overseas.
- Inputs/services for sponge iron production are mainly in government hands.
- High cost of capital.
- Slowdown of economy, resulting in demand recession.
- Availability of right grade and quality of non-coking coal is a must to optimize cost of production of sponge iron. Indian coal having high ash content (30 - 35 per cent) will necessarily have to be blended with imported low ash content coal (below 12 per cent). Therefore reduction of custom duty on non-coking coal (below 12 per cent ash content) for metallurgical use is necessary.
- High prices of natural gas in comparison to international prices and cost of production resulting from high input cost and inadequate export incentives.
- The iron ore used as a raw material for sponge iron needs to be of higher quality with more than 62% Fe content. Currently, out of India's estimated reserves of 25 billion tones of iron ore, higher grade constituents only about 8.7%.

Global Scenario – Sponge Iron

It is reported by Midrex (2012), that the total World DRI production in 2011 rose to 73.3 million tons (+ 4% over 2010) setting yet another new record for the industry. Growth slowed in some areas of the world, but in other regions, increased production more than counteracted the declining locales. Although last year's production rose 3 million tons from 2010's total production, it marks nearly a 9 million ton increase from 2009's 64.4 million tons. Four nations experienced significant growth. These included the United Arab Emirates (UAE) with an increase of 1.1 million tons, Venezuela, which made 0.7 million tons more than the previous year, Mexico, which increased by 0.5 million tons and Russia, which saw an increase of 0.4 million tons. (www.spongeironindia.in/comm_news 30.html). There are four major producers in the world i.e. India, Venezuela, Mexico and Iran; accounting for 60 percent of the global production (projectmonitor.com, 2005).

Some countries did see a decline in production. Nations where there was significant decline included India, which produced 1.45 million tons less in 2011 than in 2010, and Libya, which fell by 0.8 million tons. India's drop in production was a result of several economic forces. First, there was a slowing of the general economic growth that has been developing for years. Although growth has continued, it was not rising at as rapid a pace as previously anticipated. Also, some plants were not able to obtain as much iron ore as they needed due to governmental restrictions on mining. In addition, governmental allocations were placed on natural gas that gave higher priority to electric power generation and to ammonia (fertilizer) production than to the manufacture of iron and steel. India has become the leading producer in DRI over the past decade due to the large number of small rotary kilns; however, need for better quality DRI is driving shaft furnace alternatives. With smaller amounts of natural gas anticipated for industry use, coal-based technology options are currently being pursued by a few India steelmakers. (www.spongeironindia.in/comm_news30.html)

All over the world, blast furnace will continue to remain the chief source of pig iron / molten metal for use in steel making. DRI contributes 9.2% of the world's total iron making with an output of about 64.4 million tons per annum (2009-10). Most of the DRI plants in the World use natural gas as reductant, whereas the DRI plants of India using coal as reductant constitutes almost two third of the production capacity. The major part of DRI produced all over the world is used as a substitute for steel scrap in the Electric Arc Furnace (EAF) and Induction furnace (IF) while making steel. Countries that have plenty of steel scrap available in domestic market or countries that have taken policy decision to maximize steel scrap recycling by way of reduced custom duty do not favor DRI process (Min. of Env. & Forest, 2007).

Table 6, Table 7, Table 8, shows the data of world DRI production by different classification & Fig 3, Fig.4, & Fig.5 shows the graphical representation of this data (Midrex, 2010) –

Table 6: World DRI Production by Process

Year	2008	2009	2010
Fuel used			
Gas Based	74.7%	73.1%	74.3%
Coal Based	25.3%	26.9%	25.7%

(Ref : Midrex, 2010)

Table 7: 2010 World DRI Production by Region (in Million Tons)

	2008	2009	2010
Asia / Oceania	24.43	25.56	27.17
Middle East / North Africa	18.32	19.44	22.33
Latin America	17.9	12.66	13.91
Former USSR / Eastern Europe	4.56	4.67	4.79
Sub Sahara African	1.38	1.39	1.12
USA & Canada	0.95	0.34	0.6
Western Europe	0.52	0.38	0.45

(Ref : Midrex, 2010)

Table 8: World DRI Production by years, in MT

YEAR	PRODUCTION		YEAR	PRODUCTION		YEAR	PRODUCTION
1970	0.79		1984	9.34		1998	36.96
71	0.95		85	11.17		99	38.6
72	1.39		86	12.53		00	43.78
73	1.9		87	13.52		01	40.32
74	2.72		88	14.09		02	45.08
75	2.81		89	15.63		03	49.45
76	3.02		90	17.68		04	54.60
77	3.52		91	19.32		05	56.99
78	5.00		92	20.51		06	59.79
79	6.64		93	23.65		07	67.22
80	7.14		94	27.37		08	68.03
81	7.92		95	30.67		09	64.44
82	7.28		96	33.30		2010	70.37
83	7.9		97	36.19			

(Ref : Midrex, 2010)

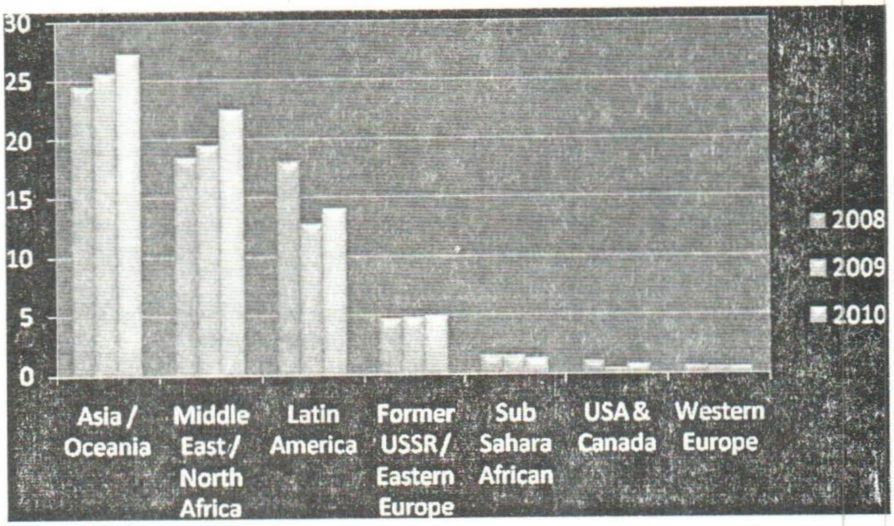

Figure 3: Graph showing comparative world DRI production by process

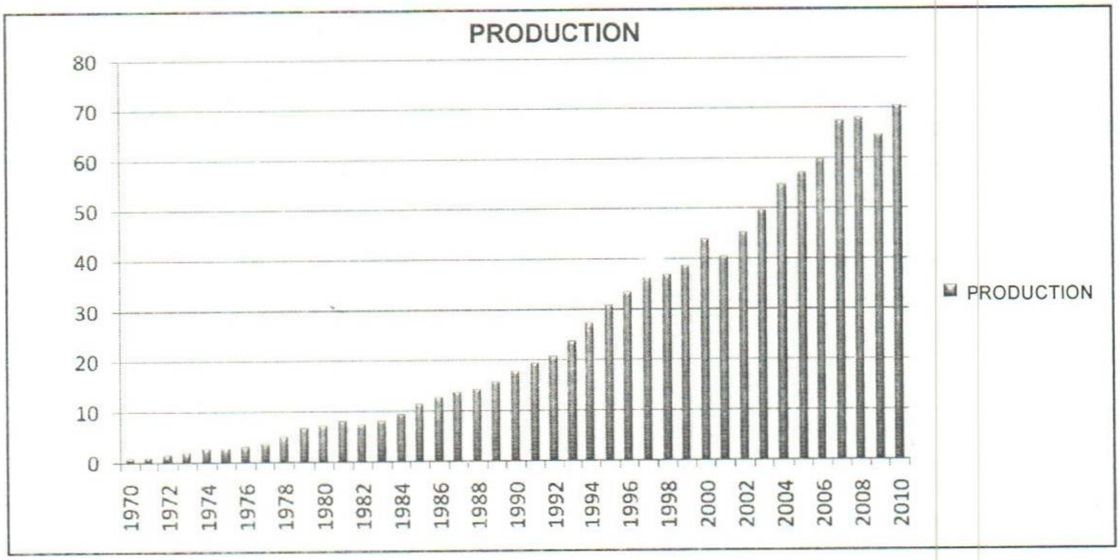

Figure 4 : Graph showing world DRI production by region. (Ref : Midrex, 2010)

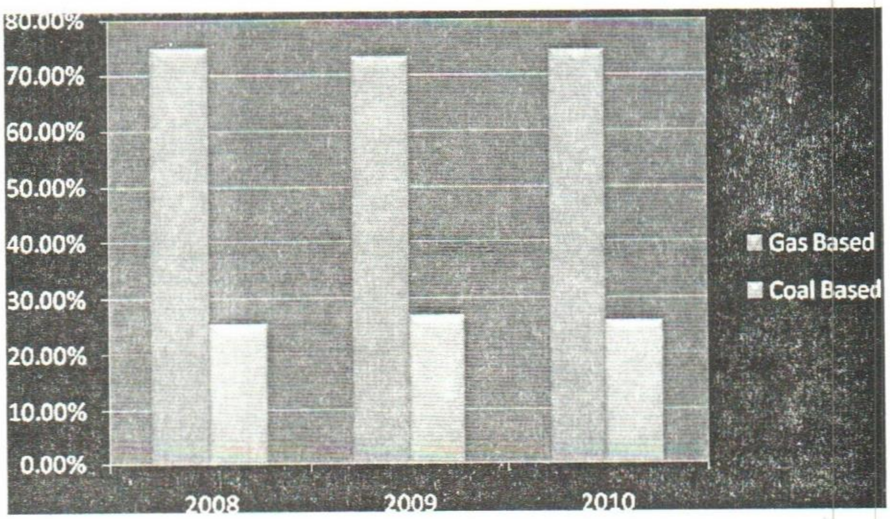

Figure 5: Graph showing the World Production of DRI from 1970 (Midrex, 2010)

Table 9 for the data of world DRI production by process & subsequent graph shown in Fig.6, clearly indicate that the share of gas based SI production is almost three times more than coal based production. However, the figures are almost reverse in India.

Table 9: World DRI Production by Process (Ref: Midrex, 2010)

Year	2008	2009	2010
Fuel used			
Gas Based	74.7%	73.1%	74.3%
Coal Based	25.3%	26.9%	25.7%

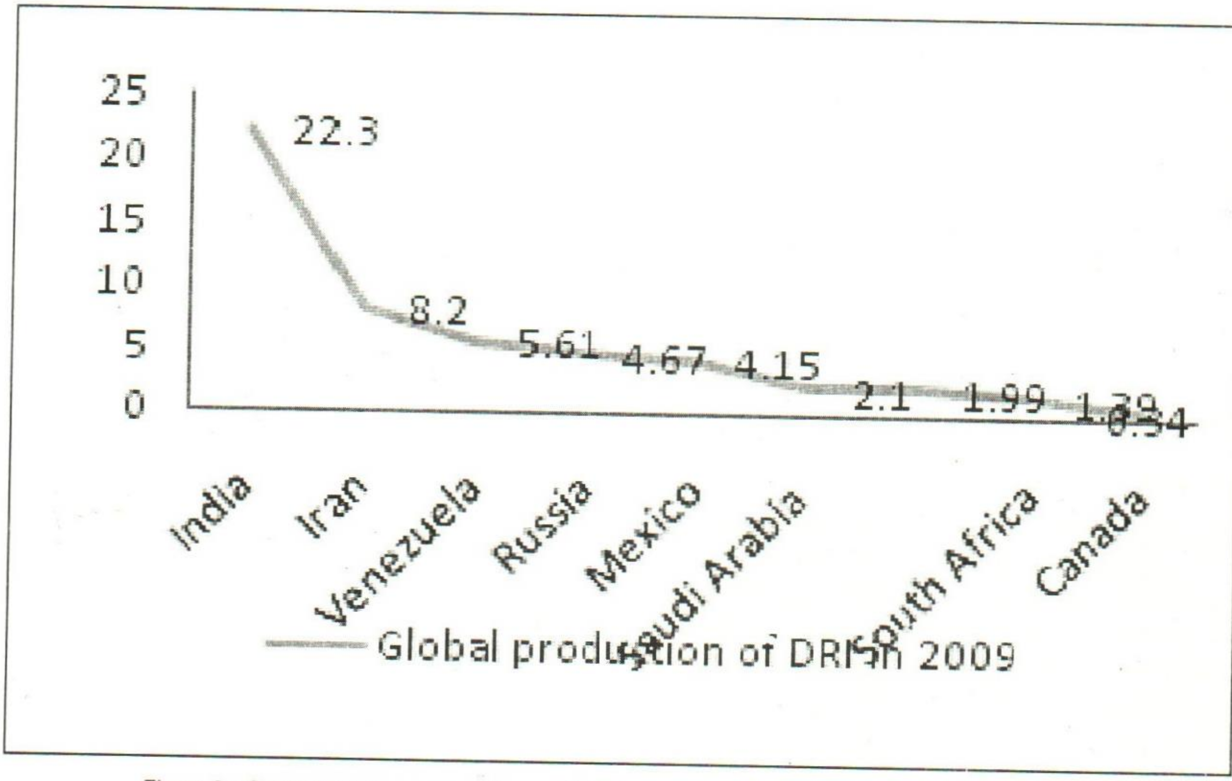

Figure 6 : Graph showing comparative world DRI production by process (Ref: Midrex, 2010)

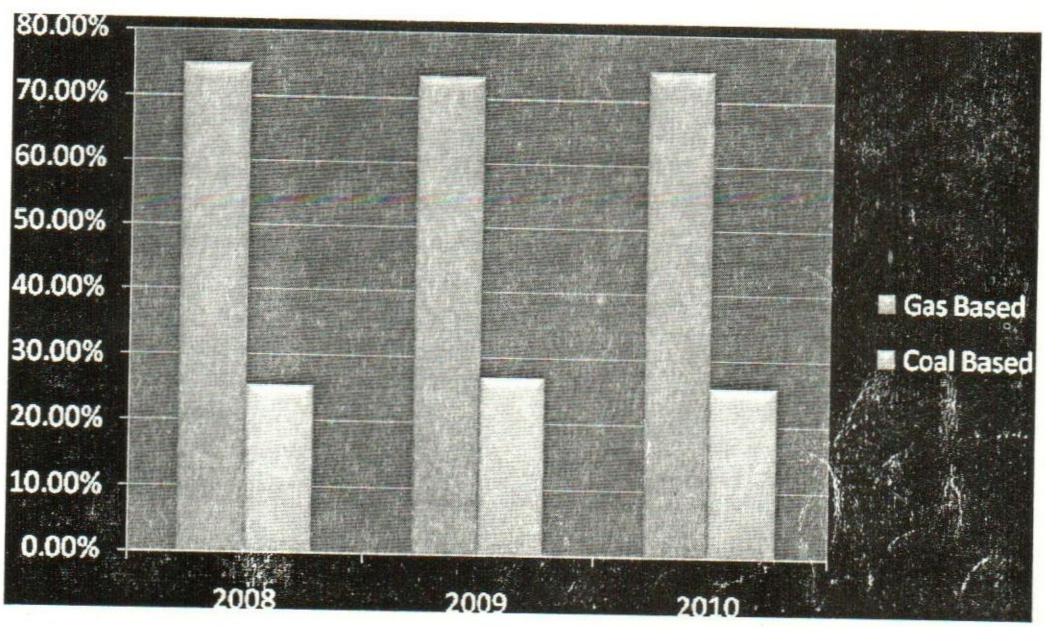

Figure 7: Comparison of global production of DRI in 2009

Table 10 shows the data for few countries from 2005 to 2009. Fig. 7 above shows the graph comparing the of production of SI for few countries in the year 2009.

Table 10: Production from 2005 to 2009 country wise

Countries	Production in metric tons per annum				
	2005	2006	2007	2008	2009
India	11.1	14.7	19.06	21.2	22.3
Venezuela	8.95	8.6	7.7	6.87	5.61
Mexico	5.98	6.2	6.3	6.01	4.15
Iran	6.85	6.9	7.4	7.46	8.20
Trinidad & Tobago	2.25	2.1	3.5	2.78	1.99
South Africa	1.78	1.8	1.7	1.18	1.39
Canada	0.59	0.5	0.9	0.69	0.34
Saudi Arabia	3.63	3.6	4.3	1.68	2.10
Russia	3.34	3.3	3.4	4.56	4.67

(Ref : www.worldsteel.org/statistics)

Factors affecting quality & productivity

Fruchan et al (1997) reported that the quality of steel has improved dramatically in US due to technological advances, people working smarter, training, continuing education & quality control. Factors affecting competitiveness & innovations are human resources, trade issues, minimills, customers, foreign investment, regulatory policy, education & training, government support of R&D, internationally funded R&D, market focus, management of capital & human resources, foreign trade & exchange rates. Further he pointed out that customer acceptance is one of the measure of quality acceptance.

Srajkumar (2011) observed for indian steel industry that productivity improvement is possible through usage of state of the art technology, higher quality raw materials, higher level of efficiency of operations, effective management practices and higher level of motivation amongst employees. The ways suggested for improving the productivity were avoiding wastage & better utilization of resources, adopting improved working methods, use of new technologies & technological innovations.

About Sponge Iron Manufacturer's Association (SIMA) India

India took its first tentative step towards economic liberalization in 1991. The economy was in the midst of a radical change and the Sponge Iron Manufacturers Association (SIMA) was constituted and started operation from 11 February 1992. It was officially registered under the society registration act XXI of 1860 on 31 January 1994. The fundamental premise behind the formation of the association was to promote and protect the interest of the Indian sponge iron industry.

SIMA has come a long way since inception to bring all sponge iron manufacturers together. Now in a multi-dimensional role, it represents the Indian DRI industry and provides a common platform for regular interface with the government of India and other regulatory authorities. The association is a common forum for its members to share and exchange each other's experience, views and problems. The Association concentrates on market development, compilation and dissemination of industrial data and technical and commercial information, essential for decision making in the current fast changing business environment.

Besides its traditional role of keeping members updated with development and data, both at national and international levels, SIMA also takes up image building exercise at regular intervals. These are to project and ensure the continued development and growth of the sponge iron industry in India. In the current economic scenario, the role of SIMA has significantly enhanced to maintain a coherent plan, which represents in totality, the requirements and hardships faced by the industry. As on date, SIMA has a membership of 80 sponge iron manufacturing units. These include coal based 77 and gas based 3.

(Source : www.spongeironindia.in/whatis.html An official website of SIMA, India)

Discussion

Major share of sponge iron production in India comes from coal-based plants. If the number of units is considered in India, the number for gas based plant is negligible (i.e.3) as compared to coal based plants (more than 500). Many coal based plants are of very small capacity of 50 or 100 TPD due to promoting policy of Govt. of India in mid nineties. The issues like quality & productivity are highly neglected in small plants. In the present high volatile environment, the very survival of these plants are at stake. The implementation of tools of TQM have proved few companies improve their top line & bottom line.

Worldwide, the sponge iron manufacturing plants are concentrated in Asia, Africa & Latin America; the so-called developing area or underdeveloped area where the businesses are run by thumb rule. Awareness about the total quality management is very less & if at all they know, they have wrong perceptions about it. Authors have experienced it during the plant visits & conferences and hence, feel strongly the need of awareness & implementation of TQM in sponge iron industry in India, particularly in coal based plants.

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Productivity and the growth of productivity must be the first economic consideration at all times, not the last. That is the source of technological innovation, jobs and wealth.

—William E. Simon

Focus

Analysis of Total Factor Productivity Growth in Karnataka Agriculture

ELUMALAI KANNAN

The present study has estimated TFP of ten major crops grown in the Indian state of Karnataka and analysed its determinants. Growth accounting method of Tornqvist-Theil Index was used to estimate TFP. The study relied on Cost of Cultivation data published by Ministry of Agriculture, Government of India. The study draws motivation from lack of research evidence to show whether productivity growth in crop sector has improved during post 2000s on account of its widespread slow down or negative growth witnessed during 1980s and 1990s. Analysis confirms that most crops have registered low productivity growth during these periods. Interestingly, during 2000-01 to 2007-08 all crops have showed positive growth in TFP. However, to maintain the productivity growth in the long run, it is necessary that both public and private investment should be enhanced in agricultural research and technology, and rural infrastructure.

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Karnataka is one of the developed Indian states that is placed above the median level of social and economic development (Bhalla and Singh, 2001; Deshpande, 2004). Growth and structure of Karnataka economy have undergone dramatic changes since the introduction of new economic policy in 1990s. The economy has registered an impressive average annual growth rate of over 7.0 per cent during 1999-00 to 2007-08. The major source of this high growth has largely come from booming services (tertiary) sector. With structural change, the share of agriculture and allied sector in Gross State Income at 1999-00 prices has declined from 30.8 per cent in 1999-00 to 16.4 per cent in 2008-09. The share of industry has only marginally increased from 23.9 per cent to 27.7 per cent. However, the contribution of services sector has increased significantly from 45.3 per cent to 55.9 per cent between 1999-00 and 2007-08. The structural change in the state economy is largely in line with changes evident at the national level.

The structure of the economy has shifted towards tertiary sector with anticipated decline in contribution of agricultural and allied sectors in the state income. But, this structural transformation should have substantially transferred people dependent on agriculture to non-agricultural sector. This has not happened both at the state and national level. According to 2001 Population Census out of 23.5 million total workers, about 13.1 million workers (55.7 per cent) depend on agriculture and allied sector for employment in the state of Karnataka. Combined with decline in income share and large dependence of workforce has hindered productivity gains in this sector over time. Further, despite considerable efforts taken by the state government to augment irrigation potential, per cent area irrigated to gross cropped area has remained low at 29 per cent.

The green revolution technology introduced in late 1960s in the form of new seeds cum chemical fertilisers had helped to increase crop production in the State. This was made possible with higher public investment in agricultural research, education and training, irrigation and other infrastructures. However, the technological gains could not spread evenly across the regions and crops in the state due to diverse agro-climatic conditions and varying natural resources endowments. The growth performance of agricultural sector has also varied and marked with wide fluctuations. Meanwhile, concerns on stagnation in production and productivity of crops have emerged during 1980-81 to 1989-90. An Expert Committee constituted by the State Government in 1993 had concluded that investments made in agriculture during 1980s had not been optimally utilised to sustain the growth momentum witnessed during seventies. While analysing the impediments to agricultural growth, Deshpande (2004) contended that both public and private investments have not adequately been made in the lagging regions particularly in un-irrigated plateau zone of Northern Karnataka and that of Southern Karnataka to spur the growth process. There is also empirical evidence to suggest that productivity growth measured by Total Factor Productivity (TFP) has declined during eighties (Ananth et al, 2008). But, there is lack of research evidence to show whether declining productivity growth in the crop sector has reversed during recent years. This is particularly important from the point of view of renewed efforts made by the state government through various developmental programmes to accelerate growth in the agricultural sector. This, in fact forms the motivation of the present study to estimate and analyse trends in total factor productivity of important crops in the state of Karnataka. From the policy perspective, it is also important to assess and understand determinants of TFP so as to take appropriate initiatives to accelerate agricultural output growth. More specifically, the present study estimates total factor productivity growth of major crops in Karnataka and analyses the factors affecting TFP at the state level.

The rest of the paper is organised as follows. The second section discusses data and analytical method. Changes in cropping pattern and growth in area, production and yield of crops are discussed in the third and fourth section, respectively. Fifth section analyses trend in public investment in Karnataka agricultural sector. Cost structure of major crops is discussed in the sixth section. Seventh and eight sections discuss growth in input, output and TFP index. Concluding remarks are made in the final section.

Data and methodology

Data

In the present study, TFP is estimated taking into account two outputs and nine inputs. Output index included main product and by-product. The input index comprises seed, fertiliser, manure, human labour, animal labour, machine labour, pesticide, irrigation and land. Data on quantity and value of output and inputs for ten major crops viz., paddy, jowar, maize, ragi, arhar, groundnut, sunflower, safflower, cotton and sugarcane were compiled from Cost of Cultivation of Principal Crops published by Ministry of Agriculture, Government of India and Department of Agriculture, Government of Karnataka. However, for some inputs only value is available and quantity of such inputs is measured through indirect methods.

For instance, quantity of by-product was generated by using grain-straw ratios given by Nirman et al (1982) and Kolay (2007). Machine labour was measured as number of four-wheeled tractors. Land was measured as the total area under respective crops. Wholesale price index of pesticide and electricity consumption in agriculture was used to derive quantity of pesticide and irrigation, respectively. Further, to construct aggregate (weighted) output, input and TFP index for Karnataka, share of area of respective crops in total gross cropped area was used as weights.

Analytical Method

In simple terms, productivity is defined as the ratio of output to input. The partial productivity measures like labour productivity and land productivity are of limited use in the presence of multiple outputs and multiple inputs as they do not indicate overall productivity when considered in isolation. When the productivity concept is extended beyond single output and single input case, an alternative approach of aggregating outputs and inputs is used. The Total Factor Productivity (TFP) relates aggregate output index to aggregate input index. Growth accounting (index number method) is commonly used to measure TFP in agricultural sector as it is easier to implement without econometric estimation (Evenson et al (1999); Kumar and Mruthynjaya (1992); Kumar and Rosegrant (1994); Desai and Namboodiri (1997); Mukherjee and Kuroda (2003); Elumalai and Pandey (2004); Kumar et al (2004); Murgai (2005)). Under growth accounting method, TFP measures growth in output which is not accounted for growth in inputs. In other words, the residual productivity is considered as a measure of technical change, which indicates shift in the production function.

Among index number methods Tornqvist-Theil index, which is an approximation to Divisia index, is widely used to construct aggregate output index and aggregate input index. The properties and difficulties in using Divisia index in its original integral form is expounded in Hulten (1973). The popularity of Tornqvist-Theil index can be attributed to the fact that it is exact for linear homogenous translog production function. Such index is called 'superlative' by Diewert (1976). Further explanation on theoretical properties and issues in measurement can be found be in Diewert (1978, 1980), Christensen (1975), Capalbo and Antle (1988) and Coelli et al (2005).

Tornqvist-Theil output, input and TFP index in logarithmic form can be expressed as follows.

Output Index

$$\ln\left(\frac{Q_t}{Q_{t-1}}\right) = 1/2\sum_j (S_{jt} + S_{jt-1}) \ln\left(\frac{Q_{jt}}{Q_{jt-1}}\right)$$

Input Index

$$\ln\left(\frac{X_t}{X_{t-1}}\right) = 1/2\sum_i (S_{it} + S_{it-1}) \ln\left(\frac{X_{it}}{X_{it-1}}\right)$$

TFP Index

$$\ln\left(\frac{TFP_t}{TFP_{t-1}}\right) = \ln\left(\frac{Q_t}{Q_{t-1}}\right) - \ln\left(\frac{X_t}{X_{t-1}}\right)$$

where, S_{jt} is the share of output j in total revenue, Q_{jt} is output *j*, S_{it} is the share of input i in total input cost, X_{it} is input *i* and all specified in time *t*.

In constructing TFP index, chain index is preferred to fixed base index (Coelli et al, 2005). Chain index combines annual changes in productivity to measure changes in productivity over a period of time. Formally, let I(t+1, t) be an index for the period t+1 with base period t. This index is applied to time series t=0 to T. Comparison

Table 1: Changes in Cropping Pattern in Karnataka

(Percentage share of GCA)

Crop	TE 1962-63	TE 1972-73	TE 1982-83	TE 1992-93	TE 2000-01	TE 2007-08
Rice	9.9	10.7	10.3	10.3	11.9	11.2
Jowar	28.0	21.8	19.2	18.0	15.4	11.3
Bajra	4.8	4.6	5.4	3.3	2.6	3.3
Maize	0.1	0.7	1.4	2.3	4.9	7.8
Ragi	9.6	9.8	9.8	8.8	8.1	6.2
Wheat	2.9	2.9	3.0	1.7	2.2	2.1
Small Millets	4.2	4.1	3.2	1.1	0.6	0.3
Cereals	59.7	55.4	52.4	45.5	46.6	42.2
Arhar	2.7	2.5	3.3	3.9	4.3	4.9
Gram	2.5	1.4	1.3	1.7	2.8	4.4
Pulses	11.9	11.0	13.2	13.8	15.8	17.6
Foodgrains	71.9	68.3	66.6	59.4	62.4	59.7
Groundnut	8.4	9.2	7.6	10.5	9.3	7.1
Sunflower	-	-	1.0	8.6	4.9	9.6
Total Oilseeds	9.7	11.0	12.2	22.7	17.3	19.5
Cotton	9.3	10.2	9.0	5.0	4.7	3.1
Sugarcane	0.7	1.0	1.6	2.2	3.1	2.2
Tobacco	0.4	0.3	0.5	0.4	0.6	0.8
Fruits and nuts	-	-	-	1.2	2.6	2.1
Vegetables	-	-	-	1.0	2.8	3.1
Others*	0.7	1.3	4.6	4.8	6.7	7.2
GCA	100.0	100.0	100.0	100.0	100.0	100.0

Note: * include coconut, arecanut, chillies and coffee

Source: Statistical Abstracts of Karnataka (various issues), Government of Karnataka between period t and fixed base 0 is made by following chain indexing of successive periods.

$$I(0,t) = I(0,1) \times I(1,2) \times I(2,3) \times \ldots\ldots\ldots\ldots \times I(t-1,t)$$

Changes in cropping pattern

Food grain crops dominate the cropping pattern accounting for about two-third of total gross cropped area (GCA) in Karnataka (Table 1). Among food grains, coarse cereals occupy prominent place in the cropping pattern. Nevertheless, per cent area under food grains has declined from 71.9 per cent in triennium ending 1962-63 to 60.0 per cent in triennium ending 2007-08. The decline in area under food grains is offset by increase in area under oilseeds and other crops (which include coconut, arecanut, chillies and coffee). Data on horticultural crops compiled by Directorate of Economics and Statistics, Government of India and National Horticultural Board (NHB) do not match due to differences in method of collection of data. Coverage of crops by these two government agencies also differ. Despite data limitation, as per NHB data share of area under fruits and nuts in GCA has marginally declined during recent years. However, share of area under vegetables has increased to 3.1 per cent in 2007-08 from 1.0 per cent in 1992-93.

In 2007-08, jowar and rice have occupied predominant positions in the cropping pattern followed by sunflower and maize. Despite occupying relatively high share, area under jowar has declined drastically since early sixties. Similar pattern could be noticed with respect to other coarse cereals like bajra, ragi and small millets. In fact, jowar and small millets have lost their area by over 50 and 80 per cent, respectively between 1962-63 and 2007-08. However, crops like maize, arhar (pigeon pea) and gram have gained in their relative area during the study period. Maize occupied only 0.1 per cent of GCA in 1962-63, which has increased steadily to reach 1.4 per cent in 1982-83 and then to 7.8 per cent in 2007-08. Similarly, per cent area under arhar in total cropped area has increased from 2.5 per cent in 1972-73 to 4.9 per cent in 2007-08. Share of area under gram decelerated during seventies and early eighties, but started picking up since nineties.

Groundnut is one of the traditional crops grown in Karnataka. It is cultivated both under irrigated and rain fed conditions. The per cent area under this crop has declined sharply since 2000 due to persistent drought like conditions in the State. However, share of area under sunflower has registered sharp increase from 1.0 per cent in 1982-83 to 9.6 per cent in 2007-08. Among cash crops, area under cotton has declined drastically over time. However, sugarcane area has increased considerably from 1960s to 2000s, but has showed declining trend since 2001-02. It emerges from the analysis that there is marked shift in area from cereals to pulses, oilseeds and high value crops like vegetables and plantation crops.

Growth in area, production and yield

The compound annual growth in area, production and yield of major crops grown in Karnataka is given in Table 2. Growth rate have been computed for four different periods viz., pre-green revolution (1960-61 to 1966-67), green revolution (1967-68 to 1979-80), post-green revolution (1980-81 to 1989-90) and economic reforms (1990-91 to 2007-08). The compound annual growth in area under food grains was 0.3 per cent during pre-green revolution and has declined to -0.1 per cent in during green revolution period. However, growth in food grains production was high at of 3.5 per cent during the green revolution period. This high growth rate has largely come from growth in yield (3.8 per cent) when compared to pre-green revolution period during which growth in production was contributed by growth in area. However, during post-green revolution period growth in area under food grains was positive at 0.4 per cent, but growth in its production has declined due to fall in growth in yield. During the period of economic reforms, food grains production grew at respectable rate of 2 per cent per annum, which was mainly contributed by growth in yield. These results broadly indicate that growth in yield of food grains has fallen during 1980s and consequently it has impacted production. Interestingly, decline in growth in production and yield has got reversed during the recent period.

However, the crop-wise analysis of growth rates will be more revealing. During the pre-green revolution, growth in area for most of food crops was negative except rice (2.5 per cent), maize (12.0 per cent), ragi (3.5 per cent) and arhar (0.7 per cent). Further, growth in yield was negative for rice, maize, ragi, small millets and wheat. However, the situation has changed from mid-1960s to 1970s during which Karnataka agriculture has started benefiting from the new seed and fertiliser technology. In fact, this period can be called golden period of Karnataka agriculture with relative high growth in production of most crops. Though growth in area under certain crops has declined, remarkable achievements have been made on the fronts of production and yield growth. Except gram, yield of all other food grain crops have recorded positive growth during this period.

Table 2: Compound Annual Growth Rates of Area, Production and Yield of Major Crops

Crop	1960-61 to 1966-67			1967-68 to 1979-80			1980-81 to 1989-90			1990-91 to 2007-08		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Rice	2.5	1.7	-1.0	-0.4	1.9	2.2	0.2	0.0	-0.2	0.4	1.7	1.3
Bajra	-0.3	1.7	1.9	3.0	5.6	2.6	-2.9	0.4	3.2	0.2	1.7	1.5
Jowar	-1.0	3.0	3.8	-2.5	0.8	3.5	1.4	-0.1	-1.5	-2.5	-1.4	1.1
Maize	12.0	2.2	-8.1	12.0	15.0	3.0	6.1	7.0	0.8	8.6	7.9	-0.7
Ragi	3.5	-7.2	-10.3	0.9	8.4	6.7	0.9	0.6	-1.7	-1.7	-0.6	1.1
Small Millets	-2.9	-5.3	-2.5	2.3	8.0	5.6	-6.9	-5.8	1.2	-7.0	-6.2	0.9
Wheat	-3.4	-8.5	-6.3	2.3	7.1	4.7	-3.8	-6.4	-5.5	1.3	1.9	0.6
Cereals	0.3	0.3	0.0	-0.3	3.5	4.2	0.2	0.4	0.2	-0.7	1.9	2.1
Arhar	0.7	2.9	2.0	1.3	5.3	3.9	4.2	2.0	-2.1	5.7	6.3	3.5
Gram	-12.9	-4.2	8.8	-1.7	-2.1	-0.3	6.1	3.0	-3.9	2.7	8.1	2.3
Pulses	-2.1	1.5	0.0	2.2	3.4	2.5	1.7	0.1	-1.0	1.2	3.9	2.7
Foodgrains	0.3	0.4	0.1	-0.1	3.5	3.8	0.4	0.4	0.1	0.4	2.0	1.6
Groundnut	0.3	3.2	0.1	-1.0	-1.6	-0.6	5.0	7.1	2.0	-2.7	-4.6	-1.9
Sunflower	-	-	-	-9.0	-11.2	-2.4	32.1	26.8	-4.0	0.3	1.6	1.4
Total Oilseeds	-1.4	1.2	1.5	3.4	3.3	-0.1	7.7	9.2	0.8	-1.2	-1.8	
Cotton	0.1	-7.3	-6.2	0.3	4.9	3.9	-7.3	1.7	9.7	-3.1	-2.8	0.3
Sugarcane	4.1	6.6	2.1	4.2	2.0	-2.1	4.7	5.4	0.6	-0.3	-0.5	-0.2
Tobacco	-1.9	-9.5	-8.6	1.4	5.4	4.7	-0.6	1.4	1.9	4.3	1.0	-3.2
Fruits and nuts	-	-	-	-	-	-	-	-	-	0.6	0.2	
Vegetables	-	-	-	-	-	-	-	-	-	1.8	-0.2	-2.0

Source: Statistical Abstracts of Karnataka (various issues), Government of Karnataka

However, exuberance in yield growth in food grains did not continue during 1980s. Most of the crops have registered negative growth rates. Only bajra, maize and small millets have witnessed positive growth in yield. Except gram, growth in production of food crops has declined. But, during 1990-91 to 2007-08 there was a reversal in growth in yield of food grain crops. Only maize has registered negative growth in yield, but its production growth was impressive at 7.9 per cent, which was contributed by high growth in area. Despite positive growth in yield, production of jowar, ragi and small millets was negative due to drastic decline in their area.

The performance of oilseeds seemed to be better during 1980s with the introduction of Technology Mission of Oilseeds. Growth in area under total oilseeds was negative at 1.4 per cent during pre-green revolution period, which has increased to 3.4 per cent in green-revolution period and then to 7.7 per cent during post-green revolution period. Although growth in yield of oilseeds has not changed in the same manner as the expansion of area, but it has registered positive growth of 0.8 per cent during 1980s. However, growth momentum did not continue during 1990-91 to 2007-08. Growth in area, production and yield of all oilseeds was negative. Among individual oilseed crops, growth in area, production and yield of sunflower was positive and that of groundnut was negative.

In case of cotton, growth in area has declined continuously since 1980s. However, it is encouraging to note that growth in yield of cotton has increased from -6.2 per cent in pre-green revolution period to 3.9 per cent in green-revolution and 9.7 per cent in post-green revolution periods. Unfortunately, it has again declined during the recent period. Meanwhile, growth in production of sugarcane was largely driven by increase in area during pre-green revolution, green revolution and post-green revolution periods. But, negative growth in its area as well as yield has resulted in decline in production during the reforms period. Area under tobacco has showed high growth rate during recent period, which has helped to register positive growth in its production. Overall, the growth analysis indicates that yield of most crops particularly food grains has declined during 1980-81 to 1989-90 and has led to stagnation in production. Interestingly, during 1990-91 to 2007-08 there is reversal in growth rate in production and yield for some food and non-food crops. Among various growth promoting factors, public investment in agriculture seemed to have played an important role in accelerating growth and this merits some discussion here.

Public Investment in Agriculture

Public investment in agriculture takes place in the form of provisions of basic infrastructures like irrigation, market, roads, storage facilities, and research and technology. Table 3 presents public investment in agriculture and allied sectors in Karnataka. In absolute terms, at 1999-00 prices average public investment in agriculture was Rs. 6,737 lakhs during triennium ending 1976-77 and it had declined steadily to Rs. 2,405 lakhs in triennium ending 1992-93. Though there was some reversal in trend during recent years, but it had never reached the level registered during 1976-77. The similar trend can be observed on per thousand hectare basis also. In fact, capital expenditure per thousand hectare of net sown area was Rs. 67,490 in 1976-77 and thereafter it declined continuously till late nineties.

Table 3: Public Investment in Agriculture and Allied Sector

Year	Capital Expenditure (Rs. Lakhs)		Capital Expenditure/000' ha of Net Sown Area (Rs.)	
	Current Prices	Constant Prices (1999-00)	Current Prices	Constant Prices (1999-00)
TE 1976-77	1077	6737	10806	67490
TE 1982-83	1355	5689	13320	55985
TE 1992-93	1368	2405	12946	22780
TE 2002-03	2753	2571	27208	25400
TE 2008-09	8484	6122	81755	59007

Source: Finance Accounts (various issues), Comptroller and Auditor General of India

Decline in public investment seem to have adversely affected growth in agriculture sector during 1980s and early 1990s. According to Report of the Expert Committee (1993) constituted by Government of Karnataka, decline investment and its non-optimal utilisation has resulted in stagnation in agricultural productivity. Public investment in agricultural infrastructure has potential to attract private investment, which would help to make improvements in farming activities. Understandably, increase in public investment in agricultural sector during the since early 2000s has provided some hope for the revival of growth in the sector. It is also quite encouraging to note seriousness of the state government to invigorate agricultural research and education to develop and disseminate better technology to farmers. This is evident from high growth in public investment in agricultural research and education by 10.1 per cent during 2000-01 to 2007-08, which otherwise was declining continuously from 15.8 per cent in 1970s to 6.8 per cent in 1980s and 4.7 per cent in 1990s (Kannan and Shah, 2010).

Changing cost structure of principal crops

The cost structure of crops is expected to change with advent of new technology, machinery and management practices. Availability of modern inputs at affordable rates and their increased use determine the crop productivity. In this section, an attempt has been made to analyse trends in cost structure of major crops like paddy, jowar, arhar, groundnut and cotton. Traditional inputs like land and human labour have accounted for over 50 per cent of total cost of paddy cultivation in Karnataka (Table 4a). The cost share of seed was 4.5 per cent during triennium ending 1982-83, which declined to about 3.2 per cent in 1992-93 and further down to 2.8 per cent in 2007-08. The decline cost of seed might be due to supply of seeds at subsidised rate by the state government through developmental programmes and schemes.

While per cent cost share of animal labour has declined, the share of machine labour has increased over time. The share of pesticides by and large, has increased between 1982-83 and 2000-01. However, the share of

Table 4a: Trends in Cost Structure of Paddy

(Per Cent)

Items	TE 1982-83	TE 1992-93	TE 2000-01	TE 2007-08
Traditional Inputs				
Land	28.4	31.1	27.5	27.5
Seed	4.5	3.2	3.1	2.8
Manure	6.8	3.9	4.7	2.0
Human Labour	25.8	30.1	31.7	29.0
Animal Labour	9.8	7.7	4.8	5.4
Modern Inputs				
Pesticides	0.3	2.0	2.8	2.2
Irrigation	2.2	2.2	2.2	3.0
Fertilizers	10.8	9.3	11.8	13.3
Machine Labour	0.6	2.2	6.2	9.2
Others	10.9	8.4	5.3	5.7
Total Cost	100.0	100.0	100.0	100.0

Table 4b: Trends in Cost Structure of Jowar

(Per Cent)

Items	TE 1982-83	TE 1992-93	TE 2000-01	TE 2007-08
Traditional Inputs				
Land	25.4	30.0	21.9	22.1
Seed	3.3	2.0	2.2	1.9
Manure	4.7	2.7	3.4	1.1
Human Labour	25.9	24.8	28.9	32.0
Animal Labour	16.8	9.9	15.9	19.2
Modern Inputs				
Pesticides	0.3	0.8	0.4	0.0
Irrigation	0.9	1.1	0.7	0.3
Fertilizers	6.4	9.4	9.7	8.2
Machine Labour	1.0	2.2	5.6	5.7
Others	15.5	17.3	11.3	9.5
Total Cost	100.0	100.0	100.0	100.0

fertilisers in total cost of cultivation has showed declining trend. "Others" included land revenue, cesses and taxes, interest on working and fixed capital, and depreciation on farm implements and buildings. The cost share of "others" has by and large, showed declining trend over time.

Jowar is one of the major coarse cereals cultivated in Karnataka. Of the total cost of cultivation, land and human labour together accounted for about 50 per cent (Table 4b). As this crop is cultivated largely under dry land conditions, the use of modern inputs like fertilisers, pesticides and irrigation are very much limited. The share of pesticides and irrigation was less than one per cent of total cost. Animal labour accounted for relatively high cost share when compared to that of machine labour. Further, cost share of seed has come down marginally over time due to operation of State subsidy schemes for distribution of seeds to small and marginal farmers. Overall, traditional inputs accounted for about three-fourth of total cost.

Arhar is largely cultivated under dry land conditions. Availability of improved varieties and favourable prices induced farmers to expand area under arhar in recent times. Traditional inputs accounted for about two-third of the total cost. Land and human labour together accounted for relatively high cost shares (Table 4c). The cost share of pesticides was little over 11 per cent until 1992-93 and has come down during recent years. Further, share of fertilisers has showed increasing trend over time. Though use of machine labour has increased, but animal labour continues to dominate operations involved in cultivation of arhar.

Table 4c: Trends in Cost Structure of Arhar

(Per Cent)

Items	TE 1982-83	TE 1992-93	TE 2000-01	TE 2007-08
Traditional Inputs				
Land	29.1	26.3	22.2	26.0
Seed	4.9	3.8	3.4	3.1
Manure	3.5	3.7	3.8	3.8
Human Labour	25.8	28.2	27.9	25.0
Animal Labour	12.6	10.8	11.3	13.5
Modern Inputs				
Pesticides	11.7	11.5	7.0	9.0
Irrigation	0.0	0.0	0.6	0.0
Fertilizers	3.1	4.6	7.3	5.9
Machine Labour	0.0	0.7	4.6	4.6
Others	9.2	10.3	11.9	9.2
Total Cost	100.0	100.0	100.0	100.0

Table 4d: Trends in Cost Structure of Groundnut

(Per Cent)

Items	TE 1982-83	TE 1992-93	TE 2000-01	TE 2007-08
Traditional Inputs				
Land	23.0	27.8	19.4	22.7
Seed	21.5	22.9	19.4	20.2
Manure	5.7	4.8	4.0	1.7
Human Labour	21.7	20.8	29.2	23.9
Animal Labour	9.7	7.2	9.0	10.4
Modern Inputs				
Pesticides	0.2	1.0	0.4	0.4
Irrigation	0.3	0.9	1.1	1.7
Fertilizers	6.4	4.9	6.3	6.0
Machine Labour	0.2	0.3	2.3	4.9
Others	11.4	9.5	8.9	8.1
Total Cost	100.0	100.0	100.0	100.0

Table 4e: Trends in Cost Structure of Cotton

(Per Cent)

Items	TE 1982-83	TE 1992-93	TE 2000-01	TE 2007-08
Traditional Inputs				
Land	25.6	30.6	20.6	27.4
Seed	3.6	5.8	6.3	10.0
Manure	2.2	4.1	4.1	2.9
Human Labour	27.1	20.5	30.4	26.9
Animal Labour	4.7	9.7	11.4	8.3
Modern Inputs				
Pesticides	14.0	6.9	6.4	3.3
Irrigation	0.1	0.3	0.9	0.8
Fertilizers	16.6	9.5	8.7	8.7
Machine Labour	2.3	2.0	1.7	5.2
Others	3.6	10.5	9.6	6.6
Total Cost	100.0	100.0	100.0	100.0

Groundnut is an important oilseed crops cultivated in Karnataka. Among cost components, seed cost accounted for about one-fifth of total cost of cultivation (Table 4d). Human labour and animal labour have accounted for about 23.9 per cent and 10.4 per cent of total cost, respectively in 2007-08. Since, this crop is cultivated largely under dry land conditions, the share of improved inputs like pesticides, irrigation and machine labour is found to be low. However, the cost share of fertilisers has by and large, increased over time.

The cost structure of cotton is presented in Table 4e. Traditional inputs constituted about 70 per cent of total cost. Among traditional inputs, land and human labour accounted for 50 per cent. Interestingly, the cost share of animal labour, by and large has declined and that of machine labour has increased. The share of pesticides has declined considerably during recent years with 3.3 per cent in 2007-08. This might be due to rapid spread of B.t. cotton technology in the state. Fertilisers and others have constituted about 8.7 per cent and 6.6 per cent, respectively.

It is clear from the analysis of cost structure that traditional inputs have accounted for higher cost shares than modern inputs. However, the share of modern inputs like machine labour and fertilisers has by and large, increased over time. As expected, cost share of irrigation is found to be low for major crops grown in Karnataka.

Growth in output, input and TFP index

Average annual growth in output, input and TFP index for ten major crops across different periods is presented in Table 5. The period of analysis for different crops is dictated by the availability of data on inputs and output from the cost of cultivation study. It can be observed from the table that TFP of paddy has registered positive growth during 1980-81 to 1989-90 (1980s), 1990-91 to 1999-00 (1990s) and 2000-01 to 2007-08 (2000s). Higher output growth triggered by technological change has resulted in positive TFP growth. Annual growth in TFP was impressive at 1.48 per cent in 1990s and 2.68 per cent in 2000s when compared to 0.42 per cent during 1980s. During entire period of analysis, i.e. 1980-81 to 2007-08 TFP has risen at 1.49 per cent. Overall, the contribution of TFP to output growth was found to be 60.02 per cent. Contribution of technological change to paddy output growth was positive and respectable across the sub-periods. This indicates that productivity growth rather than input growth is the main driver of paddy production in Karnataka.

Jowar has registered output growth of 2.7 per cent in 1980s. But, higher growth of inputs over output during nineties has resulted in negative TFP growth. However, TFP had risen positively during 2000-01 to 2007-08. During 1980-81 to 2007-08 annual growth in TFP was 2.03 per cent, which contributed over 80 per cent of jowar output growth. A similar growth pattern could also be observed in case of maize. Growth in maize output index was

Table 5: Annual Growth in Input, Output and TFP Index of Various Crops in Karnataka (%)

Crop	Input	Output	TFP	Share of TFP in Output Growth
Paddy				
1980-81 to 1989-90	0.42	0.84	0.42	50.20
1990-91 to 1999-00	2.99	4.47	1.48	33.19
2000-01 to 2007-08	-0.87	1.82	2.69	147.53
1980-81 to 2007-08	0.99	2.48	1.49	60.02
Jowar				
1980-81 to 1989-90	1.71	2.70	0.99	36.56
1990-91 to 1999-00	0.45	-0.90	-1.35	150.55
2000-01 to 2007-08	-0.97	6.45	7.42	115.00
1980-81 to 2007-08	0.45	2.48	2.03	81.74
Maize				
1980-81 to 1989-90	0.54	2.52	1.98	78.60
1990-91 to 1999-00	0.79	-0.56	-1.35	241.98
2000-01 to 2007-08	0.69	3.91	3.23	82.46
1980-81 to 2007-08	0.68	1.79	1.12	62.22
Ragi				
1980-81 to 1989-90	0.95	-2.70	-3.65	135.22
1990-91 to 1999-00	1.84	2.66	0.82	30.83
2000-01 to 2007-08	-1.19	6.56	7.75	118.17
1980-81 to 2007-08	0.64	2.03	1.39	68.25
Arhar				
1980-81 to 1989-90	1.63	7.10	5.47	77.06
1990-91 to 1999-00	2.12	-0.75	-2.87	382.89
2000-01 to 2007-08	0.15	7.29	7.14	97.89
1980-81 to 2007-08	1.37	4.25	2.88	67.65
Groundnut				
1980-81 to 1989-90	3.27	3.83	0.56	14.70
1990-91 to 1999-00	-1.59	-3.27	-1.68	51.29
2000-01 to 2007-08	-1.01	10.97	11.98	109.18
1980-81 to 2007-08	0.20	3.32	3.12	93.93
Sunflower				
1980-81 to 1989-90	11.49	12.04	0.55	4.57
1990-91 to 1999-00	-1.16	-1.28	-0.12	9.48
2000-01 to 2007-08	3.02	6.38	3.35	52.59
1980-81 to 2007-08	4.30	5.43	1.13	20.85
Safflower				
1980-81 to 1989-90	5.77	15.20	9.43	62.02
1990-91 to 1999-00	-1.52	1.45	2.97	205.06
2000-01 to 2007-08	0.41	1.74	1.32	76.19
1980-81 to 2007-08	1.48	6.12	4.64	75.77

to be continued....

continuation....

Crop	Input	Output	TFP	Share of TFP in Output Growth
Cotton				
1980-81 to 1989-90	0.34	4.00	3.67	91 59
1990-91 to 1999-00	-0.56	-4.98	-4.42	88.77
2000-01 to 2007-08	-1.77	15.62	17.39	111.34
1980-81 to 2007-08	-0.62	4.12	4.74	115.04
Sugarcane				
1980-81 to 1989-90	-7.03	-0.34	6.69	Negative
1990-91 to 1999-00	6.04	0.78	-5.27	Negative
2000-01 to 2007-08	-0.55	0.97	1.51	156.45
1980-81 to 2007-08	-0.27	0.46	0.73	157.93
All Crops				
1980-81 to 1989-90	1.72	1.81	0.09	4.95
1990-91 to 1999-00	0.42	-0.56	-0.98	174.27
2000-01 to 2007-08	0.13	5.01	4.88	97.47
1980-81 to 2007-08	0.77	1.88	1.11	59.26

impressive at 2.52 per cent in 1980s, but it had declined to 0.56 per cent 1990s. However, turnaround in higher output growth in recent period was commendable. Overall, TFP of maize has grown at 1.12 per cent contributing 62.22 per cent of output growth.

In case of Ragi, except in 1980s both output and TFP have registered positive growth rates across all other periods of analysis. During 1990s and 2000s, it showed splendid output growth of 2.66 and 6.56 per cent, respectively. Annual growth in TFP during the corresponding periods was 0.82 per cent and 7.75 per cent. During the entire period of analysis, TFP has recorded annual growth rate of 1.39 per cent, which contributed 68.25 per cent of total output growth.

For Arhar, except during 1990s output growth was mainly driven by technology. In fact, output growth of arhar was impressive at 7.10 per cent and 7.29 per cent during 1980s and 2000s, respectively. Growth in TFP during the corresponding periods was 5.47 per cent and 7.14 per cent. Overall, growth in TFP of arhar was 2.88 per cent and its contribution to output growth was 67.65 per cent.

Barring 1990-91 to 1999-2000, growth in output and TFP of groundnut was positive in all other periods under study. TFP has registered positive growth rate of 0.56 per cent in 1980s. But, it has decelerated to -1.68 per cent in 1990s. During entire period of analysis, respective growth in output and TFP was 3.32 per cent and 3.12 per cent. TFP has contributed about 93.93 per cent to output growth indicating that technology has played greater role in augmenting the production of groundnut in Karnataka.

In Sunflower production, use of inputs seems to be relatively high. Growth in inputs was the main driver of output growth during 1980s and 1990s. Interestingly, during 2000s growth in output and TFP of sunflower was positive at 6.38 per cent and 3.35 per cent, respectively. Contrarily, growth pattern of TFP appears to be different for safflower. Both output and TFP have risen positively across all periods. But, growth in TFP has decelerated from 9.43 per cent in 1980s to 2.97 per cent in 1990s and then to 1.32 per cent in 2000s.

For cotton, input, output and TFP have shown positive growth rates during 1980s. TFP has registered healthy growth rate of 3.67 per cent with its contribution of 91.59 per cent to output growth. However, during 1990s all the three indices have registered negative growth. But, output and TFP grew impressively in 2000s which could be attributed to spread of B.t. cotton technology. During the entire period of analysis growth in output and TFP was 4.12 and 4.74 per cent, respectively. Technical change played an important role in increasing cotton output growth in Karnataka.

In case of sugarcane, input and output index have registered negative growth during 1980s. However, higher input growth than output growth has resulted in negative TFP growth of 5.27 per cent in 1990-91 to 1999-00. During 2000s growth in output and TFP was 0.97 and 1.51 per cent, respectively. Overall, TFP of sugarcane has registered positive growth of only 0.73 per cent indicating that sugarcane production is input based and technology has played a little role in it.

For Karnataka state as whole, during the entire period of analysis, input and output indices have registered growth rate of 0.77 and 1.85 per cent, respectively. TFP has risen at 1.09 per cent per annum and it has contributed 58.67 per cent to total output growth. Low TFP growth implies that there is huge scope to increase agricultural production through new technological breakthrough. Among sub-periods, growth in TFP was almost zero during 1980s and it supports the contention that crop sector in Karnataka had witnessed stagnation in growth during that period. Even though output and TFP have showed negative growth rates in 1990s, they have improved remarkably during 2000s. In fact, deceleration in TFP growth in Indian agriculture during 1990s has been well documented in Kumar et al (2004 and 2008).

On the whole, analysis of TFP shows that most of crops have registered decline in productivity growth during nineties. Interestingly, during 2000-01 to 2007-08, all crops have showed positive growth in TFP.

Summary and Conclusion

The present study has estimated total factor productivity growth of ten major crops in Karnataka and analysed the factors affecting it at state level. A widely used Tornqvist-Theil Index was utilised to construct aggregate output and aggregate input of individual crops. Two outputs and nine inputs have been used to construct output and input index. The cropping pattern has undergone visible changes since 1960s with shift in area from cereals to pulses, oilseeds and high value crops like vegetables and plantation crops. The growth analysis has revealed that yield of most crops in particular food grains has declined during 1980-81 to 1989-90 and has led to stagnation in production. However, during 1990-91 to 2007-08 there is reversal of growth in production and yield for some food and non-food crops. Among various growth promoting factors, public investment in agriculture seemed to have played an important role in accelerating growth.

TFP of most of crops has registered decline in productivity growth during 1990s, but with revival in terms of positive TFP growth in recent period. For Karnataka state as whole, input and output indices have registered growth rate of 0.77 and 1.85 per cent, respectively during 1980-81 to 2007-08. TFP has risen at 1.09 per cent per annum and it has contributed about 58.67 per cent to total output growth. Low TFP growth implies that there is huge scope to increase agricultural production through new technological breakthrough by enhancing investment in research and technology, and rural infrastructure. More private investments should be attracted in under developed regions of the state by providing incentives and favourable policy environment.

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The Productivity of work is not the responsibility of the workers but of the manager.

—Peter Drucker

Focus

Economic Liberalisation and Productivity Growth In Indian Small Scale Industrial Sector

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The study is an endeavor to analyse the productivity performance of Indian small scale industrial sector over the period of 1980-81 to 2003-04 using the Malmquist productivity index (MPI). The analysis reveals a TFP regress to the tune of -0.57 percent per annum during the entire study period. However, a comparison of the two sub-periods reveals that the TFP growth has turned out to be positive (reflected by TFP above unity) during the post-liberalisation period in comparison of the negative TFP growth during the pre-liberalisation period. Thus, it can be inferred that the TFP growth has accelerated during the post-liberalisation period, which is an indicator of sustainable growth in the small scale industrial sector of India. The decomposition of TFP growth into two components viz. technical efficiency change and technical progress reveals that efficiency regress is a dominant source and technological regress is relatively a scant source of TFP growth in the small scale industrial sector of India.

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The present study has been undertaken with the primary objective to evaluate the TFP growth in Indian Small Scale Industrial (SSI) sector. The relevance of the study stems from the fact that SSI: i) provides immediate scale employment; ii) has comparatively higher labour capital ratio; iii) needs shorter gestation period and relatively smaller markets to be economic; iv) need low investment; v) offer a method of ensuring a more equitable distribution of national income; vi) facilitates effective mobilization of capital and skill; vii) stimulate the growth of entrepreneurship and promote a more diffused pattern of ownership and location; viii) it absorbs about 193.21 lakhs of workers; and ix) contributes 35.47 percent of total Indian exports (Gill and Singh, 2010). This sector is therefore, considered the harbinger of economic progress and has stemmed out from India's own skill, resources, enterprise and culture and thus, is considered as elixir for the ills of a developing economy like India.

However, the economic liberalisation process launched in 1991 heralded the liberalisation of Indian industrial sector from various controls and regulations. This also implied a movement towards the establishment of a competitive market system with optimum resource utilisation. Under this process the firms were exposed to international competition which forced them to introduce new methods of production, import quality inputs along with modern technology to improve their efficiency. In this era, productivity growth is recognised as a key feature of economic dynamism. The industrial growth driven mainly by input growth is inevitably subject to diminishing returns to scale and may not be sustainable in the long run. Therefore, the policy makers are now pursuing the industrial growth through improvement and productivity driven strategies than lay emphasis on enhancing total factor productivity growth rather that investment driven growth.

In this context the basic objective of the present study is to analyse the impact of economic liberalisation on Total Factor Productivity (TFP) growth in Indian small scale industrial sector. Attempt has also been made to explore the factors affecting TFP growth along with testing the TFP convergence hypothesis for Indian small scale industrial sector. In India, some studies such as Banerjee (1975), Qomen and Evenson (1977), Mehta (1980), Goldar (1983), Ahluwalia (1991), Ray (1997), Neogi and Ghosh (1998), Mitra (1999), Ray (2002), Goldar and Kumari (2003), Chattopadhyay (2004), Sidhu (2007), Sahoo (2008), and Kumar and Arora (2009), have tried to measure the TFP growth in Indian manufacturing. However, handful of literature is available on measuring the TFP growth of Indian small scale industrial sector. The present study is an endeavour in this direction and tries to fulfil the existing void in the literature on measuring TFP of Indian small scale industrial sector.

To fulfill this objective, the paper has been divided into five broad sections. Section 2 presents a methodological framework to work out the non-parametric Malmquist Productivity Index (MPI) to analyse the TFP growth. Section 3 deals with the sources of database and construction of input and output variables. In Section 4, the empirical results relating to partial productivities and TFP growth in Indian small scale industrial sector have been presented. The last section concludes the discussion along with certain policy implications.

Malmquist Productivity Index: A Theoretical Survey

The Malmquist productivity index, as proposed by Caves, Christensen and Diewert (1982), is defined using distance functions, which describes multi-input, multi-output production without involving explicit price data and behavioural assumptions (such as cost minimisation or profit maximisation). One may define input distance function characterising the production technology by looking at a minimal proportional contraction of the input vector, given an output vector. An output distance function considers a maximal proportional expansion of the output vector, given an input vector or for the purpose of this paper, output distance functions have been utilised to calculate MPI since the manufacturing firms are more likely to increase their outputs given their use of inputs, rather than to decrease inputs given their outputs.

Fare, Grosskopf, Norris and Zhang (1994) define an output distance function at time *t* as

$$D_0^t(x^t, y^t) = \inf\{\theta : (x^t, y^t/\theta) \in S^t\} = [\sup\{\theta : (x^t, \theta y^t) \in S^t\}]^{1} \quad (1)$$

where x^t is a vector of input quantities at time t and y^t is a vector output quantity at time *t*. S^t describes a production technology or production possibility set that is feasible using the technology available at time *t*.

The term in $f\{\theta x^t, y^t/\theta S^t\}$ in equation (1) states that of the set of real numbers, θ, where θ is such that the input/output combination $(x^t, y^t/\theta)$ is part of the production possibility set that is technically feasible given time t technology, we need to find the infimum or greatest lowest bound of θ. The infimum of θ is the biggest real number that is less than or equal to every number in θ. The last part of equation (1) states that finding this infimum is equivalent to finding the reciprocal of $\sup\{\theta.(x^t, \theta y^t) \in S^t\}$. That is, we want to find the reciprocal of the supremum of the set of real numbers θ, where this time θ is the set of real numbers such that for a given input vector x^t the input/output combination $(x^t, \theta y^t)$ is part of the production possibility set that is technically feasible given time t technology. The supremum (sup) of θ is the smallest real number that is greater than or equal to every number (inf) of θ.

The term $D_0^t(x^t, y^t)$ in equation (1) is the output distance function based on the input and output vectors at time t. The subscript "o" signals that the distance function is an output distance function. The superscript "t" on the D is important as it signals which period reference technology (or production possibility frontier) the distance is being measured from. To calculate $D_0^t(x^t, y^t)$, it is necessary to find the largest factor by which all the outputs in the output vector could be increased while making production as technically efficient as possible, based on the input vector x^t. $D_0^t(x^t, y^t)$ is then the reciprocal of this value. The closer the manufacturing sector is to the production frontier the smaller the factor increase will be and consequently the larger the value of $D_0^t(x^t, y^t)$. If the manufacturing sector is operating on the frontier then $D_0^t(x^t, y^t)$ will take a value of 1. In contrast, when the manufacturing sector is below the frontier, $D_0^t(x^t, y^t)$ will be less than 1. The distance function is actual output divided by the frontier level of output. Caves, Christensen and Diewert (1982) define the Malmquist Productivity Index as:

$$M^t = \frac{D_0^t(x^{t+1}, Y^{t+1})}{D_0^t(x^t, y^t)} \quad (2)$$

i.e., they define their productivity index as the ratio of two output distance functions, which both utilise technology at time t as a reference technology. The numerator is the output distance function at time t+1 based on period t technology and the denominator is the output distance function at time t based on period t technology. Instead of using period t's technology as the reference technology it is possible to construct output distance functions based on period t+1's technology and consequently a Malmquist productivity index can be constructed as:

$$M^{t+1} = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)} \quad (3)$$

Fare et al. (1994) avoided choosing an arbitrary benchmark technology by specifying their Malmquist productivity change index as the geometric mean of the indices shown in equations (2) and (3). That is:

$$M_0(x^{t+1}, y^{t-1}, x^t, y^t = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)\left(\frac{D_0^{t+1}(x^{t+1}, y^{t-1})}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \quad (4)$$

Equation (4) can also be written as:

$$M_0(x^{t-1}, y^{t+1}, x^t, y^t) = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \times \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \quad (5)$$

Fare et al. (1994) gave the following interpretation to the two terms on the right hand side of equation (5):

$$\text{Efficiency change} = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \quad (6)$$

$$\text{Technical change} = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \quad (7)$$

Hence, the Malmquist productivity index they derived is simply the product of the change in relative efficiency that occurred between period's t and t+1, and the change in technology that occurred between periods t and t+1.

In the literature, there are different methods such as Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) that could be used to measure the Malmquist productivity index. However, the widely used method is linear programming based Data Envelopment Analysis (DEA) method, using which, four aforementioned distance functions can be estimated as follows:

$$D_0{}^t(x_t, y_t) = \min_{\theta\lambda} \theta \quad (8)$$

Subject to

$$y_{kt}/\theta \geq y_t\lambda$$

$$\lambda x_t \leq x_{kt}$$

- $$\lambda \geq 0$$

The above problem can be written to reflect the traditional Farrell output-oriented measure as well as the standard DEA models as:

$$[D_0{}^t(x_t, y_t)]^{-1} = \max_{\varphi\lambda}\varphi \quad (9)$$

Subject to

$$-\varphi y_{kt} + yt\lambda \geq 0$$

$$x_{kt} - x_t\lambda \geq 0$$

$$\lambda \geq 0$$

The other three linear programmes can be similarly derived as:

$$[D_0{}^{t+1}(x_{t+1}, y_{t+1})]^{-1} = \max_{\varphi\lambda}\varphi \quad (10)$$

Subject to

$$\varphi y_{k't+1} + y_{k't+1}\lambda \geq 0$$

$$x_{k,t+1} - x_{t+1}\lambda \geq 0$$

$$\lambda \geq 0$$

$$[D_0{}^t(x_{t+1}, y_{t+1})]\text{-}1 = \max_{\varphi}\lambda\varphi \quad (11)$$

Subject to

$$\varphi y_{kt} + y_{t+1}\lambda \geq 0$$

$$x_{kt} - x_{t+1}\lambda \geq 0$$

$$\lambda \geq 0$$

and

$$[D_0{}^t + 1\ (x_t, y_t)]\text{-}1 = \max_{\varphi}\lambda\varphi \quad (12)$$

Subject to

$$\varphi y_{kt} + y_{t+1}\lambda \geq 0$$

$$x_{kt} - x_{t+1}\lambda \geq 0$$

$$\lambda \geq 0$$

where, y_{kt} is a M x 1vector of output quantities for the observation k at time t; x_{kt} is a N x 1 vector of input quantities for the observation k at time t; y_t is a K x M matrix of output quantities for all K observations at time t; x_t is a K x N matrix of input quantities for all K observations at time t; l is a K´1 vector of weights and j is a scalar.

Database and Construction of Variables

It is well acknowledged in the literature for measuring TFP growth, a well defined set of the inputs and outputs is required. The required data for present paper have been culled out from the various issues of "Summary Results and Annual Survey of Industries (ASI) (Factory Sector)". Various reports of Center for Monitoring Indian Economy (CMIE), Economic surveys, Reports on Currency and Finance, Reserve Bank of India Bulletins, National Accounts statistics, Handbook of Statistics on Indian Economy, World development Indicators and World Global Competitive Report are worth to mention as the additional sources of the data.

The present paper is confined to the period from 1980-81 to 2003-04. The choice of terminal year is governed by the availability of latest comparable data from the Central Statistical Organisation (CSO). The CSO has ceased the publication of data on Indian manufacturing sector on the basis of different employment categories after 1998. However, the data disks provided by EPW Research Foundation contains the data on the basis of above mentioned classification for the later periods of the study. The economic and technical efficiencies for the small scale industry, classified among 13 industrial groups at 2-digit level of aggregation, have been estimated using the Annual Survey of Industries (ASI) dataset over the period 1980-81 to 2003-04. Following Rao (1996), small enterprises have been defined as those employing between 10 and 99 employees (firms with less than 10 employees are not covered in the ASI). Thus small scale sector constitutes all the enterprises having workers in the range of 10-99. This definition, however, does not fit easily into those adopted by the Government of India. In the present study, we considered two inputs (gross fixed capital at constant prices and number of employees) and only one output (gross value added at constant prices). The detailed definitions of these inputs and outputs have been given in ASI as follows:

Labour Input

In present paper, the number of employees consisting of both non-production and production workers have been taken as the measure of labour market. As per the definition provided by ASI the production workers relate to all persons employed directly or through agency whether for wages or not and engaged in any manufacturing process or in cleaning any part of the machinery or premises used for manufacturing process are lying under the production workers. However, persons holding the positions of supervisor, or management or employed in administrative office, store keeping section and welfare section, engaged in the purchase of raw material, etc. are included in the non-production workers.

Capital Input

In the present paper, we use the gross fixed capital stock as a measure of capital input. The standard practice of perpetual inventory method has been followed here to generate the series of gross fixed capital stock at constant prices. This requires a gross investment series, an asset price deflator, a depreciation rate, and a benchmark capital stock. We followed the procedure adopted by Martin and Warr (1990), Austria and Martin (1995), Wu (1997) and Fan et al. (1999) for getting an estimate of initial value of capital stock. This procedure involves the following steps:

Step 1: The gross real investment (I_t) has been obtained by using relationship:

$$I_t = (B_t - B_{t-1} + D_t) / P_t$$

where B_t = Book value of fixed capital in the year t; D_t = Value of depreciation of fixed assets in the year t, and P_t = Price index of machinery and machine tools in the year t.

Step 2: The logarithm of gross real investment was first regressed against a time trend to obtain its average growth rate ω and a trend value of investment at the beginning of the same i.e. I_0.

Step 3: Making the conventional assumption that the capital stock grows at a steady state at time t_0 the value of capital stock for initial year (K_0) has been then estimated as:

$$K_0 = \frac{I_0}{\omega + \delta}$$

where, K_0 =Gross value of initial capital stock; ω = Estimated growth rate of investment; and δ = Annual rate of discarding of capital. In the present analysis, we have taken annual rate of discarding of capital equal to 5 percent.

Step 4: After obtaining the estimate of fixed capital for the benchmark year, the following equation has been used for the measurement of gross fixed capital series at 1981-82 prices:

$$K_t = K_{t-1} + I_t - \delta K_{t-1}$$

where, K_t = Gross fixed capital at 1981-82 prices by the end of year t; I_t = Gross real investment in fixed capital during the year t; and δ = Annual rate of discarding of capital.

Gross Value Added

The figures of Gross Value Added are arrived at by deducting the cost of total input from the value of total output. The figures of 'total output' comprise of total ex-factory value of products and by-products manufactured as well as other receipts from non industrial services rendered to others, work done for others on material supplied by them, value of electricity produced and sold, sale value of goods sold in the same conditions purchased, addition in stock of semi-finished goods and value of own construction. However, 'total inputs' comprise of total value of fuels, materials consumed as well as expenditures such as cost of contract and commission work done by others on materials supplied by the factory, cost of materials consumed for repair and maintenance work done by others to the factory's fixed assets, inward freight and transport charges, rate and taxes (excluding income tax), postage, telephone and telex expenses, insurance charges, banking charges, cost of printing and stationery and purchase value of goods sold in the same condition as purchased. Rent paid and interest paid are not included.

Further, all monetary data have been deflated by using appropriate price deflators. The gross value added figures at constant price have been utilised as an index of output. Following Jayadevan (1995) and Goldar (1986), the use of gross value added has been preferred as an index of output in place of net value added because depreciation charges in the Indian industries are known to be highly arbitrary and are fixed by the income tax authorities and seldom represent actual capital consumption. Last but not the least, the implicit GDP price deflators have been used as the price of output. However, the CPI has been used as the index of the price of labour. The average price of the term lending institutions namely, Industrial Capital Investment Corporation of Indian (ICICI), Industrial Development Bank of India (IDBI), Small Industries Development Bank of India (SIDBI), etc. has been used as the price of capital.

Empirical Results

In this section empirical results pertaining to partial productivities and total factor productivity growth in Indian small scale industrial sector have been presented. It has been well acknowledged in the literature that the labour productivity defines a ratio of output (i.e., gross value added in the present paper) to the total number of labour employed in a representative production plant. However, in the present study, these ratios have been obtained for the small-scale industries classified according to National Industrial Classification (NIC)-1998, 2-digit classification of aggregation. Table 1 presents the growth rates of labour productivity during the entire study period (1980-81 to

Table 1: Labour Productivity in Indian Small Scale Industrial Sector

Industry	Entire Period (1980-81 to 2003-04)	Pre-Liberalisation Period(1980-81 to 1990-91)	Post-Liberalisation Period(1991-92 to 2003-04)
Food Products	1.434	0.471	4.360
Chemical and Chemical Products	2.055	1.662	2.541
Basic Metal	0.961	0.895	1.031
Hosiery Garments	1.519	0.657	3.514
Metal Products	1.670	1.205	2.314
Rubber and Plastic	1.729	2.364	1.264
Machinery and Parts Except Electrical	0.672	0.458	0.985
Electrical Machinery and Apparatus	1.245	-0.547	2.452
Paper Products and Printing	1.962	1.224	3.145
Transport Equipments and Parts	1.628	1.654	1.602
Wood Products	0.510	0.254	1.024
Non-Metallic Mineral Products	0.256	-0.564	0.845
Others industries (n.e.c.)	2.346	2.125	2.589
All Industries (GM)	1.383	0.912	2.128

Source: Author's Calculations

Note: i) n.e.c. refers to not elsewhere classified; and ii) GM refers to geometric mean.

2003-04) and two sub-periods, namely, pre-liberalisation period (1980-81 to 1990-91) and post-liberalisation period (1992-92 to 2003-04). It has been observed that the labour productivity of Indian small scale industrial sector has grown at an average annual growth rate of 1.383 percent during the entire study period. However, this figure has been observed to be 0.912 percent for the pre-liberalisation period which accelerated by 1.216 percentage points and was observed to be 2.128 percent per annum during the post-liberalisation period. Thus, the growth of labour productivity has found to have improved during the post-liberalisation period relative to the pre-liberalisation period.

Looking at the inter-industry variations in labour productivity growth, it has been observed that except for these four industries viz. Basic Metal, Machinery and Parts Except Electrical, Wood Products, and Non-Metallic Mineral Products, all the remaining nine industries have shown an increase in labour productivity by more than 1 percent per annum during the entire study period. However, the Chemical and Chemical Products industry, and Other industries not elsewhere classified, have exhibited an increase in labour productivity by recording the highest average annual growth rate of above two percent per annum (i.e., 2.055 percent and 2.346 percent per annum, respectively). The comparative analysis of the two sub-periods reflects that except for the classification of Rubber and Plastic industry, an increase in labour productivity has been observed for the remaining 12 industrial groups in the period after 1991. Substantial increase in labour productivity has been observed in the Food Product industry, Hosiery Garments and Paper Products and Printing industry during the period 1991-92 to 2003-04. Thus, the liberalisation-process has proved to be beneficial and seems to be improving the labour productivity growth in small scale industry of India.

Moreover, another partial productivity measure namely, capital productivity, can be calculated from the available dataset. The ratio of Gross Value Added (GVA) to the gross fixed capital provides the measure of capital productivity. Table 2, provides evidence regarding the capital productivity measure for the Indian small scale industrial sector. An average annual growth rate of capital productivity to the tune of 1.255 percent per annum has been observed for the small scale sector of India for the entire study period. Except three industrial classifications viz. Machinery and Parts Except Electrical, Wood Products, and Non-Metallic

Table 2: Capital Productivity in Indian Small Scale Industrial Sector

Industry	Liberalisation Period (1980-81 to 1990-91)	Entire Period (1980-81 to 2003-04)	Pre period Post-Liberalisation Period (1991-92 to 2003-04)
Food Products	1.451	0.578	3.645
Chemical and Chemical Products	1.443	1.234	1.687
Basic Metal	1.088	0.968	1.224
Hosiery Garments	1.455	0.982	2.157
Metal Products	1.402	1.256	1.564
Rubber and Plastic	1.210	1.389	1.054
Machinery and Parts Except Electrical	0.821	0.659	1.024
Electrical Machinery and Apparatus	1.245	-0.985	1.956
Paper Products and Printing	1.693	1.395	2.054
Transport Equipments and Parts	1.586	2.005	1.254
Wood Products	0.994	0.985	1.003
Non-Metallic Mineral Products	0.256	0.236	0.986
Others industries (*n.e.c.*)	1.666	1.358	2.045
All Industries (GM)	1.255	0.928	1.666

Source: Author's Calculations
Note: *n.e.c.* refers to not elsewhere classified;
GM refers to geometric mean

Mineral Products, the capital productivity in remaining 10 industries has been observed to be growing at an average annual growth rate of above 1 per cent per annum during the overall period. The industrial classification of Paper Products and Printing recorded the highest average annual growth rate in capital productivity to the tune of 1.693 percent per annum during the entire study period.

The comparative analysis of capital productivity for the two sub-periods reveals an acceleration in capital productivity during the period 1991-92 to 2003-04. An increase in capital productivity has been observed from 0.928 percent in pre-liberalisation period to 1.666 percent in post-liberalisation period. However, except two industries viz. Rubber and Plastic, and Transport Equipments and Parts, the remaining 11 industrial groups have shown an improvement in the capital productivity during the post-liberalisation period relative to the pre-liberalisation period. Marked improvement in capital productivity has been displayed by Food Product and Hosiery Garments industry, in the period after 1991 relative to decade of eighties. Thus, the liberalisation process has been observed to be imparting a positive impact on the partial productivity measures of growth in the small scale industrial sector.

Although the partial productivity measures portray a glittering picture of the effect of liberalisation process on the growth of Indian small scale industrial sector, yet these measures are not free from certain defects. Partial productivity estimates;

- are deterministic and thus ignore stochastic component ;
- are biased towards the input utilised and thus are not suitable for growth accounting framework ; and
- are not able to decompose the effect of efficiency.

The measure of Total Factor Productivity (TFP) can be utilised to overcome these defects of ratio based partial productivity measures and as such can decompose the measure of TFP into diverse components, namely, Technical Change (TCH) and Technical Efficiency Change (ECH). Table 3 provides the Malmquist Productivity Index which has been calculated by using model (5). The model (5) can be estimated by solving four distinct linear programming problems [(9), (10), (11) and (12)] given in the procedure explained for the model (8). The computation of (5) will provide us productivity index (given as MALM INDEX). However, we use the growth rates of TFP for interpretation purposes. The growth rate of TFP can be obtained using the following formula:

Table 3: Total Factor Productivity Growth in Indian Small Scale Industrial Sector

Industry	Liberalisation Period (1980-81 to 1990-91)	Entire Period (1980-81 to 2003-04)	Pre period Post-Liberalisation Period (1991-92 to 2003-04)
Food Products	1.0195	1.0025	1.0241
Chemical and Chemical Products	0.9895	0.9725	0.9924
Basic Metal	0.9625	0.9612	0.9854
Hosiery Garments	0.9738	0.9701	1.0254
Metal Products	1.0156	0.9968	1.0168
Rubber and Plastic	1.0029	1.0248	1.0239
Machinery and Parts Except Electrical	1.0048	0.9824	1.0256
Electrical Machinery and Apparatus	0.9974	0.9889	0.9652
Paper Products and Printing	0.9878	0.9927	0.9654
Transport Equipments and Parts	0.9691	0.9524	0.9854
Wood Products	0.9905	0.9988	1.0354
Non-Metallic Mineral Products	1.0024	1.0124	1.0098
Others (n.e.c.)	1.0125	1.0025	1.0456
All Industries (GM)	0.9943	0.9889	1.0074

Source: Author's Calculations
Note: n.e.c. refers to not elsewhere classified;
GM refers to geometric mean

$$TFPG = (MALMINDEX - 1) \times 100$$

It can be observed from Table 3 that the total factor productivity growth (TFPG) is negative to the tune of -0.57 [(0.9943-1) x 100] percent per annum during the entire study period. However, six industrial groups viz. Food Products, Metal Products, Rubber and Plastic, Machinery and Parts Except Electrical, Non-Metallic Mineral Products, and Others industries not elsewhere classified, exhibited TFP growth greater than unity and positive average annual growth rates during the entire study period.

Further, a comparison of the two sub-periods reveals that the TFP growth has turned out to be positive (reflected by TFP above unity) during the post-liberalisation period in comparison of the negative TFP growth during the pre-liberalisation period. However, except for the two industrial groups viz. Paper Products and Printing, and Electrical Machinery and Apparatus which registered a slowdown in the TFP growth, all the remaining eleven industrial groups have shown an improvement in the TFP growth during the period 1991-92 to 2003-04. Amongst these eleven industrial groups, the most dynamic industry in terms of rising total factor productivity levels in the post-liberalisation period has been the Hosiery Garments industry (from -2.99 percent to 2.54 percent), closely followed by Machinery and Parts Except Electrical (from -1.76 percent to 2.58 percent). In sum, it can be inferred that the TFP growth has become positive during the post-liberalisation period, which is an indicator of sustainable growth in the Indian small scale industrial sector during the liberalised regime.

Decomposition of Total Factor Productivity Growth

The sustainability of growth also depends upon the sources of TFP which can be decomposed under the Malmquist TFP framework. Using the Malmquist TFP index, the TFP growth can be decomposed into two components viz., efficiency change and technical progress i.e.,

$$TFP = ECH \times TCH$$

where, TFP is total Factor productivity index and ECH is efficiency change and TCH is the measure of technical progress. The first term ECH defines the change in technical efficiency from period t to t+1, i.e. moving closer (or away) from the production frontier. Hence, ECH is a combined indicator of managerial improvement and improvements in scale of production. The second term TCH is the proxy of shift in frontier from time t to period t+1 and thus represents the advances in knowledge relating to the state of art of production. A value of technical change index greater than unity implies the outward shift, while

Table 4: Efficiency Change in Indian Small Scale Industrial Sector

Industry	Entire Period (1980-81 to 2003-04)	Pre-Liberalisation Period (1980-81 to 1991-92)	Post-Liberalisation Period (1991-92 to 2003-04)
Food Products	1.0214	1.0195	1.0345
Chemical and Chemical Products	0.9658	0.9701	0.9784
Basic Metal	1.0324	1.0214	0.9985
Hosiery Garments	0.9928	0.9895	1.0024
Metal Products	1.0068	1.0021	1.0156
Rubber and Plastic	1.0136	1.0021	0.9985
Machinery and Parts Except Electrical	0.9824	0.9824	1.0235
Electrical Machinery and Apparatus	0.9906	0.9854	1.0425
Paper Products and Printing	0.9625	0.9564	1.0012
Transport Equipments and Parts	1.0025	1.0047	1.0168
Wood Products	0.9989	0.9878	1.0289
Non-Metallic Mineral Products	1.0152	0.9501	1.0235
Others (n.e.c.)	0.9562	0.9509	0.9944
All Industries (GM)	0.9952	0.9861	1.0121

Source: Author's Calculations
Note: n.e.c. refers to not elsewhere classified;
GM refers to geometric mean

value less than unity implies the inward shift of the production frontier. An outward shift of production frontier represents technical progress whereas, an inward shift is termed as technical regress.

Table 4, presents efficiency change index, which reflects an improvement (deceleration) in technical efficiency if the index value is above (lower than) unity. It is evident from this table that an efficiency regress has been observed during the entire study period at the rate of 0.48 [(i.e., 1-0.9952)x100] percent per annum. Thus, the small scale industry has observed a deceleration in technical or operational efficiency during the entire study period. In addition, 0.48 percentage points of 0.57 percent negative TFP growth comes from efficiency change. Thus, negative efficiency growth is the dominant source and technical progress is relatively a feeble source of deceleration in TFP growth in small scale industrial sector of India. Moreover, eight industrial classifications viz. Chemical and Chemical Products, Hosiery Garments, Machinery and Parts Except Electrical, Electrical Machinery and Apparatus, Paper Products and Printing, Wood Products, Non-Metallic Mineral Products and Others industries not elsewhere classified, have been observed to be operating with the efficiency change index below unity and thus have been found to be responsible for the negative average annual growth rate of efficiency in general and TFP in particular during the pre-liberalisation period in Indian small scale industrial sector.

However, a comparative analysis of the technical efficiency change reflects an improvement in the operational efficiency during the post-liberalisation period. The efficiency growth has improved from a negative figure of 1.39 [(i.e., 1-0.9861)x100] percent per annum during the period 1980-81 to 1990-91 to a positive of 1.21 percent per annum for the period 1991-92 to 2003-04. Four industrial groups viz. Chemical and Chemical Products, Basic Metal, Rubber and Plastic, Others industries not elsewhere classified, registered a negative growth rate during the post-liberalisation period respectively. Thus, these four industrial groups are the laggards on the efficiency front in the small scale industry of India and need to enhance their efficiency levels to survive in the competitive era under WTO regime. However, the remaining industrial groups have shown an improvement in the efficiency growth rates which turned out to be positive during the post-liberalisation era. This improvement in the efficiency is the result of competitive environment, imposed upon the small scale industry of India, during the post-liberalisation period and can be termed as liberalisation spillovers on this sector.

Table 5: Technical Progress in Indian Small Scale Industrial Sector

Industry	Entire Period (1980-81 to 2003-04)	Pre-Liberalisation Period (1980-81 to 1990-91)	Post-Liberalisation Period (1991-92 to 2003-04)
Food Products	0.9981	0.9833	0.9899
Chemical and Chemical Products	1.0245	1.0025	1.0143
Basic Metal	0.9323	0.9411	0.9869
Hosiery Garments	0.9809	0.9804	1.0229
Metal Products	1.0087	0.9947	1.0012
Rubber and Plastic	0.9894	1.0227	1.0254
Machinery and Parts Except Electrical	1.0228	1.0000	1.0021
Electrical Machinery and Apparatus	1.0069	1.0036	0.9259
Paper Products and Printing	1.0263	1.0380	0.9642
Transport Equipments and Parts	0.9667	0.9479	0.9691
Wood Products	0.9916	1.0111	1.0063
Non-Metallic Mineral Products	0.9874	1.0656	0.9866
Others (n.e.c.)	1.0589	1.0542	1.0515
All Industries (GM)	0.9991	1.0028	0.9954

Source: Author's Calculations

Note: n.e.c. refers to not elsewhere classified;
GM refers to geometric mean

Further, the second component of TFP growth is technical progress, which is a measure of shift in production frontier. Table 5 provides evidence regarding technical progress in the Indian small scale industrial sector. A figure of technical change index above (below) unity reflects technical progress (regress) in the India's small scale industry. It has been observed that -0.09[(i.e., 1-0.9991)x100] percentage points of -0.57 percent TFP growth has been contributed by technical regress in Indian small scale sector. Thus, the results support our earlier finding that efficiency regress is a dominant factor and technological regress is relatively a scant source of negative TFP growth in the small scale sector of India. Although a negative coefficient of technical progress has been observed for this sector yet it can be stated that such a small coefficient may be the result of statistical noise and thus it can be concluded that technical progress has remained almost stagnant in Indian small scale sector. Further, a comparison of the rate of technical progress during the two sub-periods reflects a decline in the rate of technical progress during the post-liberalisation period as compared to the positive growth during the pre-liberalisation period. However, the figures for two sub periods are near about unity thereby supporting our argument about the stagnant technical progress in the Indian small-scale industrial sector.

Determinants of Total Factor Productivity Growth

The TFP growth in Indian small scale industrial sector has assumed to be affected by certain factors such as the growth of capital intensity (KLGROW), growth of output (OUTGROW), growth of wage rate (WGGROW) and degree of entrepreneurship (ENTRE). All these variables have been hypothesized to be affecting TFP growth positively. The explanatory variable 'KLGROW' represents average annual growth rate of capital intensity, which reflects growth in the capital accumulation per employee. It is a measure of the relative degree of mechanisation and is expected to facilitate higher growth of TFP. However, the variable 'OUTGROW' refers to the average annual growth rate of output (value-added). The output growth has also been expected to affect TFP positively. Further, the explanatory variable 'WGGROW' represents the growth of wages and is measured as an average annual growth rate of real emoluments per employee. However, to obtain the real value of emoluments, the total emoluments have been deflated using the consumer price index (CPI) of industrial workers obtained from economic intelligence reports by CMIE. This variable has also been hypothesized to be affecting TFP growth positively and significantly. The fourth variable included into the right hand side of regression is 'ENTRE', which represents the degree of entrepreneurship and is measured as the proxy variable for i^{th} industrial group as:

$$E = \left[\frac{(F/Q)_i}{(F/Q)_n} \right]$$

where, E represents the degree of entrepreneurship and F and Q specify the number of factories and total output (i.e., gross real value added), respectively. The subscript n specifies the total figure of all industrial groups. The index of entrepreneurship also reflects the degree of competition. However, in the literature, an unsolved debate exists regarding the effect of degree of entrepreneurship and competition on growth of productivity (Kumar, 2001).

Table 6 represents the point estimates of factors affecting TFP growth in Indian small scale industrial sector. It has been observed that except ENTRE, all other variables are positively affecting TFP growth. However, the coefficients of two variables viz. KLGROW and WGGROW are statistically significant. Thus, it can safely be inferred that capital intensity is affecting the TFP growth significantly and any policy based upon the modernisation can augment TFP growth in the Indian small scale industrial sector.

Table 6: Factors Affecting Total Factor Productivity Growth

Variable	Estimated Value	p-value
Constant	2.431	0.069
KLGROW	0.721*	0.019
OUTGROW	0.127	0.629
WGGROW	0.987**	0.008
ENTRE	-0.004	0.694

Source: Author's Calculations

Note: *indicates that parameter is significant at 5 percent level of significance; and

**indicates that parameter is significant at 1 percent level of significance

Further, WGGROW also affects the TFP growth and any hike in emoluments acts as an incentive to sacrifice leisure for work and induce the workers to work more. Thus, both these variables are important to attain a sustained productivity growth in Indian small scale industrial sector. However, the remaining variables although satisfy *a-priori* expectations about the directions of their impact yet due to their insignificant nature they are less important for policy formulation.

Convergence Hypothesis

In this study, an attempt has also been made to test the validity of convergence hypothesis for 13 major industrial groups classified at 2 digit level of aggregation. In the empirical literature on international productivity convergence, the catching-up hypothesis is one of the most important factors of the convergence process (Abramovitz, 1956). According to this hypothesis, industrial groups should experience higher growth rates when they are initially located far below the production frontier. In other words catching-up hypothesis implies a negative relationship between initial efficiency levels and subsequent efficiency growth rates. However, as noted by Lichtenberg (1994), most of these traditional tests establish necessary but not sufficient conditions for convergence. In fact, if analysis of productivity rate dispersion is applied, it is not possible to determine whether the levels of productivity converge in long run or not. In order to investigate the convergence more deeply, it is necessary to compute the initial levels of the technical efficiency and technical efficiency change obtained by means of the Malmquist productivity index.

Lee *et al.* (1996) discussed three types of convergence. With cross-section data, convergence involves the investigation of relationship between growth rates and initial efficiency levels. Unconditional or absolute β convergence exists when regressing a growth measure, such as efficiency change, on initial efficiency gives a negative and significant coefficient. If other, conditioning variables are included, they should be jointly insignificant, for absolute convergence to hold. Conditional convergence will also require a negative coefficient on initial efficiency, after controlling for the effects of other explanatory variables, at least some of which prove to be significant. However, a negative relationship between growth rates and initial efficiency does not guarantee a reduction in the dispersion of the log of TFP, because a negative relationship is only a necessary and not a sufficient condition for less dispersion. This is called σ convergence. The movement of the cross-section variance of TFP over time will reflect both the evolution of dispersion of the industry-specific equilibrium and the rate of adjustment within each industrial group. In this case, if steady states are assumed to differ, the third notion of convergence is whether each industrial group is converging to its own steady-state equilibrium in the time series dimension of the data. The definition of convergence is whether effects of shocks persist and whether output levels tend to return to a long-run equilibrium or not.

Although the above analysis of total factor productivity growth is quite useful from policy perspective yet it does not answer the question: whether a convergence in productivity has taken place after the adoption of economic liberalisation package or not? In order to explore an answer to this question, following regression equations have been estimated:

$$AECH_{1980-81\ to\ 1990-91} = \alpha_1 + \beta_1\, Effi_{1980-81} + \varepsilon_1 \quad (13)$$

$$AECH_{1991-92\ to\ 2003-04} = \alpha_2 + \beta_2\, Effi_{1991-92} + \varepsilon_2 \quad (14)$$

$$AECH_{1980-81\ to\ 2003-04} = \alpha_3 + \beta_3\, Effi_{1980-81} + \varepsilon_3 \quad (15)$$

where *AECH* and *Effi* are Average Efficiency Change and Initial Efficiency levels respectively for the periods, 1980-81 to 1990-91, 1991-92 to 2003-04 and 1980-81 to 2003-04. The αs and βs are the regression coefficients and εs are error terms. In the equations $Effi_{1980-81}$ and $Effi_{1991-92}$ have been utilised as the 'catch-up potentials' to analyse the convergence in the efficiency gaps among industrial groups under evaluation. The convergence or 'catching-up' hypothesis states that industrial groups with low initial efficiency should experience high average

Table 7: β - Convergence Regression Result in Indian Small Scale Industrial Sector

Parameter	Pre-liberalisationPeriod (1980-81 to 1990-91)	Pre-Liberalisation Period (1991-91 to 2003-04)	Post-Liberalisation Period (1980-81 to 2003-04)
a	1.08**(38.17)	1.07**(27.68)	1.04**(39.97)
b	-0.11**(-3.08)	-0.09(-1.87)	-0.05(-1.53)
R2	0.404	0.202	0.142
F	9.48	3.50	2.33

Source: Author's Calculations

Note: * indicates that parameter is significant at 5 percent level of significance; and
** indicates that parameter is significant at 1 percent level of significance

efficiency change in the whole period i.e. inter-industry differences in efficiency should decline. Thus, a negative sign of regression coefficients of βs would imply that the convergence in efficiency gaps is taking place.

Using the results of efficiency change (ECH) and initial efficiency levels, computed using Malmquist Productivity index, we estimate the equation (13) and (14) and equation (15) for two sub periods and the entire study period respectively. The estimated regression results have been given in the Table 7. The analysis of this table indicates that catching up has been significant in the pre-liberalisation period as the estimated value of β_1 is negative and significant at 1 percent level of significance. Further, by using F-ratio and its tabulated value, ($F_{0.05(V_1=1,\ V_2=14}$= 4.6001) the estimated regression has been found to be significant and plausible at 1 percent level. Therefore, it can be inferred that the industrial groups under small scale industrial sector with low initial efficiency level experienced high efficiency change in period 1980-81 to 1990-91.

On the other hand, in the post-liberalisation period, the estimated coefficient of β is although negative yet statistically insignificant. Also, the calculated value of F (3.50) is less than the tabulated value ($F_{0.05(V_1=1,\ V_2=14}$= 4.6001), which depicts the insignificance of estimated regression. Thus during the post-liberalisation period, convergence among industrial groups has been observed to be missing. The same inference holds valid for the analysis of convergence for the entire study period. In sum, these results shows that the protectionist pre-liberalisation policies were better for the laggards of sample industrial groups as they were converging to the lead groups during the pre-liberalisation period.

As stated earlier that β-convergence is necessary but not the sufficient condition of catching up. Therefore s-convergence has been examined by regressing cross sectional variance of efficiency over time which is given as follows:

$$\sigma_t^2 = \alpha_4 + \beta_4 t + \varepsilon_t \qquad (16)$$

where, σ_t^2 is cross sectional variance of efficiency i.e. variance of efficiency of 13 industrial groups, t is the time variable varies from 1,2,....,n, α_4 and β_4 are the parameters of regression and ε_t is white noise stochastic disturbance term. For the σ-*convergence* to exist estimated value of β i.e. $\hat{\beta}$ should be negative and significant.

Table 8 indicates that in the pre-liberalisation period, the estimated value of β is negative but insignificant. Therefore, in pre-liberalisation period industrial groups did not converge significantly. As calculated value of *F* is less than the tabulated value ($F_{0.05(v1=1,V_2=9)}$ =5.1174) therefore, we conclude regression is insignificant and implausible. On the other hand in post-liberalisation period industrial groups have experienced divergence at the place of convergence because the fitted regression reveals the positive sign of $\hat{\beta}$ in post-liberalisation period. The calculated value of F is also greater than the tabulated value ($F_{0.05(v1=1,V_2=9)}$ =5.1174) which shows that regression is significant with the implication that liberalisation process has had a negative impact on catching up process. Moreover, in the case of entire study period the variability between the efficiencies of industrial groups has reduced but this reduction has been observed to be insignificant. The value of F is also less than the tabulated value ($F_{0.05(v1=1,V_2=9)}$ =4.3009) which indicates that the fitted regression is insignificant and not very much plausible. Thus it can be inferred that the catching up process (learning-by-doing) in Indian small scale industrial sector is not in the desired direction as envisaged in the New Industrial Policy of 1991.

Table 8: σ Convergence Regression Result in Indian Small Scale Industrial Sector

Parameter	Pre-liberalisation Period (1980-81 to 1990-91)	Post-Liberalisation Period (1991-91 to 2003-04)	Entire Period (1980-81 to 2003-04)
a4	0.102**(2.47)	0.02** (2.28)	0.06** (2.88)
b4	-0.01 (-1.59)	0.001* (2.28)	-0.002 (-1.32)
R2	0.22	0.37	0.08
F	2.54	5.20	1.75

Source: Author's Calculations

Note: * indicates that parameter is significant at 5 percent level of significance; and
** indicates that parameter is significant at 1 percent level of significance

Conclusion and Policy Implications

To check the growth robustness of Indian small scale industrial sector, the trends in partial productivity along with total factor productivity (TFP) growth have been analysed. The Malmquist productivity index (MPI) has been used to analyse TFP growth. The use of MPI has been preferred over traditional non-frontier techniques given the property of MPI that it decomposes the TFP into two mutually exclusive and non-additive components namely, efficiency change (indicator of catching-up) and technological change (indicator of shift in production function). However, the non-frontier techniques assume that all firms are efficient and thus, TFP is the outcome of frontier shift or technological change only.

The empirical evidences about the partial productivity show that the labour productivity of Indian small scale industrial sector has grown at an average annual growth rate of 1.383 percent during the entire study period and the same has been observed to be rising during the post-liberalisation period in comparison to the pre-liberalisation period. However, the capital productivity has been observed to have grown by an average annual growth rate of 1.255 percent per annum, whereas the comparative analysis identified acceleration in capital productivity during the post-liberalisation period relative to the pre-liberalisation period.

Further, it has been observed that the TFP growth is negative to the tune of -0.57 percent per annum during the entire study period. However, a comparison of the two sub-periods reveals that the TFP growth has turned out to be positive (reflected by TFP above unity) during the post-liberalisation period in comparison of the negative TFP growth during the pre-liberalisation period. Thus, it can be inferred that the TFP growth has accelerated during the post-liberalisation period, which is an indicator of sustainable growth in the small scale industrial sector of India during the forthcoming years.

However, the decomposition of TFP growth into two components viz. technical efficiency change and technical progress reveals an efficiency regress during the entire study period at the rate of 0.48 percent per annum. Thus, Indian small scale industrial sector has observed a deceleration in technical or operational efficiency during the entire study period. In addition, 0.48 percentage points of 0.57 percent negative TFP growth comes from efficiency change. Thus, negative efficiency growth is the dominant source and technical progress is relatively a feeble source of deceleration in TFP growth in Indian small scale industrial sector. However, a comparative analysis of the technical efficiency change reflects an improvement in the growth of operational efficiency during the post-liberalisation period, which has improved from a negative figure of -1.39 percent per annum in the pre-liberalisation period to a positive of 1.21 percent per annum during the post-liberalisation period.

In addition, the second component of TFP growth, namely, technical progress has been observed to be contributing -0.09 percentage points of -0.57 percent TFP regress in the Indian small scale industrial sector. Thus, the empirical results support our earlier finding that efficiency regress is a dominant factor and technological regress is relatively a scant source of negative TFP growth in the small scale sector of India. A comparison of the rate of technical progress during the two sub-periods reflects a decline in the rate of technical progress during the post-liberalisation period as compared to the positive growth during the pre-liberalisation period. However, both the figures for the two sub periods are near about unity and thus, support our argument about the stagnant technical progress in the Indian small-scale industrial sector.

The search for the factors affecting TFP growth ends up with the conclusions that two variables viz. KLGROW and WGGROW are positively and significantly affecting TFP growth. A significant association between productivity levels, remunerative wages and capital intensity has been observed. Thus, it can be safely inferred that any policy based upon the modernisation and hike in emoluments can help the Indian small scale industrial sector to achieve a sustained growth. The evidences regarding the test of catching-up hypothesis although identify the presence of learning-by-doing process in the pre-liberalisation period, yet its presence has been refuted during the post-liberalisation period. Thus, it can be inferred that the catching-up process in Indian small scale industrial sector is not in the desired direction as envisaged in the New Industrial Policy of 1991.

Hence, the analysis reveals that the small scale industrial sector of India is growing with a negative TFP growth and thus, growth based upon TFP regress is not sustainable. However, the comparative analysis of pre- and post-liberalisation periods reveals that TFP growth has become positive during the post-liberalisation period relative to TFP regress during the pre-liberalisation period. Thus, the impact of competition provided through opening up the trade boundaries seems to be trickling down to the Indian small scale industrial sector. In addition, the technical efficiency change is the dominant source of TFP growth and technical progress has remained the insignificant source of it. It simply highlights the limited role of technology in the small scale industrial sector of India. Therefore, an improvement in production efficiency is the most plausible policy tool which must be followed by Indian planners to enhance the competitiveness and economic efficiency of small scale industrial sector in the liberalised regime.

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Our future growth relies on competitiveness and innovation, skills and productivity, and these in turn rely on the education of our people.

—Julia Gillard

Feature

Improvement of Productivity and Quality Dimensions of a Foundry Process with TPM Technique–A Case Study

ASHWINI G. JOSHI AND JAYDEEP S. BAGI

Quality and Productivity are need of all the industries for achieving required profits. TPM is being recognized in the developing world as a widely used technique of improvement in quality and productivity of products and services requiring the highest possible standards. The fast changing economic conditions such as global competition, customer demand for high quality product, product variety has major impact on manufacturing industries. The paper focuses on implementation of TPM in some areas of foundry thereby improving the productivity and quality. It represents the study of various casting defects and analysis as well as implementation of Total Productive maintenance technique.

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Productivity is the quantitative relation between what we produce and what we use as a resource to produce them i.e. arithmetic ratio of amount produced (output) to the amount of resources (input). Productivity can be expressed as

Productivity= Output/ Input

It is the concept that guides the management of the production system. It is an indicator of how well the factors of production (Land, Capital, Labour and Energy) are utilized. In other words, 'Productivity is the measure of how well the resources are brought together in an organization and utilized for accomplishing a set of objectives.'

A convenient tool to measure productivity is Overall Equipment Effectiveness.

Overall Equipment Effectiveness (OEE)

Overall equipment effectiveness i.e. OEE truly reduces complex production problems into simple, intuitive presentation of information. It helps to systematically improve the process with easy-to-obtain measurements.

OEE takes into account all the three OEE factors, and is calculated as

OEE = Availability * Performance * Quality

Availability

It is the ratio of Operating time to Planned Production time where operating time is planned production time less downtime loss.

Availability= Operating time /Planned production time

Thus, availability takes into account, Down time loss which includes any events that stop planned production for an appreciable length of time (usually several minutes) e.g. equipment failure, material shortages and changeover time. The remaining available time is called Operating time.

Plant Operating Time: It is the amount of time for which the plant is open and available for equipment operation.

Planned Production Time: It is the time obtained by subtracting plant shutdown time from plant operating time.

Planned Shutdown Time: It includes all events that should be excluded from effectiveness analysis because there was no intention of running production.

e.g. Breaks, Lunch, Scheduled Maintenance or periods where there is nothing to produce.

Performance

It is the ratio of Net operating time to operating time where net operating time is operating time less speed loss.

Performance = Ideal cycle time / (operating time/total pieces) = Ideal cycle time /Actual cycle time

Ideal Cycle time is the minimum cycle time that the process can be expected to achieve in optimal circumstances. It is also called as the Designed cycle time or Theoretical cycle time.

Performance can also be calculated as

Performance = (Total pieces/Operating time)/ Ideal Run rate

Ideal Run Rate: It is the theoretical maximum production rate. It is the inverse of Ideal Cycle time.

Actual Run Rate: It is the actual rate of production, when it is running.

Actual run rate = Total pieces/ Operating time.

Quality

It is the ratio of fully productive time to net operating time where fully productive time is net operating time minus quality loss.

Quality = Good piece/ Total pieces.

Thus, quality takes into account quality loss which accounts for produced pieces that do not meet quality standards, including pieces that require rework. The remaining time is called fully productive time.

Quality can be improved by reducing variability in processes and products. One of the important consideration in quality improvement is analysis of casting defects.

Company profile

The organization under consideration is a small scale gray cast iron foundry situated in MIDC Shiroli, Kolhapur, Maharashtra, India. Chougule Industries Ltd., is a part of 'Chougule Group of companies, Kolhapur.' which is headed by Mr. L.B.Chougule whereas the Chougule industries Ltd.(MIDC Shiroli) is headed by the partner Mr. Suresh Laxman Chougule. The company is ISO9001-2008 certified. Its major customers are

a) Mahindra and Mahindra Ltd.

b) Tractor and Farm Equipment Ltd.

c) Windals Auto parts Pvt. Ltd.

d) P.M Diesel Pvt. Ltd.

e) JM Frictech India Pvt. Ltd.

f) Indimet INC

g) Satyajeet Mechanisms

Problem definition

The foundry under consideration is mechanized and has all the facilities with some machinery like sand reclamation plant which is fully mechanized which reduces human interruption and thereby human fatigue and efforts to a great extent. However, it was noted that the Quality and Productivity were well below expectations. Work was carried out in analyzing the reasons for the same. Various parameters needed to be verified were:

1. Breakdown of machines and high maintenance costs.
2. Poor quality and defects leading to rejection

Hence it was decided to use TPM as the tool for improving quality and productivity.

Research Objectives

The main objective is enhancing productivity of a moulding line of M/s Chougule Industries Ltd, MIDC, Shiroli, Kolhapur through implementation of TPM. The work carried out includes:

1. Study of the present productivity of the industry through evaluation of Overall Equipment Effectiveness (OEE)

of the foundry, where OEE = Availability X Performance X Quality

2. Study the effect of post TPM implementation on various parameters like availability, performance and quality and thereby effect on OEE of the foundry.

OEE Calculations

Data regarding production time, downtime, total production, rejection from the month of August ,2011 to January ,2012 was collected and converted respective terms into per week quantities. Accordingly, OEE factors i.e. Availability, Performance, Quality and thus OEE per week for the above period was calculated.

As per data given in table 5.1, sample OEE for week no.1 in the month of October 2011 is calculated below.

Table 5.1: Data for Sample Calculation for Week 1

Item	Data
Shift Length	12 hours= 720 min
Short Breaks	2 @ 15 min=30 min
Meal Break	1 @ 30 min=30 min
Downtime/ week	70 min per week
Ideal cycle time	0.77 min
Total pieces/ week	8402 Nos.
Rejected pieces/week	421Nos

Sample Calculation

Planned Production Time/week= (Shift length- breaks) x 6 = 7920 min/week

Operating Time/ week =Planned production Time/week – Downtime/week= 7850 min/weekS

Good Pieces/week = Total pieces- Rejected pieces= 7981 pieces/ week

Availability= Operating time/ Planned Production Time= 0.99

Performance= Ideal cycle time /Actual cycle time=0.82

Quality= Good pieces/ Total pieces = 0.94

OEE for week 1= Availability x Performance x Quality = 0.76

In the similar way, OEE for all the 26 weeks was calculated and graphs were plotted.

Availability

Table 5.2 gives the calculations of availability values for 26 weeks for the period of six months (from August 2011 to January 2012).

Table 5.2: Availability values

Week No.	Planned Production Time/week (min)	Downtime/ week (min)	Operating time/week (min)	Availability week (min)
1	7920	70	7850	0.99
2	7920	100	7820	0.98
3	7920	395	7525	0.95
4	7920	80	7840	0.98
5	7920	185	7735	0.97
6	7920	360	7560	0.95
7	7920	528	7392	0.93
8	7920	200	7720	0.97
9	7920	55	7865	0.99
10	7920	1290	6630	0.84
11	7920	1060	6860	0.87
12	7920	140	7780	0.98
13	7920	100	7820	0.98
14	7920	45	7875	0.99
15	7920	30	7890	0.99
16	7920	25	7895	0.99
17	7920	370	7550	0.95
18	7920	90	7830	0.98
19	7920	155	7765	0.98
20	7920	365	7555	0.95
21	7920	133	7787	0.98
22	7920	158	7762	0.98
23	7920	320	7600	0.96
24	7920	250	7670	0.96
25	7920	205	7715	0.97
26	7920	75	7845	0.99

Average value of availability for six months was calculated as 0.96.

Graph of Availability v/s Week Number was then plotted for the calculated values which is shown in Fig. 5.1

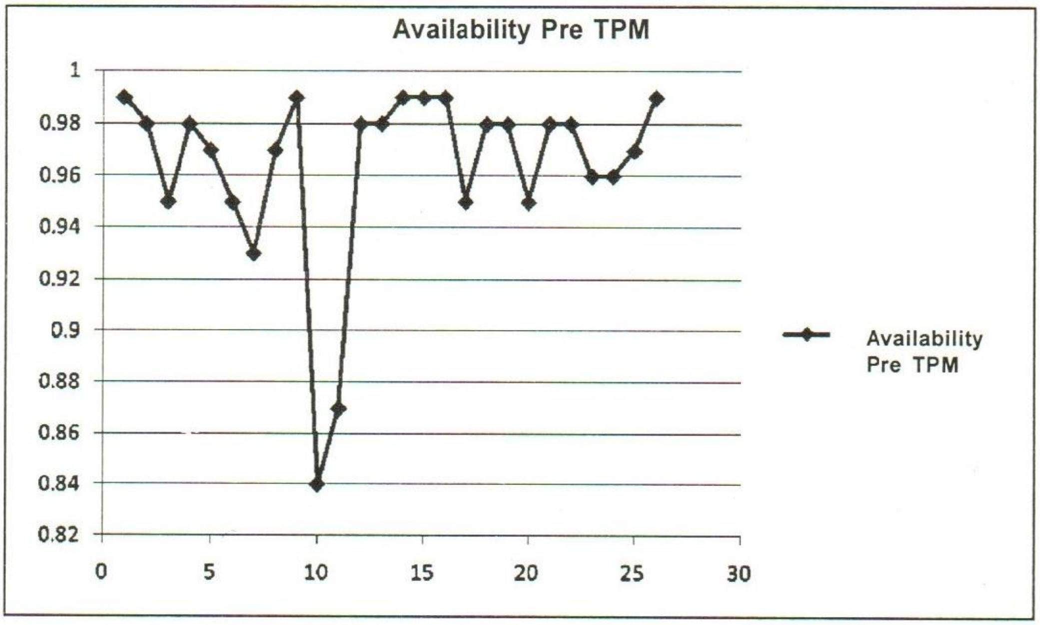


Figure 5.1: Graph of Availability v/s Week No.-Pre TPM Implementation

Pre TPM implementation status of Availability:

By observing fig 5.1, it was found that availability of plant varies from 0.93 to 0.99. Availability mainly depends on downtime i.e. stoppages of the line due to some reasons. These reasons may be either controllable or non-controllable. Non-controllable causes include breakdown

History card for daily maintainence

Equipment name: Pneumatic moulding machine specification:

Code No.: PM-1, PM-2
Month:

S.No	Checkpoint	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Check oil level in air filter lubricator unit																
2	Add 50 top 100 ml lubricating oil to jolting table through jolting hoses and fit the hose back.																

S.No	Checkpoint	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	Check oil level in air filter lubricator unit															
2	Add 50 top 100 ml lubricating oil to jolting table through jolting hoses and fit the hose back.															

Remark

Prepared by:

Checked by:

History Card for Weekly Maintenance

Equipment Name: Pneumatic Moulding Machine
Specifications:

Code No. PM-1, PM-2.
Year:

Sr. No.	Checkpoint	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13
1	Check all hose connection for air and hydraulic oil.													
2	Checkoil level in hydraulic tanks.													
3	Check adjustment of roller valves.													
4	Check lubrication connection and oil level in lubricating plump													
5	Check jotting table lock nuts													
6	Remove sand around the machine													
7	Greasing to all grease points													
8	Clean filter bowl													

Sr. No.	Checkpoint	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26
1	Check all hose connection for air and hydraulic oil.													
2	Checkoil level in hydraulic tanks.													
3	Check adjustment of roller valves.													
4	Check lubrication connection and oil level in lubricating plump													
5	Check jotting table lock nuts													
6	Remove sand around the machine													
7	Greasing to all grease points													
8	Clean filter bowl													

Remarks:

Prepared by:

Checked by:

Table 5.3: Availability values- After TPM Implementation

Week No.	Planned Production Time/week (min)	Downtime/ week (min)	Operating time/week (min)	Availability week (min)
1	2160	15	2145	0.99
2	5210	79	5131	0.98
3	4918	98	4820	0.98
4	3990	107	3883	0.97
5	4850	93	4757	0.98
6	7525	205	7320	0.97
7	7920	147	7773	0.98
8	7362	350	7012	0.95
9	5698	148	5550	0.97
10	·6542	172	6370	0.97
11	6252	109	6143	0.98
12	6390	180	6210	0.97
13	7660	197	7463	0.97

of machines and equipments due to power cut-off or sudden failure of machine or equipment etc. whereas controllable causes include lack of proper predictive maintenance systems etc.

Post TPM implementation status of Availability:

To increase availability of molding line, history cards were prepared having proper formats of daily, weekly, monthly and yearly maintenance of individual machine. These History cards were submitted to management and suggested to implement and follow the same. Also operators were suggested to do the routine maintenance activities time to time.

Upon following the schedule specified in History cards, average downtime for three months was observed and availability for the same period was calculated. Table 5.3 gives the calculations of availability values for 13 weeks for the period of three months from April, 2012 to June, 2012.

After implementation of TPM, Availability values calculated as an average of 0.98

Graph of Availability v/s week number was then plotted for the calculated values which is shown in Fig. 5.2

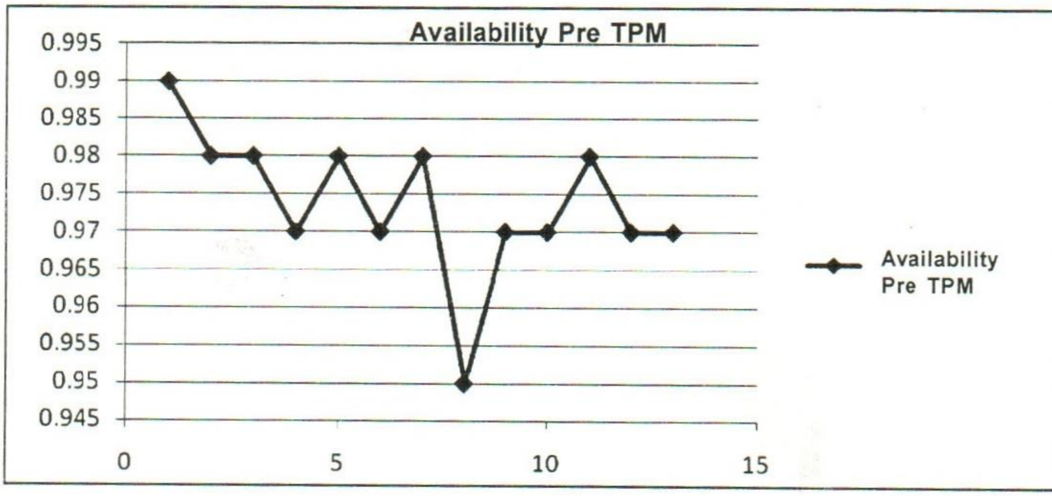


Figure 5.2: Graph of Availability v/s Week No. -Post TPM Implementation

It was found that availability values per week were improved from 0.96 to0. 98 due systematic monitoring of scheduled maintenance.

Performance

Table 5.4 gives the calculations of performance values for 26 weeks for the period of six months from August 2011 to January 2012.

Table 5.4: Performance values

Week No.	Ideal cycle time (min)	Average Actual cycle time/week (min)	Performance
1	0.77	0.93	0.82
2	0.77	0.78	0.99
3	0.77	0.79	0.97
4	0.77	2.65	0.29
5	0.77	1.26	0.61
6	0.77	1.17	0.66
7	0.77	0.96	0.80
8	0.77	1.16	0.66
9	0.77	1.02	0.75
10	0.77	1.16	0.66
11	0.77	0.78	0.99
12	0.77	0.96	0.80
13	0.77	1.15	0.67
14	0.77	1.28	0.60
15	0.77	0.79	0.97
16	0.77	0.96	0.80
17	0.77	0.85	0.90
18	0.77	0.89	0.86
19	0.77	1.28	0.60
20	0.77	1.05	0.73
21	0.77	0.80	0.96
22	0.77	1.45	0.53
23	0.77	1.20	0.64
24	0.77	1.18	0.65
25	0.77	1.97	0.39
26	0.77	1.74	0.44

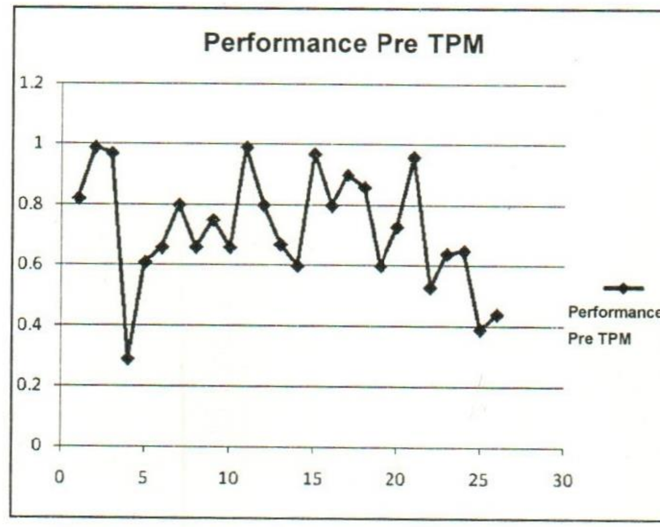


Figure 5.3 : Graph of Performance v/s Week No.-Pre TPM Implementation

Pre TPM implementation status of Performance:

By observing Performance table no.6.6, the values were found in the range of 0.60 to 0.99. But for some weeks it was observed 0.29, 0.44, 0.33 also. The actual cycle time was found greater than ideal cycle time and also demand is fluctuating.

Post TPM implementation status of performance:

KAIZEN was implemented for reduction in cycle time. Previously, the sand in mold was rammed by hand rammer, after machine molding (Fig. 5.4). Hence, time for hand moulding was different for different persons. A round based pneumatic rammer is provided for the same. The pneumatic pressure reduced the cycle time as well as maintained uniformity in the process (Fig. 5.5) Due to this, more volume of sand gets rammed in lesser time which in turn improves the performance.

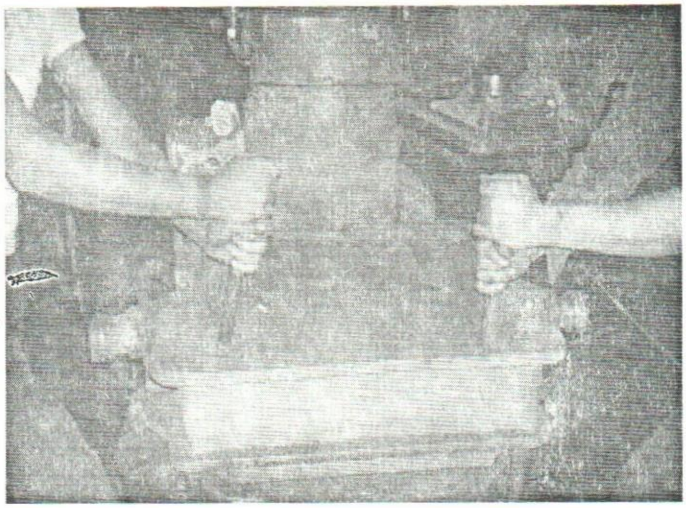


Figure 5.4: Pre TPM- Molding machine with hand rammer

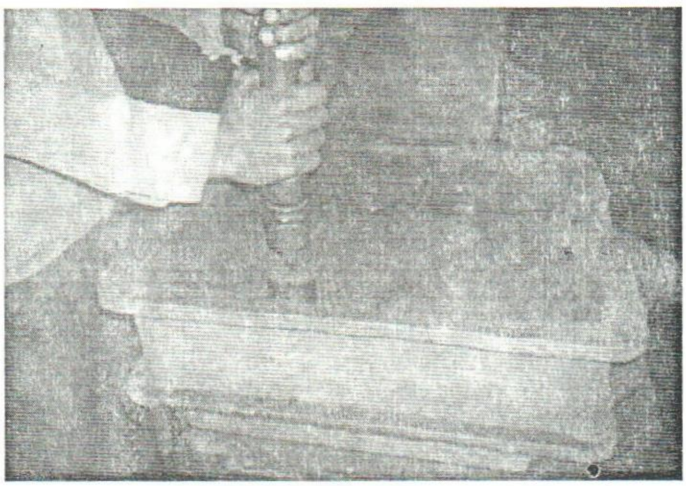


Figure 5.5: KIAZEN- Use of Pneumatic rammer

Table 5.5 gives the calculations of performance values for 13 weeks for the period of three months from April, 2012 to August, 2012.

Table 5.5: Performance values: Post TPM Implementation

Week No.	Ideal cycle time (min)	Average Actual cycle time/week (min)	Performance
1	0.77	0.89	0.86
2	0.77	0.92	0.84
3	0.77	0.93	0.82
4	0.77	0.95	0.81
5	0.77	0.96	0.80
6	0.77	0.95	0.81
7	0.77	0.96	0.80
8	0.77	0.93	0.82
9	0.77	0.96	0.80
10	0.77	0.89	0.86
11	0.77	0.93	0.82
12	0.77	0.96	0.80
13	0.77	0.90	0.85

After implementation of TPM, Performance values calculated as an average of 0.82.

Graph of performance v/s week number was then plotted for the calculated values which is shown in Fig. 5.6

By reducing actual cycle time through introduction of KAIZEN concept in moulding section, the performance has been improved from 0.72 to 0.82.

Quality

Table 5.6 gives the calculations of quality values for 26 weeks for the period of six months from August 2011 to January 2012.

Average value of Quality for six months was calculated as 0.94.

Graph of Quality v/s Week Number was then plotted for the calculated values which is shown in Fig. 5.5.

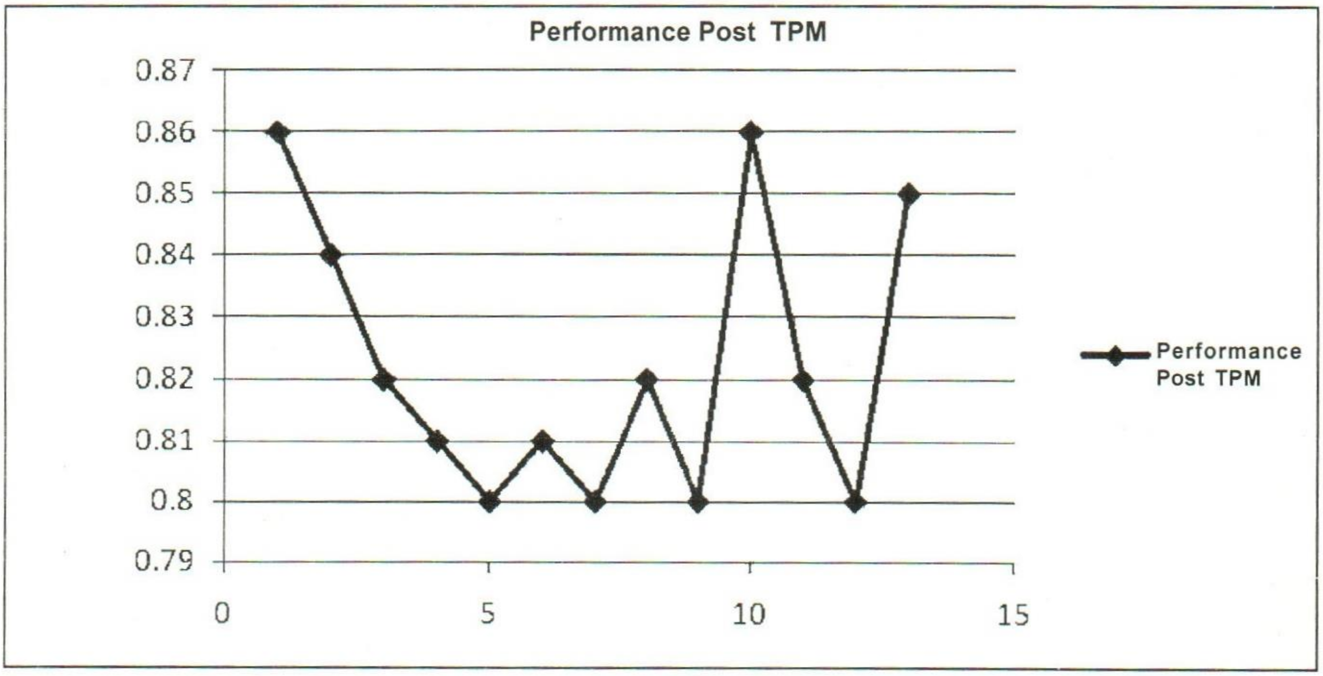


Figure 5.6: Graph of Performance v/s Week No. -Post TPM Implementation

Table 5.6: Quality values

Week No.	Total Pieces/ week (No.)	Rejected Pieces/ week (No.)	Good Pieces/ week (No.)	Quality
1	8402	421	7981	0.94
2	10070	658	9412	0.93
3	9493	508	8985	0.94
4	2990	228	2762	0.92
5	6175	477	5698	0.92
6	6579	480	6099	0.92
7	7696	444	7252	0.94
8	6683	292	6391	0.95
9	7714	422	7292	0.94
10	5739	264	5475	0.95
11	8890	585	8305	0.93
12	8127	322	7805	0.96
13	6867	276	6591	0.95
14	6215	312	5903	0.95
15	10001	529	9472	0.94
16	8262	420	7842	0.94
17	8838	411	8427	0.95
18	8748	451	8297	0.95
19	6035	322	5713	0.95
20	7153	308	6845	0.95
21	9715	444	9271	0.95
22	5342	244	5098	0.95
23	6354	235	6119	0.96
24	6512	406	6106	0.94
25	3891	96	3795	0.97
26	4456	172	4284	0.96

Pre TPM status of Quality:

By observing Quality rate table no. 5.5, it was found that quality rate varies from 0.92 to 0.97. It can be improved by reducing rejections. Rejections can be reduced by analysis of casting defects. Hence, casting defect analysis was done as follows.

Data collection and statistical analysis of various defects

It was found that, among the various components manufactured in Chougule Industries, some of the components were frequently rejected every month in considerable percentage. Thus to study and analyze the rejections became a necessary work. Therefore, casting defect analysis is done for the selected component AGNI FLYWHEEL.

Flow chart for casting defect analysis

Fig. 5.6 represents the flow chart of the casting defect analysis carried out in the organization.

Data Collection

Current working conditions in the organization are observed in which a record for monthly rejection of components in the foundry section is studied and analysis is done.

Monthly production and rejection of all the components is for the period of six months i.e. from August 2011 to January 2012 was observed. The material for all the components is Gray cast iron of which rate is Rs.49/- per Kg. As the cost per Kg does not vary, hence the criterion for selection was the total weight of rejected items per month for the same component. Accordingly, component with largest rejection percentage of total rejection was selected for further analysis.

This component AGNI FLYWHEEL was studied for distribution of casting defects.

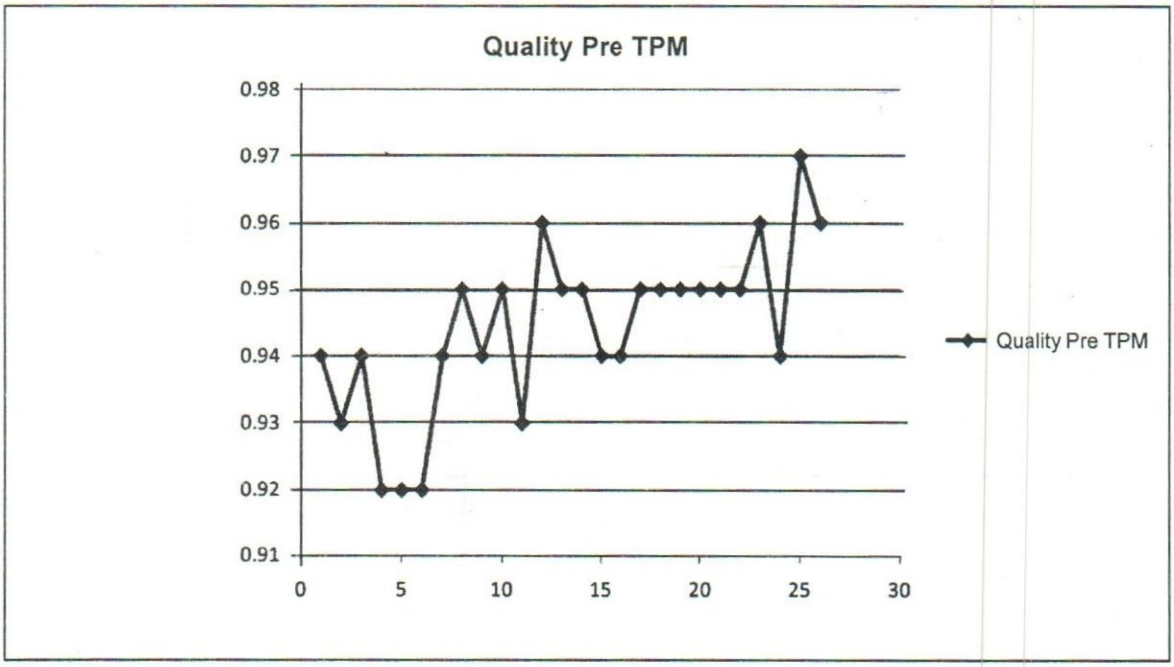


Figure 5.7: Graph of Quality v/s Week No.-Pre TPM Implementation

Table 5.7 : Pareto Chart for Agni Flywheel

Problem Type	Description	% of occurrence Cost	Cost	Cumulative % of occurrence
A	Blow Hole	52.24	1368864	52.24
B	Shrinkage	31.18	816928	83.42
C	Sand Inclusion	16.10	421792	99.52
D	Cold Shut	0.48	12544	100

Table 5.8: Casting defect analysis

Defect	Main cause	Sub cause	Remedy
	Pattern	Insufficient prints for venting	Change in pattern design for providing sufficient venting.
Blow Holes	Moldings and Molding	Low permeability High moisture improper venting Mold hardness high	Check permeability and r moisture content and of Maintaining proper hardness.
	Pouring	Cold Metal Careless pouring	Careful pouring of metal with adequate temperature.
Shrinkage	Molding	Soft Ramming Mold dilation Improper clamping, placing weights	Properly ramming the sand in the mold boxes and proper clamping.

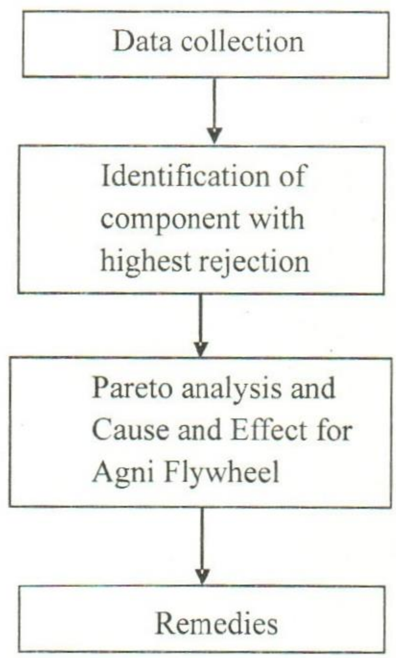


Figure 5.8: Flowchart of casting defects analysis

Pareto Analysis

Agni Flywheel was studied then for finding out defects contributing major part of rejections. For this purpose the tool Pareto Analysis is used. Defects distribution for Agni flywheel is given in table 6.1 and Pareto chart drawn for the same is shown in fig.5.8

Thus, the defects-Blow holes and Shrinkage-constitute major part of defects (83.42%) observed in the component Agni Flywheel. The further part of analysis was Root Cause Analysis of these defects using Cause and Effect diagram.

Cause and Effect Analysis

Cause and effect diagram was used for cause enumeration of defects found in the Pareto analysis. The cause enumeration is one of the most widely used graphical techniques for quality control and improvement. It usually

Table 5.9: Quality values : Post TPM Implementation

Week No.	Total pieces/ week (No.)	Rejected Pieces / week (No.)	Good Pieces / week (No.)	Quality
1	1965	29	1936	0.99
2	4763	71	4692	0.99
3	4524	67	4457	0.99
4	3587	53	3534	0.99
5	4441	111	4330	0.98
6	6964	243	6721	0.97
7	7260	176	7084	0.98
8	6260	93	6167	0.99
9	4963	124	4839	0.98
10	5831	87	5744	0.99
11	5838	145	5693	0.98
12	5815	145	5670	0.98
13	7286	107	7179	0.99

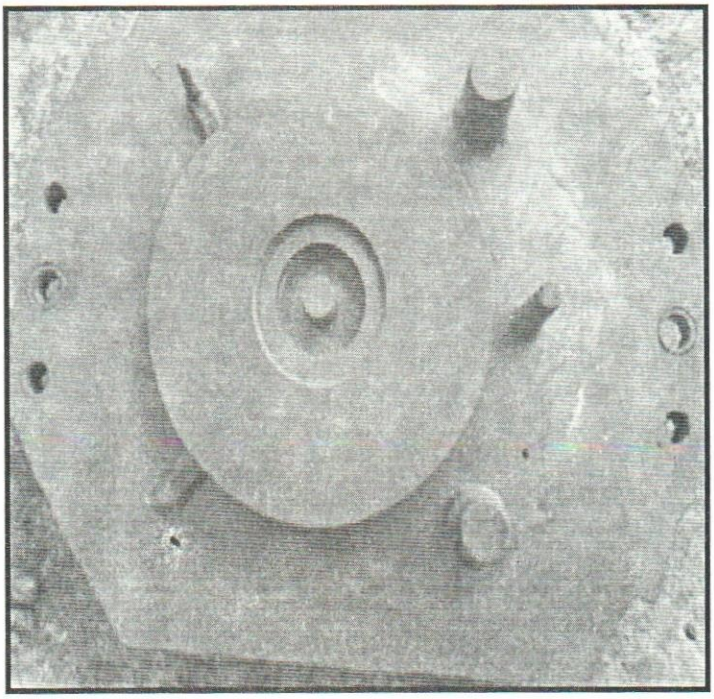


Figure 5.9: Agni Flywheel Cope

develops through a brainstorming session in which all possible types of causes are listed to show their influence on the problems or effect in question.

The procedure consists of first defining the problem or quality characteristic selected for study. Next, the major causes influencing the characteristic are noted. In a manufacturing process, for example, the major causes for a non-conformance could be equipment, operator, methods, environment and so forth. After this step, sub causes within each of the major causes are listed. Before evaluating each cause, more thought is given to defining and identifying them clearly and also to evaluating

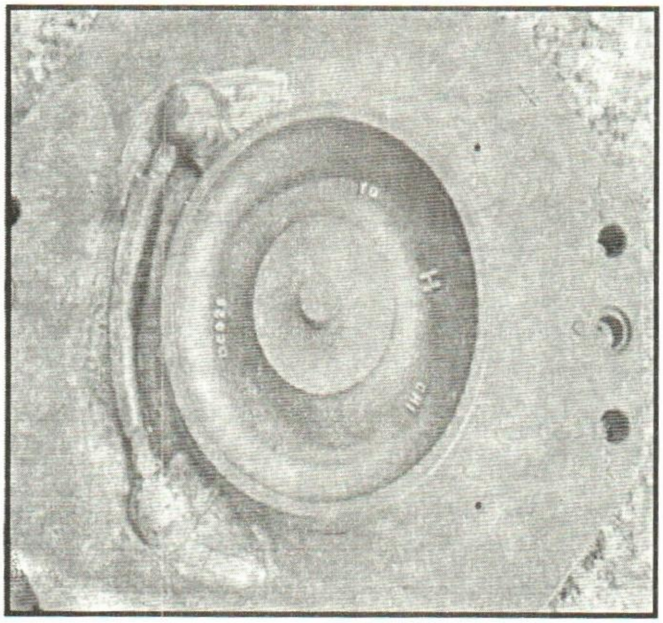


Figure 5.10: Agni Flywheel Drag

Table 5.10: OEE values : Pre TPM Implementation

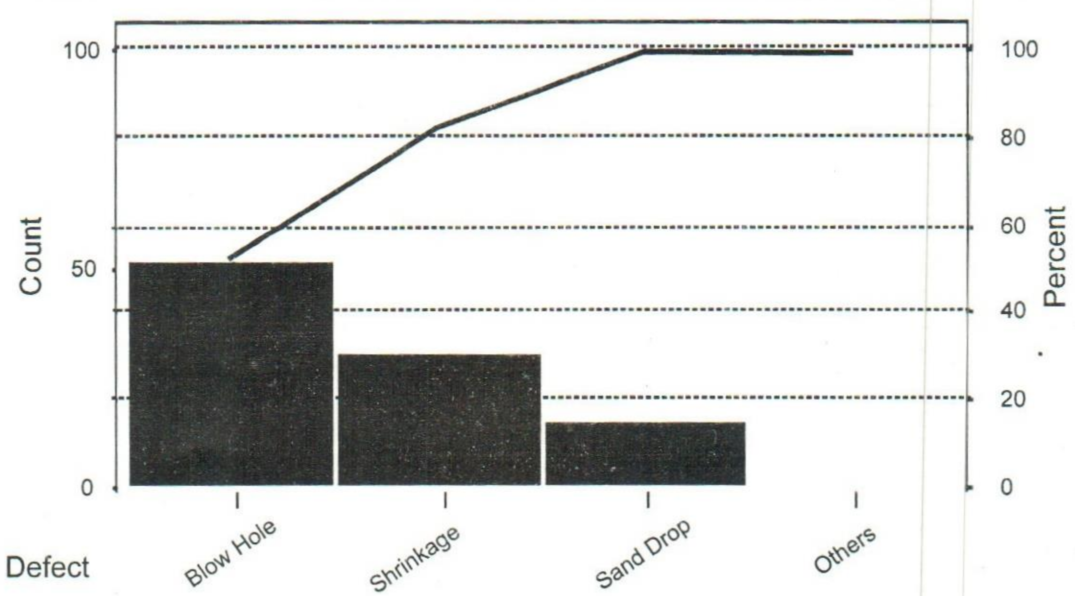
Week No.	Availability	Performance	Quality	OEE
1	0.99	0.82	0.94	0.76
2	0.98	0.99	0.93	0.90
3	0.95	0.97	0.94	0.86
4	0.98	0.29	0.92	0.26
5	0.97	0.61	0.92	0.54
6	0.95	0.66	0.92	0.58
7	0.93	0.80	0.94	0.70
8	0.97	0.66	0.95	0.61
9	0.99	0.75	0.94	0.70
10	0.84	0.66	0.95	0.53
11	0.87	0.99	0.93	0.80
12	0.98	0.80	0.96	0.75
13	0.98	0.67	0.95	0.62
14	0.99	0.60	0.95	0.56
15	0.99	0.97	0.94	0.90
16	0.99	0.80	0.94	0.74
17	0.95	0.90	0.95	0.81
18	0.98	0.86	0.95	0.80
19	0.98	0.60	0.95	0.56
20	0.95	0.73	0.95	0.66
21	0.98	0.96	0.95	0.89
22	0.98	0.53	0.95	0.49
23	0.96	0.64	0.96	0.59
24	0.96	0.65	0.94	0.59
25	0.97	0.39	0.97	0.37
26	0.99	0.44	0.96	0.42

appropriate methods of measurement. Next, one cause is singled out and analyzed. This, of course, is done systematically so that the predominant cause is analyzed first.

One advantage of using cause and effect diagrams is that the process of their construction creates a better understanding of the components, of the process and their relationships, and thus a better understanding of the process itself.

Table 5.11: OEE Values : Post TPM Implementation

Week No.	Availability	Performance	Quality	OEE
1	0.99	0.86	0.99	0.84
2	0.98	0.84	0.99	0.81
3	0.98	0.82	0.99	0.80
4	0.97	0.81	0.99	0.78
5	0.98	0.80	0.98	0.77
6	0.97	0.81	0.97	0.76
7	0.95	0.80	0.98	0.74
8	0.98	0.82	0.99	0.80
9	0.97	0.80	0.98	0.76
10	0.97	0.86	0.99	0.83
11	0.98	0.82	0.98	0.79
12	0.97	0.80	0.98	0.76
13	0.97	0.85	0.99	0.82



Defect	Blow Hole	Shrinkage	Sand Drop	Others
Count	52.2442	31.1789	16.0981	0.4788
Percent	52.2	31.2	16.1	0.5
Cum %	52.2	83.4	99.5	100.0

Figure 5.11: Pareto Chart for defects in Agni Flywheel

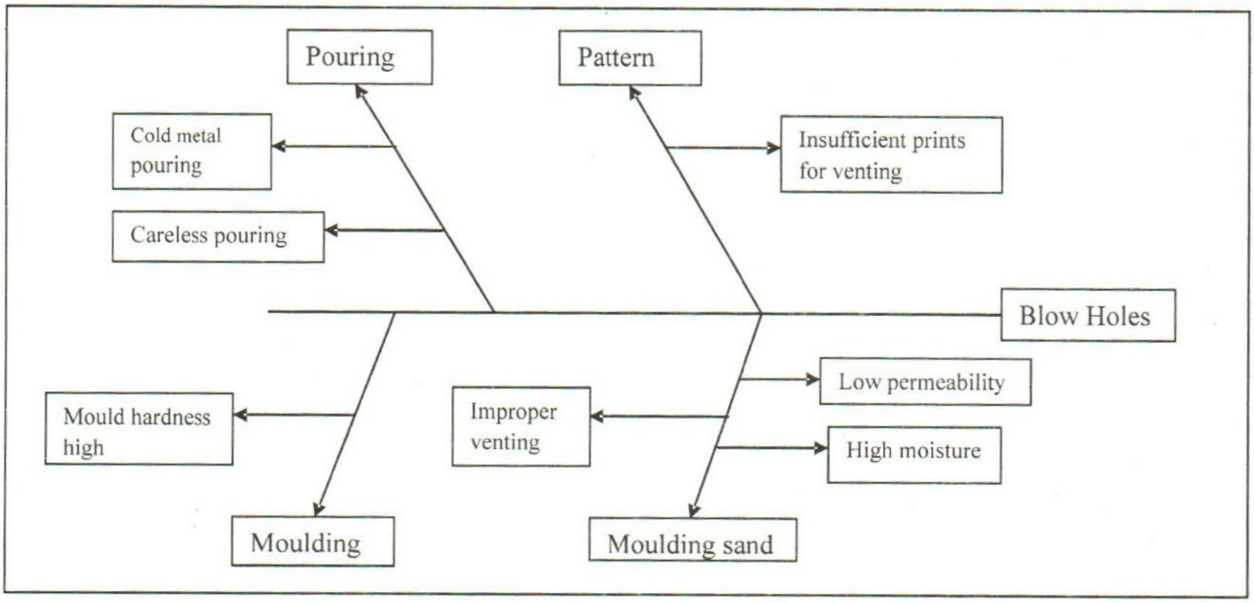


Figure 5.12: Cause & Effect diagram for Blow Holes in Agni Flywheel

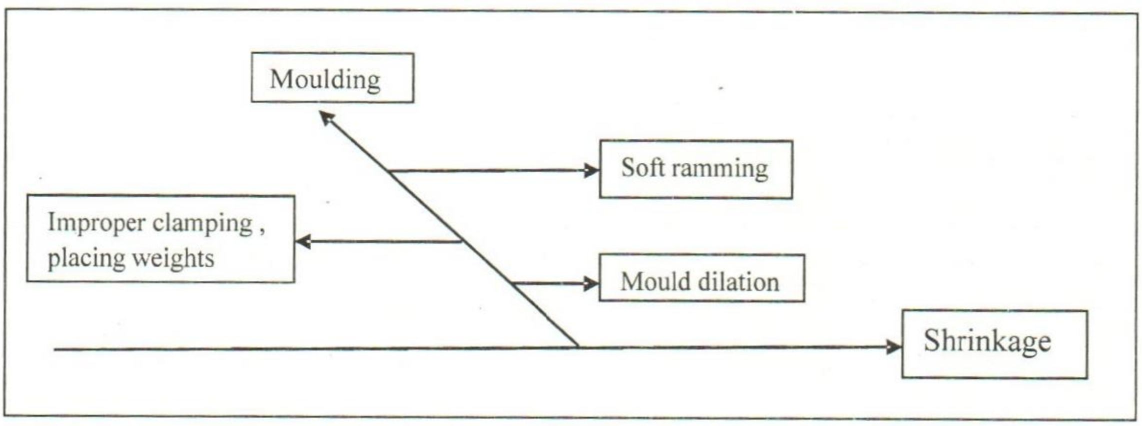


Figure 5.13: Cause & Effect diagram for Shrinkage in Agni Flywheel

Cause and Effect diagrams for defects Blow Hole and Shrinkage as shown in Fig. 5.12 and Fig. 5.13 are drawn and discussions were made with supervisor, shop floor workers and Job Inspectors and causes due to which blow holes and Shrinkage found in Agni Flywheel are shortlisted. For these causes, remedies are suggested which are given in Table 5.7.

In the interpretation casting defect analysis, it was found that, for the component Agni Flywheel, the defects 'Blow Holes' and 'Shrinkage' occur due to the causes specified in table 5.8 below:

By root cause analysis of casting defects, remedies were suggested to management were

1. Change in pattern design for providing proper venting.
2. Check permeability and moisture content of sand and maintain it to the required values i.e. permeability no. in between 102 to 140 and moisture content in between 3% to 3.5%
3. Maintaining proper mold hardness in between 80 to 95 BHN by proper ramming of sand.

Post TPM implementation status of Quality:

Improving the working of the machines by regular maintenance lead to better quality molds. Also, some the remedies suggested in casting defect analysis like maintain proper values for permeability (102-140) and moisture content (3%-3.5%) in sand , properly ramming the sand etc. were followed by the workers. Table 5.9 gives the calculations of quality values for 13 weeks for the period of three months from April, 2012 to June, 2012).

After implementation of TPM, Quality values calculated as an average of 0.98. Thus the quality rate was found to be improved from 0.94 to 0. 98.

Graph of quality vs week number was then plotted for the calculated values which is shown in Fig. 5.14.

OEE

Table 5.10 gives the calculations of OEE values for 26 weeks for the period of six months from August, 2011 to January, 2012.

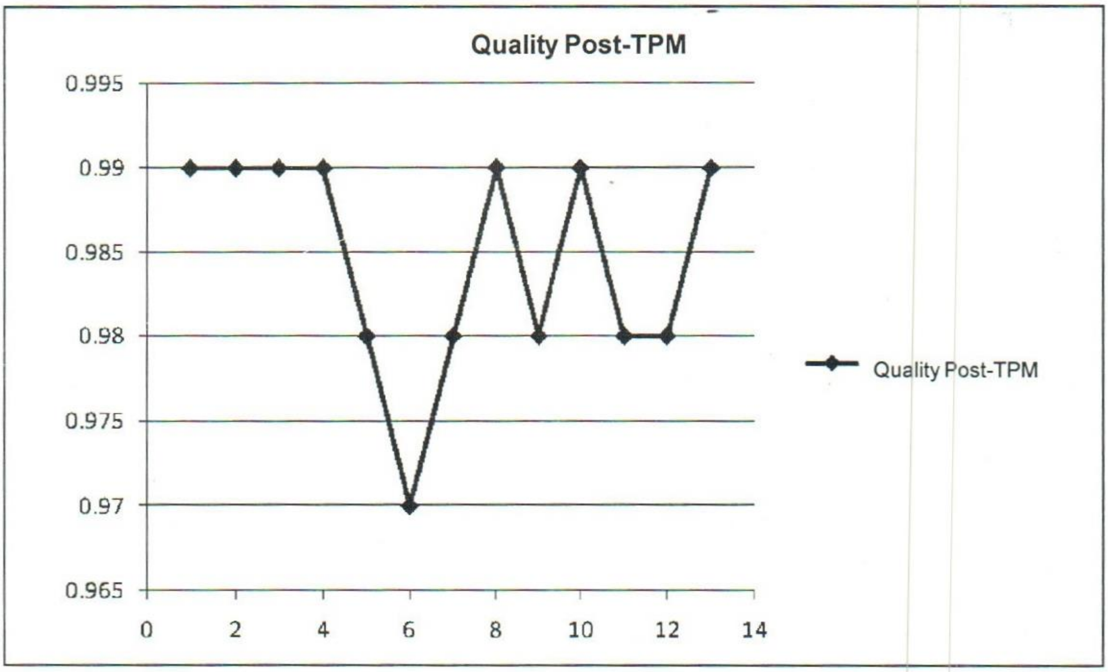


Figure 5.14: Graph of Quality v/s Week No. : Post TPM Implementation

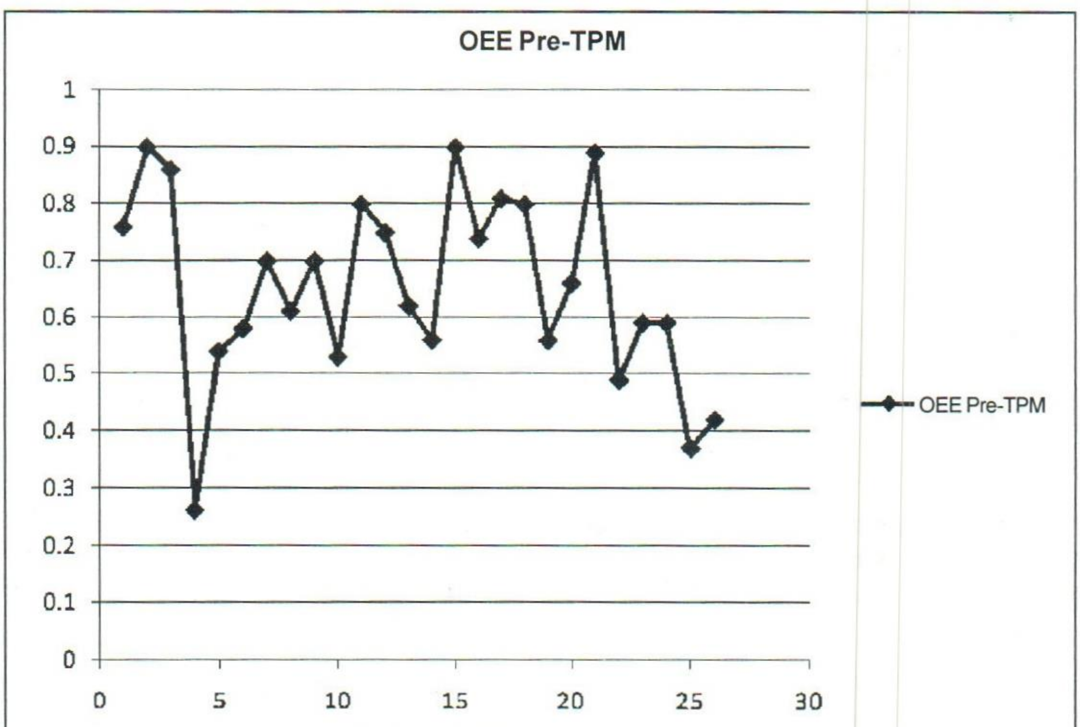


Figure 5.15: Graph of OEE v/s week no.-Pre TPM Implementation

Average value of OEE for six months was calculated as 0.65.

Graph of OEE vs week number was then plotted for the calculated values which is shown in Fig. 5.15.

Pre TPM status of OEE:

OEE per week for the plant before implementing TPM was calculated for the period of six months(Table 5.12). The analysis showed that OEE calculated was normally from 0.50 to 0.90 but for some weeks it was also 0.26, 0.42 etc.

Thus, OEE can be improved by improvements in the three factors availability, performance and quality. Table 5.11 gives the calculations of OEE values for 13 weeks for the period of three months from April, 2012 to June, 2012.

Thus, after implementation of TPM, OEE values calculated as an average of 0.79 Graph of OEE v/s Week Number was then plotted for the calculated values which are shown in Fig 5.16.

Post TPM status of OEE:

The OEE after TPM implementation is calculated as 0.79. Thus, the OEE improved due to combined effect of improvements in availability, performance and quality of the plant.

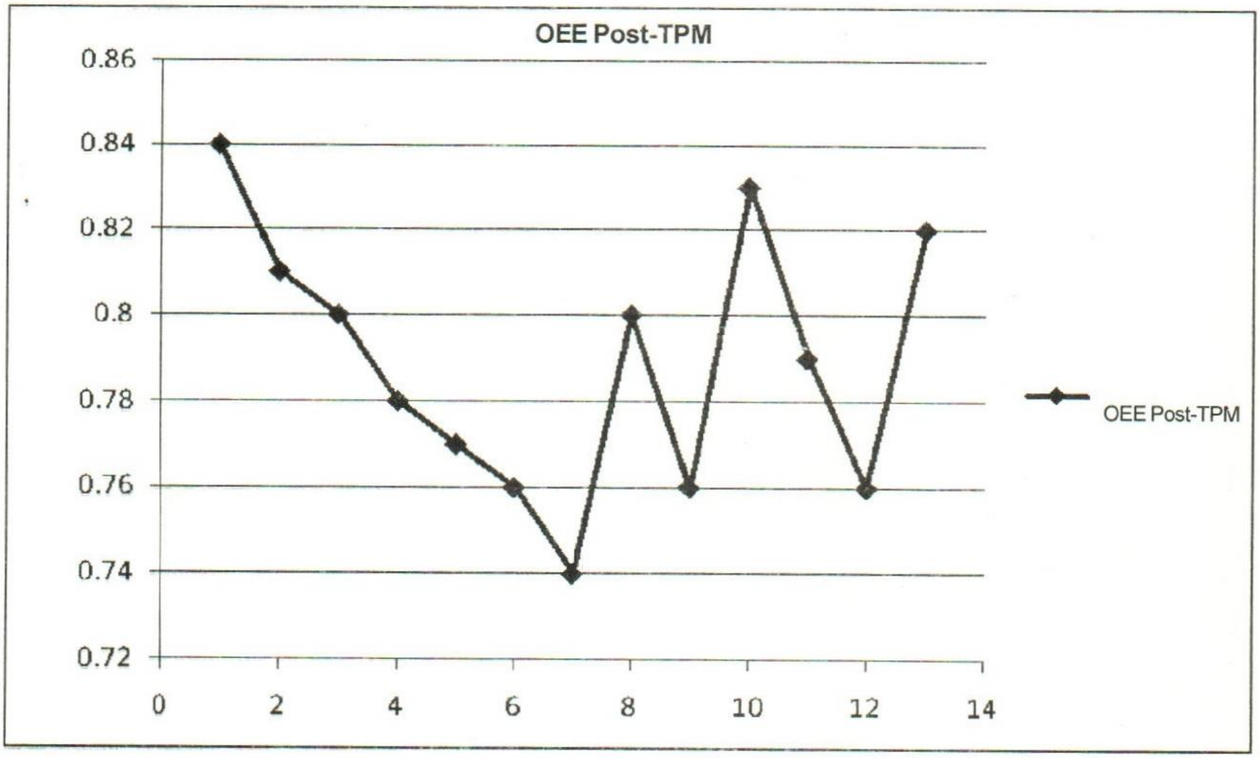


Figure 5.16: Graph of OEE v/s Week No. : Post TPM Implementation

Conclusion

Upon implementing some of the TPM techniques it was observed that

A. Availability was improved from 0.96 to 0.98 due to proper monitoring of scheduled maintenance practices.

B. Performance rate was improved from 0.72 to 0.82 due to KAIZEN implementation in moulding machines

C. Quality rate was improved from 0.92 to 0.97 by following some of the remedies suggested after casting defect analysis.

D. Overall Equipment Effectiveness was improved from 0.65 to 0.79 as a result of combined improvements in availability, performance & quality which in turn resulted in productivity improvement.

References

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The great cry that rises from our manufacturing cities, louder than their, furnace blast, is all in very deed for this- that we manfacture everything there except men.

—John Ruskin

Feature

Formulation of Generalized Field Data Based Model for the Productivity of Wheat Grinding Operation

ABHIJEET AGASHE, V. S. DESHPANDE AND J. P. MODAK

This article highlights the detailed methodology of mathematical model formulation for the productivity of the wheat grinding operation. It details the formulation of field data based model to analyze the impact of various machining field parameters on the productivity of the wheat grinding operation. In all, 34 independent variables are studied to analyze their effect on the dependent variable productivity. The independent variables are then grouped to form 7 dimensionless pi terms using the Buckinham's Pi Theorem. Further, a model is developed using matrix analysis and the effect of the independent pi terms on the dependent pi term is established. Model derived by combining positive and negative pi terms, further analyzes the effect of the independent variables on the productivity. The models are validated to gauge the accuracy. Formulation of mathematical model and sensitivity analysis reveals that the environmental condition in the workshop majorly affects the productivity. Further, in order to improve productivity, it is necessary that the inner lining of the machine parts should have lower surface roughness. Other parameters that positively affect the productivity are surface roughness of the mill stone and the pulley diameter ratio and pulley rpm ratio. Similarly the study reveals that as the ratio of shaft diameter to shaft length increases, the productivity declines. Other factors that affect productivity are BMI of the operator and years in operation as well as anthropometric data of the operators.

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Wheat is a major food staple in India, and is crucial to India's food economy. With wheat production of 70 to 75 million tons annually and a large demand, India's wheat economy is now the second largest in the world.

In the olden days, household had a 'chakki' to mill the wheat. It consisted of two stone disks, each about 20" in diameter, and 3" thick. In it, the lower disk was fixed while the top disk was rotated to ground the wheat. The top disk had a hole to feed the wheat. As the top disk was rotated, it scraped the wheat spreading it out to the outer edge. The scraping surfaces of both the stones were corrugated. The top disk sat on a spindle located on the bottom disk. The different length spindles were used to determine the coarseness of the output.

Modern flour mills, popularly known an 'Atta Chakki' machines use rotating millstones and are often driven by electric motors. The millstones do not touch each other when in operation. There is a gap between the static bedstone and rotating runnerstone which is determined by the size of the grain. Grain is fed from a chute into a hole, known as the eye, in the centre of the runnerstone. An intricate system of groves, known as furrows, distributes the grains across the millstone surface and also serves to ventilate and cool the millstones. The grinding surfaces of the millstones are known as lands and are divided into areas called harps. Once ground, the flour passes along narrow groves called cracking, and is expelled from the edge of the millstones.

Experimental Setup

Wheat grinding operation is carried on a wheat grinding machine popularly known as 'Atta Chakki'. A motor provides the power to turn the runnerstone at a given rotational speed. The power and the rotation per minute of the motor are determined during the research. The wheat grinding operation is carried out by an operator. The anthropometric as well as personal data such as age, skill, years in operation etc, of the operators are determined and taken as input variables for the system. Similarly environmental parameters are also taken as input variables. The machine parameters play a significant role in deciding the productivity and form part of the input variables.

A series of experiments were performed to study the effects of these variables on the productivity of the wheat grinding operation. These experiments were carried out to investigate the effects of various field input parameters mentioned above on the productivity of the operation i.e. total output during grinding wheat into flour. The output was measured and recorded using appropriate storage devices (personal computer) for further analysis.

Need to formulate the field data based model

Data sets contain information, often much more than can be learned from just looking at plots of those data. Models based on observed input and output data (from real life situation) help us abstract and gain new information and understanding from these data sets. They can also serve as substitutes for more process-based models in applications where speed is critical or where the underlying relationships between different activities are poorly understood.

Thus, it is not possible to plan such activities on the lines of design of experimentation[1], especially for the dynamic system (which exists in wheat grinding process). When one is studying any completely physical phenomenon but the phenomenon is very complex, to the extent that it is not possible to formulate a logic based model correlating causes and effects of such a phenomenon, then one is required to go in for the field data based models[2]. In view of the dynamic nature of the context under investigation (which reveals complex phenomenon), it was decided to formulate a field data based model in the present investigation rather than using a theoretical approach.

Formulation of field data based model

Wheat grinding process as a system

The process during wheat grinding operation can be effectively explained with the Block Representation of wheat grinding phenomenon under study in Figure 1.

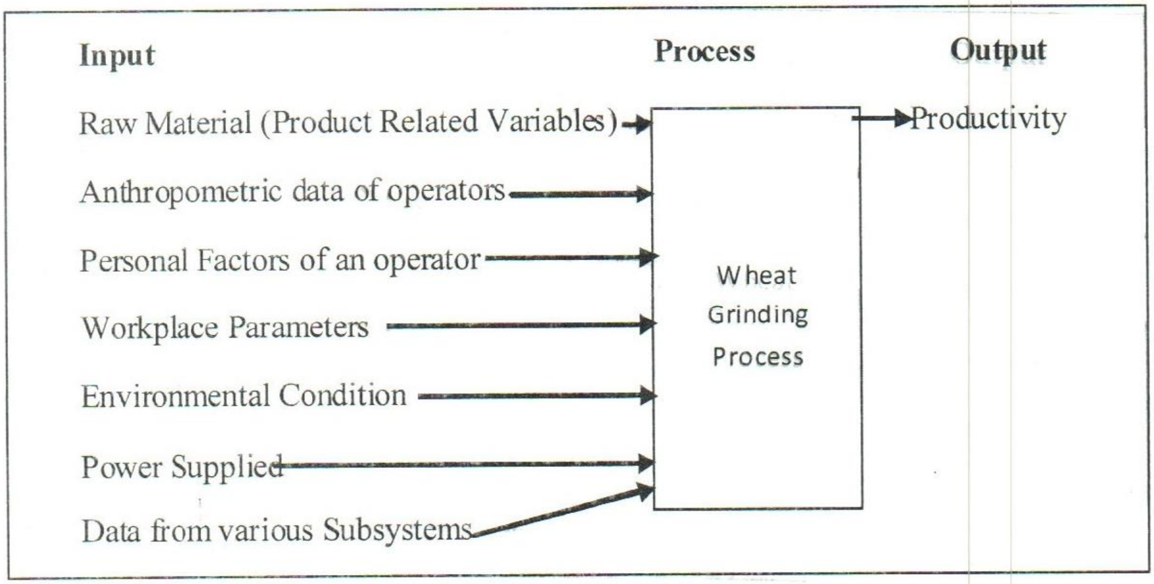

Figure 1: Block Representation of wheat grinding phenomenon

Identification of independent, dependent variables

The term variables are used in a very general sense to apply to any physical quantity that undergoes change. If a physical quantity can be changed independent of the other quantities, then it is an independent variable. If a physical quantity changes in response to the variation of one or more number of independent variables, then it is termed as dependent or response variable. Initially the independent and dependent variables under study were identified. Table 1 and Table 2 depict the independent and dependent variables along with the MLT indices and test envelops respectively.

Table 1: List of Identified Independent (Input) Variables for Wheat grinding Process

S.no	Type	Variable Name	Symbol	MLT indices	Test Envelop
1	C1	Wight of Wheat	Ww	$M^1L^0T^0$	2 constant
2	A1	Total Height	Th	$M^0L^1T^0$	149.86 to 182.88
3	A2	Shoulder Height	Sh	$M^0L^1T^0$	127 to 157.48
4	A3	Waits Height	Wh	$M^0L^1T^0$	73.66 to 101.6
5	A4	Wrist Height	Wrh	$M^0L^1T^0$	60.96 to 91.44
6	A5	Arm Span	As	$M^0L^1T^0$	161.84 to 201.16
7	A6	Arm Reach	Ar	$M^0L^1T^0$	61.9 to 87.12
8	A7	Elbow Height	Eh	$M^0L^1T^0$	95.91 to 115.21
9	A8	Elbow Span	Es	$M^0L^1T^0$	37.46 to 47.29
10	P1	Experience of the Operator	Eo	$M^0L^0T^1$	5 to 30
11	P2	Age of the Operator	Ao	$M^0L^0T^1$	22 to 56
12	P3	Body Mass Index – Prime (BMI)	BMI	$M^0L^0T^0$	14.4 to 32
13	E1	Ambient Temperature	At	$M^0L^0T^0$	35 to 41
14	E2	Illumination at Workplace	Iwi	$M^0L^0T^0$	247 to 410
15	E3	Illumination outside Workplace	Iwo	$M^0L^0T^0$	2400 to 3400
16	E4	Noise Level at Work Place	No1	$M^0L^0T^0$	53 to 68
17	E5	Noise Level at Work Place (While machine is working)	No2	$M^0L^0T^0$	86 to 98\
18	W1	Hp of the Machine Motor	HP	$M^1L^2T^{-3}$	7.5 to 20
19	W2	Motor Speed	Ms	$M^0L^0T^{-1}$	960 to 1440
20	W3	No. of Phases	P	$M^0L^0T^0$	3 constant
21	W4	Pulley Diameter Ratio	PDr	$M^0L^0T^0$	0.66 to 1
22	W5	Pulley RPM Ratio	PRr	$M^0L^0T^0$	0.66 to 1
23	W6	Distance Between pulleys	Dpp	$M^0L^1T^0$	70 to 72.5
24	W7	Hooper Height	Hh	$M^0L^1T^0$	150 to 155.5
25	W8	Break Height	Bh	$M^0L^1T^0$	48 to 54.4
26	D1	Drum Diameter	Dd	$M^0L^1T^0$	40.64 to 50.8
27	D2	Drum Width	Dw	$M^0L^1T^0$	7 to 8
28	GS1	Stone Hardness	Sh	$M^0L^0T^0$	8 constant
29	GS2	Stone Surface Roughness	Ra	$M^0L^1T^0$	0.00002 to 0.00004
30	GS3	Stone Density	Sd	$M^1L^{-3}T^0$	2.21 to 2.90
31	GS4	Stone Weight1	Sw1	$M^1L^0T^0$	23 to 41.5
32	GS5	Stone Weight2	Sw2	$M^1L^0T^0$	20.7 to 35.2
33	S1	Shaft Diameter	Dsh	$M^0L^1T^0$	3.95 to 4.15
34	S2	Shaft Length	Sl	$M^0L^1T^0$	80 to 81.5

Table 2: List of Identified Independent (Response) Variables for Wheat grinding Process

S.no	Type	Variable Name	Symbol	MLT indices	Unit of Measurement
1	Oq	Productivity	Oq	$M^1L^0T^0$	Grams

Formation of different Pi terms formulated by Buckingham's Pi theorem

There are several quite simple ways in which a given test can be made compact in operating plan without loss in generality or control. The best known and the most powerful of these is dimensional analysis. In the past dimensional analysis was primarily used as an experimental tool whereby several experimental Variables could be combined to form one.

Using this principle modern experiments can substantially improve their working techniques and be made shorter requiring less time without loss of control. Deducing the dimensional equation for a phenomenon reduces the number of independent variables in the experiments. The exact mathematical form of this dimensional equation is the targeted model. This is achieved by applying Buckingham's π theorem (Hibert, 1961).

Initially it was necessary to formulate relationships such as

Z1 = f[(C1)(A1, A2, A3, A4, A5, A6, A7, A8), (E1, E2,E3, E4, E5), (W1, W2, W3, W4, W5, W6, W7, W8), (D1, D2),(GS1, GS2, GS, GS4, GS5)(S1, S2)] (1)

where

- Product related variable(C1)
- Anthropometric Data of an operator (A1,A2,A3,A4,A5,A6,A7,A8)
- Environmental conditions(E1,E2,E3,E4, E5)
- Workplace Parameters (W1, W2, W3, W4, W5, W6, W7, W8)
- Grinding Drum Parameters (D1,D2)
- Grinding Stone Parameters (GS1,GS2,GS,GS4,GS5)
- Power transmission shaft parameters (S1,S2)

The pi terms are formulated by applying Buckingham's Pi theorem in order to combine the variables and facilitate further analysis.

Thirty four independent variables are grouped into seven independent pi terms and a separate pi term is formulated for dependent variable productivity as depicted in table 3 below.

Table 3: List of different Dimensional Pi terms formulated by Buckingham's Pi theorem

S.no	Independent Dimensionless Ratio	Independent Dimensionless Ratio	Nature of Basic Physical Quantities
1	π_1	π_1= (Th)(Sh)(Wh)(Wrh)/ (As)(Ar)(Eh)(Es)	Anthropometry related Pie Term
2	π_2	π_2=(Eo)(BMI)/ Ao	Personal Factors of operator
3	π_3	π_3= (At) (No1)/ (Iwi) (No2)	Environmental Conditions
4	π_4	π_4= $(Dpp^2)(Hh^2)(Bh^2).(Ww^3)(Ms^9)(p)^s(PDr)(PRr)/HP^3$	Power Generation Parameters
5	π_5	π_5=Dd/Dw	Drum Related Parameters
6	π_6	π_6= $(sh)(Ra^6)(Sd^2)/(Sw1)(Sw2)$	Stone Related
7	π_7	π_7=Dsh/Sl	Shaft Related
S.no	Dependent Dimensionless Ratio	Dependent Dimensionless Ratio	Nature of Basic Physical Quantities
1	π_8	π_8(Oq)=(Oq/Ww)	Productivity

Approach for formulation of models based on observed data

It is necessary to correlate quantitatively various independent and dependent terms involved in this phenomenon. This correlation is a mathematical model as a design tool for such situation. The Mathematical model for wheat grinding operation is as given below.

Formulation of models based on observed data

Seven independent pi terms (π_1, π_2, π_3, π_4, π_5, π_6 and π_7) and one dependent pi term (π_8) were decided during experimentation and hence are available for the model formulation. Each dependent π term is the function of the available independent terms

$$\pi_8=f(\pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \pi_6, \pi_7) \quad (2)$$

A probable exact mathematical form for the dimensional equations of the phenomenon could be relationships assumed to be of exponential form[5]. For example, the model representing the behavior of dependent pi term π_8 with respect to various independent pi terms can be obtained as under.

$$\pi_8 = a_0\, \pi_1^{a1*}\, \pi_2^{a2*}\, \pi_3^{a3*}\, \pi_4^{a4*}\, \pi_5^{a5*}\, \pi_6^{a6*}\, \pi_7^{a7} \quad (3)$$

There are eight unknown terms in the equation (3) i.e. constant of proportionality a_0 & indices a_1, a_2, a_3, a_4, a_5, a_6, a_7.

The values of exponent a_1, a_2, a_3, a_4, a_5, a_6, a_7 are established independently at a time, on the basis of data collected through classical experimentation. There are eight unknown terms in the equation(3), curve fitting constant a_0 and indices a_1, a_2,a_3,a_4,a_5,a_6,a_7. To get the values of these unknowns we need minimum a set of seven set of all unknown dimensionless pi terms.

$$Z=A+bX+CY........ \quad (4)$$

The equation 3 can be brought in the form of equation (4) by taking log on both sides.

$$LOG\ \pi_8=LOG\ a_0 + a_1\ LOG\ \pi_1 + a_2 LOG\ \pi_2 + a_3\ LOG\ \pi_3 + a_4\ LOG\ \pi_4 + a_5\ LOG\ \pi_5 + a_6\ LOG\ \pi_6 + a_7\ LOG\ \pi_7 \quad (5)$$

After solving using MATLAB, the mathematical model formulated is

$$\pi_8= 1.3465\ \pi_1^{-0.0938} * \pi_2^{-0.0026} * \pi_3^{0.0251} * \pi_4^{-0.0117} * \pi_5^{0.022} * \pi_6^{0.0073} * \pi_7^{-0.1294} \quad (6)$$

Formulation of Models Based on combination of observed data

Two more independent pi terms (π_a, π_b) were formed and already formed one dependent pi term (π_8) were decided during experimentation and hence are available for the model formulation.

π_a is formed by the product of the positive independent π as specified in equation(6).

$$\pi_a = (\pi_3 * \pi_5 * \pi_6) \quad (7)$$

π_b is formed by the product of the negative independent π as specified in equation(6)

$$\pi_b = (\pi_1 * \pi_2 * \pi_4 * \pi_7) \quad (8)$$

Each dependent π term is the function of the available independent terms

$$\pi_8=f(\pi_a, \pi_b) \quad (9)$$

A probable exact mathematical form for the dimensional equations of the phenomenon could be relationships assumed to be of exponential form [26]. For example, the model representing the behavior of dependent pi term $\pi 8$ with respect to various independent pi terms can be obtained as under.

$$\pi_8=a_0\ \pi_a^{a1*}\ \pi_b^{a2} \quad (10)$$

Therefore two unknown terms in the equation 10 i.e. constant of proportionality a_0& indices a_1, a_2.

The values of exponent are a_1 and a_2 are established independently at a time, on the basis of data collected through classical experimentation. There are three unknown terms in the equation (10) curve fitting constant a_0 and indices a_1 and a_2. To get the values of these unknowns we need minimum a set of three set of all unknown dimensionless pi terms.

After solving using MATLAB, the mathematical model formulated is as indicated herein

$$\pi_8= 1.0335\ \pi_a^{0.0005} * \pi_b^{-0.0021} \quad (11)$$

Graphical Analysis of combination of observed data for Individual Mathematical Model for dependent pi term Productivity (Oq)

To obtain 2-D graph, dependent pi term π_8 is plotted on Y axis, where as the product of all independent pi terms is plotted on the X axis in Figure 2.

It can be observed from the plot that as the product of the independent pi terms increases, the productivity Oq, as tends to gradually decrease. 6 peaks observed, needs involvement of 12 mechanisms.

To obtain 2-D graph, dependent pi term π_8 is plotted on Y axis, where as the product of all positive independent pi terms is plotted on the X axis in Figure 3.

It can be observed from the plot that as the product of the independent positive pi terms increases, the productivity Oq, as tends to gradually decrease. 8 peaks observed, needs involvement of 16 mechanisms.

To obtain 2-D graph, dependent pi term π_8 is plotted on Y axis, where as the product of all negative independent pi terms is plotted on the X axis in Figure 4.

It can be observed from the plot that as the product of the independent negative pi terms increases, the productivity Oq, as tends to gradually decrease. 6 peaks observed, needs involvement of 12 mechanisms.

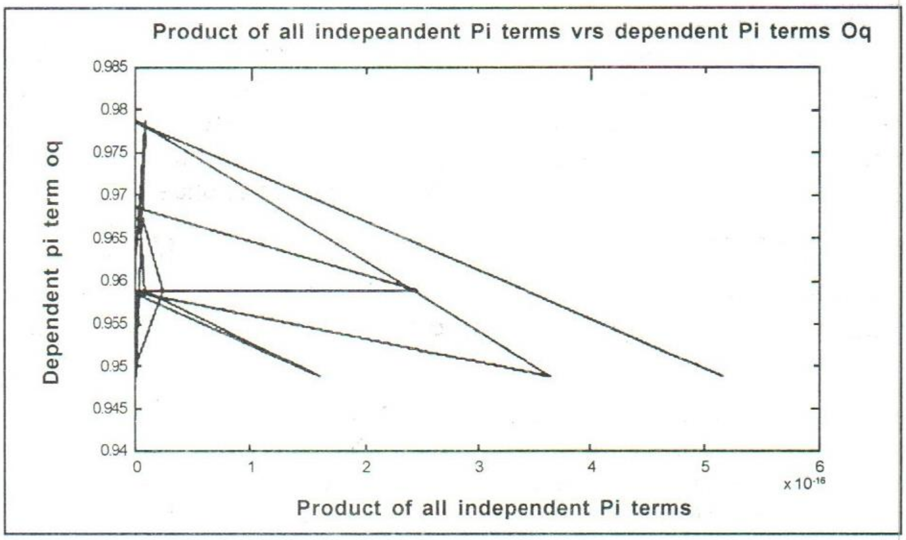

Figure 2 : 2-D Plot of Product of all independent pi terms Vs dependent Pi term π_8

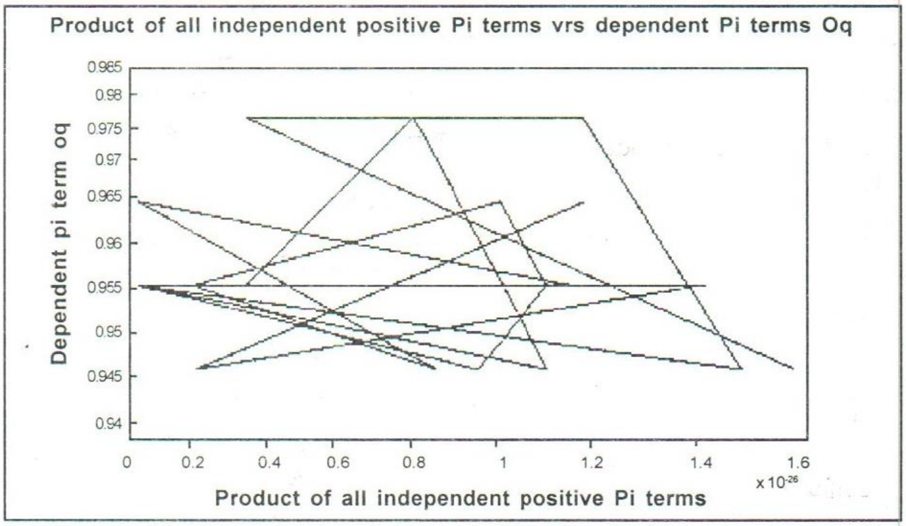

Figure 3 : 2-D Plot of Product of all independent Positive pi terms Vs dependent Pi term π_8

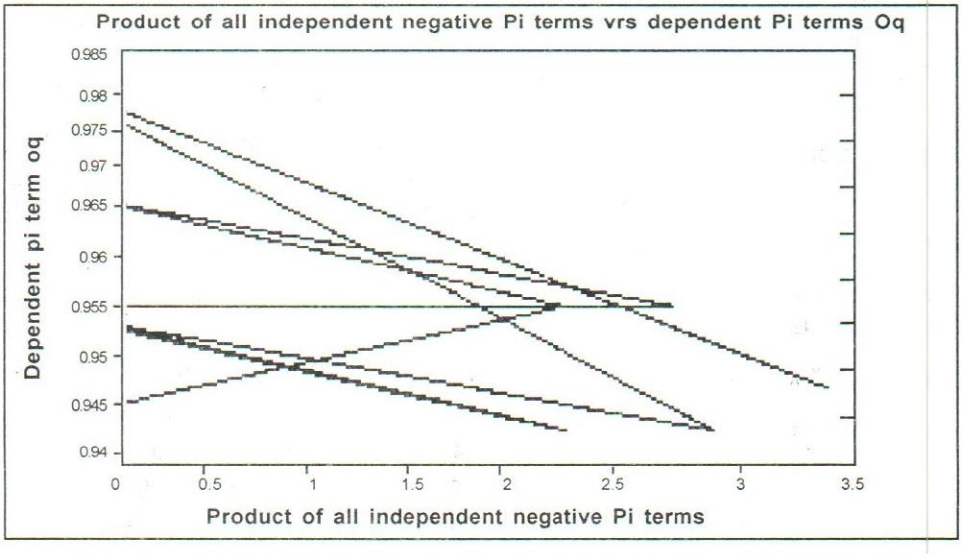

Figure 4 : 2-D Plot of Product of all independent negative pi terms Vs dependent Pi term π_8

Model Sensitivity Analysis

The influence of the various independent π terms has been studied by analyzing the indices of the various π terms in the models. Through the technique of sensitivity analysis, the change in the value of a dependent π term caused due to an introduced change in the value of individual π term is evaluated. In this case, change of ± 10 % is introduced in the individual independent π term independently (one at a time).Thus, total range of the introduced change is ±20 %. The effect of this introduced change on the change in the value of the dependent π term is evaluated .The average values of the change in the dependent π term due to the introduced change of ± 10 % in each independent π term. This defines sensitivity. The total % change in output for ±10% change in input is shown in Table 4.

Table 4 : Sensitivity Analysis of the formulated model

Pi Terms	% change
π_1	-0.5987037
π_2	-0.0005218
π_3	0.0050362
π_4	-0.002348
π_5	0.0044143
π_6	0.0014648
π_7	-0.0259844

The graphical distribution of the sensitivity analysis of the formulated model with respect to different pi terms is shown in figure 5.

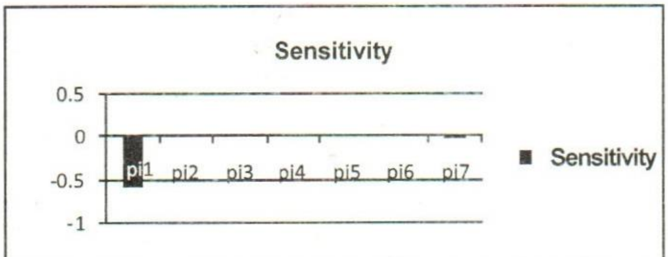

Figure 5: Graph of sensitivity analysis of the formulated model for Productivity

Model optimization for the Productivity

The ultimate objective of this work is not merely developing the models but to find out best set of independent variables which will result in minimization of the objective functions. In this case, there is one objective functions corresponding to productivity of grinding process. The objective function for the productivity of wheat grinding process needs to be maximized. The models have non-linear form; hence, it is to be converted into a linear form for optimization purpose. This can be achieved by taking the log of both the sides of the model. The linear programming technique as detailed below is applicable for wheat grinding operation.

Taking log of both the sides of the equation 4, we get the objective function

$$Zmax = LOG\ (1.3465)-0.0938LOG(\pi_1)\ -0.0026\ LOG(\pi_2)+0.0251LOG\ (\pi_3)-0.0117LOG(\pi_4)\ +\ 0.022\ LOG\ (\pi_5)+0.00732LOG(\pi_6)\ -0.1294\ LOG\ (\pi_7) \qquad (12)$$

Subject to the following constraints

$$1X_1+0X_2+0X_3+0X_4+OX_5+OX_6+OX_7<= LOG\ (Max\ \pi_1)$$

$$1X_1+0X_2+0X_3+0X_4+OX_5+OX_6+OX_7>= LOG\ (Min\ \pi_1)$$

$$0X_1+1X_2+0X_3+0X_4+OX_5+OX_6+OX_7<= LOG\ (Max\ \pi_2)$$

$$0X_1+1X_2+0X_3+0X_4+OX_5+OX_6+OX_7>= LOG\ (Min\ \pi_2)$$

And so on up to

$$0X_1+0X_2+0X_3+0X_4+OX_5+OX_6+1X_7<= LOG\ (Max\ \pi_7)$$

$$0X_1+0X_2+0X_3+0X_4+OX_5+OX_6+1X_7>= LOG\ (Min\ \pi_7) \qquad (13)$$

On solving the above problem by using MS solver we get values of X_1, X_2, X_3,X_4 ,X_5, X_6, X_7 and Z.

Thus π_8 min =Antilog of Z and corresponding to this value of the π_8 min the values of the independent π terms are obtained by taking the antilog of X1,X2,X3,X4,X5,X6, X7 and Z.

The optimized values are tabulated in table 5

On substituting the values of π_1 to π_7 in equation 12, Zmax = 2

Table 5: Optimized values of response variables for Productivity

Pi Terms	Log Values	Anti Log Values
Z	-0.10928	0.775
π_1	0.302	2.0045
π_2	0.455	2.851
π_3	0.926	8.433
π_4	7.823	66527315.6202
πi_5	0.86	7.24
π_6	-27.403	3.94974E-28
π_7	-1.311	0.0489

Thus conclusion can be drawn that on reaching the optimized values of π_1 to π_7, one can Maximize the value of response variable Productivity to 2 kg which is 100%.

Validation of the formulated generalized field data based model

The validity of the formulated model can be checked by comparing the actual experimental value of the pi term related with productivity and its values obtain from the formulated mathematical model. Figure 6 depicts the actual observed and Mathematical Model Predicted values for Dependent variable Productivity.

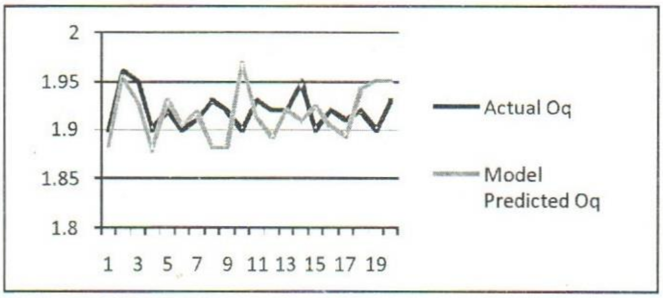

Figure 6: Actual observed and Mathematical Model Predicted values for Dependent variable Productivity

Table 6 : Actual observed and Mathematical Model Predicted values for Dependent variable Productivity

Actual Oq	Oq (Model Predicted Oq)	% error
1.9	1.88	0.85%
1.96	1.95	0.31%
1.95	1.93	1.14%
1.9	1.88	1.13%
1.92	1.93	-0.55%
1.9	1.91	-0.27%
1.91	1.92	-0.42%
1.93	1.88	2.49%
1.92	1.88	1.98%
1.9	1.97	-3.61%
1.93	1.91	0.89%
1.92	1.89	1.47%
1.92	1.92	-0.04%
1.95	1.91	2.09%
1.9	1.92	-1.31%
1.92	1.90	0.84%
1.91	1.89	0.88%
1.92	1.94	-1.16%
1.9	1.95	-2.67%
1.93	1.95	-1.05%

Reliability = 100 – Percentage Mean Error

$$\text{Mean Error} = \frac{\Sigma(x_i * f_i)}{f_i} \qquad (14)$$

Mean Error (Oq) = 0.149%

$$\text{Reliability} = 100\ \frac{\Sigma(x_i * f_i)}{f_i}$$

Reliability = 99.85%

Interpretation and Discussion

Mathematical model for Productivity

Referring to equation 6, it is observed that the absolute index of a_3 of π_3 term is the highest viz. 0.0251. This indicates the highest influence of the pi term π_3 on the productivity. Since index a_3, is positive, the relationship between productivity π_3 is direct, meaning that if value of π_3 increases, the productivity shall increase. This pi term is related to the environmental conditions in the workshop. π_3 majorly has ambient temperature in the workshop in the numerator, this indicates that as the temperature inside the workshop increases, the productivity also increases. The logical reasoning behind this behavior can be that when the machine is cold and probably not in operation for some time, the wheat flour gets deposited on the inner parts of the machine, thus reducing productivity. Once the machine is in operation for some time, the input-output ratio subsequently increases, thus improving productivity. In order to improve productivity, it is necessary that the inner lining of the machine parts should have lower surface roughness, thus lowering the deposits and increasing the productivity. This does not apply to the millstone as reducing the surface roughness of the millstone shall have an adverse effect on the productivity. Therefore while doing so, one needs to take into consideration the impact of such reduction on other operational parameters.

The pi term π_6 has a positive index meaning that as the value of this pi term increases, the productivity shall increase. π_6 is formed with parameters related to the mill stone. Considering the independent variables in this pi term, one may conclude that as surface roughness of the stone and the pulley diameter ratio and pulley rpm ratio increases, the productivity shall increase, which is desirable.

Studying the index a_7 of pi term π_7 which is negative, inference can be drawn that as the ratio of shaft diameter to shaft length increases, the productivity declines. Incase if it is possible to reduce the shaft diameter without affecting the length of the shaft, the productivity shall improve.

The pi term π_2 with a negative index indicates that as the BMI of the operator as well as years in operation increases, the productivity decreases, though the factor does not significantly influence the response variable productivity. Similar is the case with the anthropometric data of the operators.

Interpretation for Curve Fitting Constant

The magnitude of the curve fitting constant for the mathematical model as depicted in equation 6 for productivity time is 1.34. This value represents collectively the influence of various extraneous variables that affect the productivity but are not part of the study. Such extraneous factors in this case are related to factors such as vibration in the machine, condition of the machine components, hours of continuous operation by the operator, his psychological condition and power fluctuations etc.

Formulation of models based on combination of observed data for dependent pi term productivity

With reference to equation 11 one understands that the indexes a_1 and a_2 of π_a formed by the product of all positive pi terms and π_b formed by the product of all the negative pi terms are 0.0005 and – 0.0021 respectively. It may be safely concluded that the positive pi terms put together have a significant and positive impact on the response variable productivity. In order to increase the productivity, the parameters in π_3, π_5, π_6 should be increased where as parameters in $\pi_1, \pi_2, \pi_4, \pi_7$ should be decreased.

Reliability of the model

From the values of percentage error, one can infer that the mathematical models can be successfully used for the computation of the values of dependent pi terms and subsequently that of the response variables.

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The simple act of paying positive attention to people has a great deal to do with productivity

—Tom Peters

Feature

Improving Livestock Productivity: The Role of Diffusion and Adoption of Technologies

MAHESH CHANDER AND DWAIPAYAN BARDHAN

Productivity of livestock in India is very low and even lower than that of the world averages, mainly due to low adoption of improved technologies. Only 5.1% farmer households in India access any new information on animal husbandry against 40.4% of the Indian households accessing information on modern technology for crop farming (Government of India, 2005). There is considerable gap in the technologies developed and available at research institutions and technologies actually being adopted or used by the farmers. The livestock technologies developed with high expectations of the researchers and considered very promising like urea treatment of straw, deworming, vaccinations, artificial insemination/cross breeding, fodder chaffing, feed supplements etc have huge regional variations in terms of their adoption by the livestock farmers.

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The path breaking research on the diffusion of innovations by Ryan and Gross (1943), explained through diffusion of hybrid seed corn among Iowa farmers, followed by Rogers' studies on diffusion have had significant influence on the extensionists around the world, leading to scores of studies, mostly in context of crops. Whereas, being relatively less addressed, it could be interesting to test these theories in the field of livestock innovations as well. It is assumed that with better understanding of the theories of diffusion and adoption, technology transfer practices can be improved, leading to more, wider and faster adoption of livestock technologies.

Over the last three decades, Indian dairy sector has progressed from a situation of scarcity to that of plenty. The fact that India now occupies the proud position of the highest milk producer in the world, can largely be attributed to millions of landless agricultural labourers, and small and marginal farmers of India who account for the bulk of the country's milk production. An unique feature of Indian dairy sector is its low productivity. As per a recent estimate, 5 dairy cows in India produce as much milk as 1 dairy cow in USA and 10 dairy cows in India produce the quantity of milk that is produced by a single dairy cow in New Zealand (Hemme *et al.*, 2003). Average milk productivity is 6.63 litres/day/cow in case of crossbred cows, 2.22 litres/day/cow in case of indigenous cows and 4.58 litres in case of buffaloes. Average egg productivity in the country is about 222 number per fowl per year and average meat productivity is 10 kg goat/year and 1.21 kg/poultry bird/ year. (GOI, 2012).

The low productivity could be attributed to, among other factors, traditional dairy husbandry practices followed by farmers. The problem of low productivity can be overcome and exploitation of the opportunities offered by dairy sector can only be fully realized, when the farmers successfully adopt new dairy technologies that are being generated in research institutes. Various research organizations have evolved a number of technologies for application at the field level; however, many of these technologies are not often adopted by the farmers. As a result there is wide gap between the technology generation and their utilization by the farmers.

It is beyond doubt that improvement in productivity and profitability of small-holder enterprises can only occur when the farmers adopt new technologies on a sustained basis. In this context, adoption studies assume critical importance, as they provide crucial inputs to policy makers in increasing the efficiency of dissemination process of dairy technologies, and also ensuring their effective uptake by the farmers.

The diffusion adoption process in a given society is also an indicator of the progressiveness of any country. What makes this process work well in some countries or for some innovations in many countries depend on many factors including the technology itself (its attribute), socio-psychological and personal factors associated with the technology consumers, followed by the support mechanism like communication networks and inputs. The government agencies, seed/breed societies, farmer associations, private firms, besides the policies and programmes facilitating spread of technologies play important role in technology transfer process. This is what is responsible for huge regional variations in technology adoption across the world as also within the individual states in India. There is need for innovations in technology dissemination as well. For instance, NGOs and private sector can play a vital role in technology dissemination, but so far involvement of these agencies in livestock technology spread is very limited though there are some success stories like BAIF's AI service delivery in many states of India.

It is a matter of study why these regional variations are there in technology adoption, what are the processes involved here, including the role of government policies and institutions, key individuals, social networks, and economic imperatives. The efficiency of the technologies generated and disseminated also depends on effective communication which is a key process in information dissemination. Technology is only one small part of the diffusion adoption dynamics, since a lot also depends on human interactions and how the concerned organizations are treating the technology. In case of Bihar, realizing the importance of AI and crossbreeds as also recognizing the sluggishness of government agencies particularly state department of animal husbandry in delivering the breeding services to farmers, one veterinarian left his government job and raised private firm by name Patna Animal Development Private Limited (http://www.fao.org/ ag/ againfo/ programmes/en/ pplpi/docarc/LSP307.pdf.) to deliver animal breeding services. This private agency has shown that private interventions may speed up the adoption rate of technology thereby improving the living conditions of the farmers. Besides, the innovations, technology development and adoption reflects changing market demand, as well as the more complex shifts occurring in agricultural regions and institutions involved in bringing about change in the society. For instance, in Bihar the current government has galvanized the machinery towards development in different sectors including animal husbandry. Such efforts are also likely to have impact on technology diffusion and adoption leading to transformation in society due to among others changes brought about in livestock sector.

There is often a significant interval between the time an innovation is converted or developed as a technology and available in the market, and the time it is widely used by producers. As such, adoption and diffusion are the processes governing the utilization of innovations. Studies of adoption behavior emphasize factors that affect if and when a particular individual will begin using an innovation. Measures of adoption may indicate both the timing and extent of new technology utilization by individuals. Adoption behavior may be depicted by more than one variable. It may be depicted by a discrete choice, whether or not to utilize an innovation, or by a continuous variable that indicates to what extent a divisible innovation is used. For example, one measure of the adoption of high-yielding cattle by a farmer is a discrete variable denoting if this breed is being used by a farmer at a certain time; another measure is what percent of the farmer's herd is occupied with this breed. Diffusion can also be interpreted as aggregate adoption. Diffusion studies depict an innovation that penetrates its potential market. As with adoption, there may be several indicators of diffusion of a specific technology. For the adoption of new technologies and practices in agricultural sector has been an area of research and academic interest since long for the agricultural extension professionals including the sociologists and economists all over the world. The research and publications of several workers (Ryan and Gross, 1943; Hagerstrand, 1967; Brown, 1981; Ison and Russell, 2000; Vanclay, 2004) as also the students' research in the form of master's and doctoral thesis, particularly in Agricultural extension discipline across the world, highlights the role of diffusion and adoption research. Research on the diffusion of innovations model began with the Bryce Ryan and Neal C. Gross investigation (1943) of the diffusion of hybrid seed corn among Iowa farmers. By 1941, about thirteen years after its release by agricultural researchers, this innovation was adopted by almost 100 percent of Iowa farmers. Ryan and Gross studied the relatively rapid diffusion of hybrid corn in two Iowa communities in order to understand this phenomenon so that it might be applied to the diffusion of other farm innovations. After Ryan and Gross's hybrid corn study, about 5,000 papers about diffusion were published by 1994 (Rogers, 1995). These researches have proven that the agricultural production and productivity depends to a great extent on the innovations, technology development, diffusion, and adoption of the potential technologies by the farmers for whom the technologies are generated as also on the support mechanism for timely availability of the required inputs.

There is a general consensus that the application of new technologies and practices is largely based on the desire of farmers to maximize economic returns (Birkhaeser *et al.,* 1991., Black, 2000., Huffman and Evenson, 2006), while there is considerable debate regarding the processes that lead to adoption. Under normal circumstances, new technologies and farming practices are adopted within particular environmental contexts to increase productivity, reduce costs, or both (Leeuwis and Van den Ban, 2004). The adoption of new technologies and practices can result in significant transformations in farming systems, agricultural landscapes as also the socio-economic situations of the farmers. This is particularly apparent in the production of cereal crops, where the use of new technologies, such as hybrids, chemical fertilizers, herbicides, seeding and harvesting equipment, disease and drought resistant crops, and minimum-till techniques have increased production and decreased costs (Gardner, 2002; Henzell, 2007). The green revolution 1960's onwards is perhaps the best example of the successful diffusion and adoption of new technologies developed or introduced in India, which led to an intensification of crop farming especially in irrigated areas, where rice-wheat sugarcane production is prominent. The major components of Green Revolution were technology, services, public policies and above all farmers' enthusiasm, which led to significant transformation in Indian rural society as a consequence of adoption of technologies and package of practices as recommended by the research institutions.

Cattle Cross Breeding: Adoption and Consequences

The Green Revolution though primarily focused on high yielding varieties of rice and wheat had also impacted the livestock sector through the introduction or development of new breeds as a means of improving the productivity and profitability of farming. The introduction of new breeds and crossbreeding in cattle is well recognized as productivity enhancing effort. For example, the introduction of the heat and parasite tolerant Zebu (humped) cattle imported from India during the second half of the 1800s contributed to a marked increase in beef production in the hotter and more humid regions of the USA (Sanders 1980). Indian cattle breeds viz. *Ongole, Khillar, Gir* and *Kankrej* shipped to South American countries like Brazil when introduced and used to further develop the cattle suited to specific environmental conditions or market requirements have done remarkably well in these countries. American Brahman cattle was the first breed of beef cattle developed in the United States in the early 1900s as a result of crossing four different Indian cattle breeds (*Gir, Gujarat, Nelore* and *Krishna Valley*). The original American Brahman cattle originated from a nucleus of approximately 266 bulls and 22 females of several *Bos indicus* (cattle of India) types imported into the United States between 1854 and 1926. The Brahman is mainly used for breeding and the meat industry; it has been crossbred extensively with *Bos taurus* (European) beef breeds of cattle. The Brahman is one of the most popular breeds of cattle intended for meat processing and is widely used in Argentina, Brazil, United States, Colombia and northern Australia. It has also been used to develop numerous other U.S. beef breeds including Brangus, Beefmaster, Simbrah, and Santa Gertrudis. Likewise, *Holestein Friesian* and Jersey cattle breeds which originated in Europe are prominently used in cross-breeding programmes in many countries across the world including India. The development and spread of new breeds are, in effect, forms of innovation and diffusion (Rogers, 2003; Leeuwis and Van den Ban, 2004; Abdulai and Huffman, 2005). Whether Indian breeds taken to America or European breeds used in India, both ways, these breeds have followed a process in their spread and brought about a change in livestock production dynamics through the process of diffusion and adoption leading to socio-economic transformation in the social system.

Significant technological advances have been made in breed improvement. However, their adoption in the field has been limited and regionally concentrated even though micro-level evidence rarely disputes their technical and economic performance (Sirohi, 2005). Crossbreeds are unevenly distributed in India. The proportion of crossbreds in total livestock population is very high in Kerala, Tamil Nadu and Punjab compared to Uttar Pradesh, Bihar and MP, so is difference in per animal productivity. Crossbred cattle population has crossed 80%, while it is below 5% in some states. Overall, the crossbred population is below 15% in whole India, there are huge regional variations despite crossbreeding efforts going on since 1960's. For example, of the total adult female cattle population in Kerala, 83.4 per cent is crossbred and if the cattle in milk are taken into consideration, it goes up to 85 per cent. This high proportion of crossbred population was made possible among others by the Indo-Swiss Project and the expanded health care facilities and veterinary services in the state. India has 187.38 million cattle (2003 census), which is about 15 per cent of the world cattle population. Out of the 187.38 million cattle, 22.63 million were crossbred, which is 12.07 per cent of the total cattle population. The states of Tamil Nadu, Maharashtra, Kerala, Uttar Pradesh, Karnataka and Punjab account for about 60 per cent of the crossbred cattle population. In spite of India's position as highest producer of milk, productivity per animal is very poor. It is only 987 Kgs/lactation as compared to the world average of 2038 Kgs/lactation. This is mainly due to poor level of nutrition as well as low genetic potential for milk production and weak animal health care infrastructure. Moreover, crossbreeding is not the only way to improve livestock productivity, since the productivity of Indigenous cattle can also be improved by following the selection and up-gradation using systematic breeding plans. Poor productivity in milch cattle can be largely attributed to poor adoption of technologies including nutrition and breeding technologies, which in turn is due to among others weak technology transfer mechanism in place.

T&D Pig innovation: A Success Story

The development of T&D pig is one good example of livestock breeding innovation having significant implications for boosting pig production in India, especially in Eastern parts of the country. The scientists of the Department of Animal Genetics & Breeding, Birsa Agricultural University, Kanke, Ranchi evolved a new breed of black colour pig in the year 1989, named 'T & D', by crossing Tamworth - a British pig and local pig, having 50% inheritance of each by continuous selection for four generations on the basis of black colour and better reproductive performances. It is more remunerative due to its black colour, faster growth, better reproductive performance, disease resistance and better adaptability at farmers' door. The scientists involved with developing 'T&D' pig breed were appreciated and also awarded with prestigious "FAKHARUDDIN ALI AHAMAD" National Award by Indian Council of Agricultural Research (ICAR). Thus, emerged 'T&D' pig breed - an innovation. Based on field records of 4 years (2001-04), it was estimated that rearing of T&D pigs is about 5 times more remunerative than rearing *desi* pigs at village levels (Verma 2003, Mahto, 2006 and Singh, 2009), thus, considered most suitable breed of pig for rearing in villages of Jharkhand. Now, 'T&D' pig is widely spread in Jharkhand, Bihar, West Bengal, MP and North Eastern states, since, its benefits were favourably observed over the years. 'T&D' pig, as an innovation being diffused for adoption by the farmers through different channels under different schemes towards varying degree of its acceptance by the different categories of farmers. This new breed of pig has shown its potential in bringing about socio-economic transformation not only in the rural areas of tribal dominated Jharkhand state, but in the neighboring states as well in a very short period of time. It was an innovation which was need based as well as compatible to the local culture of the people so got good acceptability of the farmers. Innovations that have greater *relative advantage*, *compatibility*, *trialability*, and *observability*, along with less *complexity*, generally are better adopted over innovations which lack these perceived characteristics of innovations. Many more similar need based, compatible, locally feasible and acceptable innovations & technologies are required to be developed, diffused and adopted by the farmers towards improving the livestock productivity and production in India, where the average per animal productivity is still lower than that of world averages for many livestock species and products.

Promising Livestock Technologies: Wider Adoption Missing

Not only breeds but also several technologies when developed and diffused towards adoption by the society have led to consequences. Vaccines, improved feeds, balance ration, antibiotics, paraciticides etc developed over the years are at various stages of diffusion and adoption process. The most developed nations have the higher rates of adoption of these technologies compared to less developed countries where the technologies are being adopted example, one measure of diffusion may be the percentage of the farming population that adopts new innovations. Another is the land share in total land on which innovations can be utilized. These two indicators of diffusion may well convey a different picture. We need to understand this dynamics in context of every livestock technology developed.

The extension agencies or person introducing any livestock innovation in a social system should take into consideration three aspects: i) the adopter categories (the characteristics of the target population), ii), the characteristics of the innovation or change itself, and iii) the stages of adoption. Each of these three categories should be analyzed and planned for, when introducing an innovation or change for livestock development through a technological intervention. For any technology to be successfully adopted by the farmers, market too need to be studied for the consumption of the technology. For instance, if we are trying to introduce pigs in a predominantly non pork consuming society, possibility of resistance or failure of effort cannot be ruled out due to non availability of local market. The consumer education on importance of pork in human diet can precede through different channels, so that the consumers are made receptive to the technology leading to better adoption.

Discussion

The rate of adoption of livestock-related technologies in smallholder crop-livestock systems worldwide is consistently low. In order to solve this problem, approaches that guarantee effective linkages among researchers, extension workers, decision-makers and farmers, who have a complex knowledge base and widely dispersed expertise are needed (Francis *et al.,* 1997., Conner *et al.*,1998). Adoption of technologies depends on both, knowledge flows and local receptiveness to the technologies in the context of the theories of diffusion of innovations. The same technology may be well adopted in a region (for instance, Punjab), while finding no takers in another (ex. Bihar) or vice versa. Animal vaccinations, Artificial Insemination, deworming, fodder chaffing and crossbreeding shows differential adoption across the country. For example, chaff cutters are very well accepted even by the resource poor dairy farmers in Haryana, Punjab, Uttar Pradesh and Gujarat state of India, while

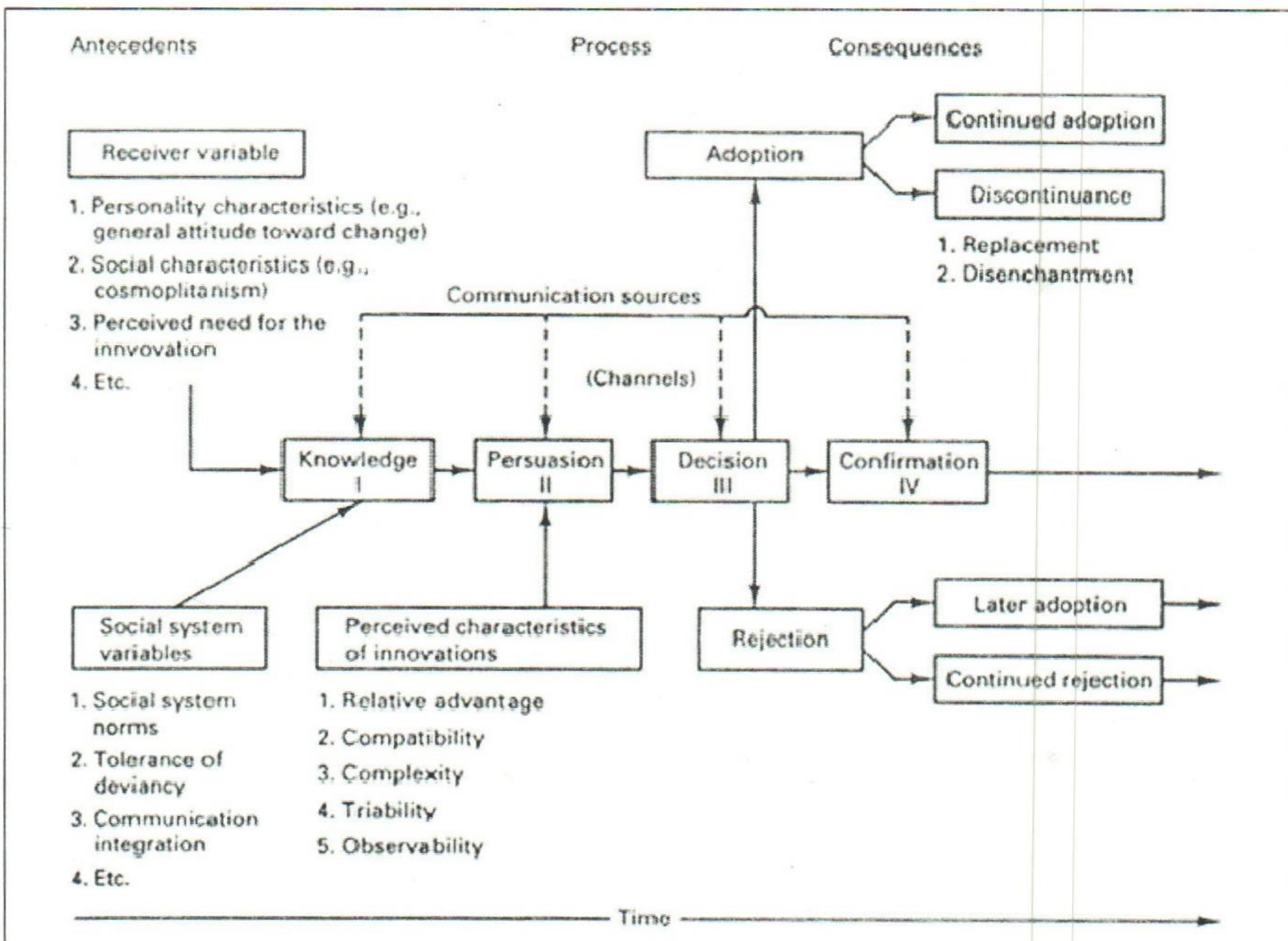

Figure 1: Technology adoption process

these are not popular in the southern Indian states, where chaffing of fodder is not a practice (Rao *et al.*, 2005). The adoption behavior of farmers depends on farmer and household characteristics (Wheeler and Outman 1990), institutions and infrastructure variables (Hayami and Ruttan 1985) and perceptions about agricultural technologies (Feder and Silverman *et al.*, 1985). Also, adoption behavior can be explained by perception about information needs, information input and information output patterns (Mudukuti and Miller, 2002; Randhir-Singh *et al.*, 1996), inter-system and intra-system communication pattern (Konju., 1992) and knowledge level about farm technologies (Vasanta and Somasundaram, 1988). Information input, information output, farmers' intra-system communication, Farmer-researcher communication, farmer-extensionist communication, availability of input facilities and overall knowledge about dairy farming technologies has been found to be having positive and highly significant relationship with overall adoption level of farmers with respect to dairy farming technologies in East Azerbaijan of Iran (Rezvanfar, 1997). Ensuring active partnership between livestock farmers, researchers and communication agents and availability of required inputs among livestock owners helps diffuse technologies towards speedier adoption of livestock innovations. Francis and Sibanda (2001) concluded that farmer participation should be an integral component of agricultural Research and Development programmes. The Diffusion of Innovation framework can be a useful tool to study livestock technology adoption behaviour by the poor from a number of perspectives as depicted in Fig. 1.

Illustration

Using one case of animal nutrition technology, i.e. urea treatment of straw as an illustration, the required work is explained in this paper. Throughout the world including India, a large number of trials involving farmers have been

Table1: Adoption of an Animal Nutrition Technology: Urea Treatment of straw

Livestock Region	Introduced In the year /Timeline	Urea Treatment of straw				
		Extent of adoption	Constraints	Suggestions	Alternatives	Conclusion
Western Himalaya						
North-West Plain						
Eastern Plain						
Central Highlands						
Eastern Plateau and Highlands						
Deccan Plateau & Hills						
Rajasthan-Gujarat Plains						
Eastern Ghat						
Western Ghats						
Assam-Bengal Plain						
North Eastern Highlands						
All regions						

conducted on straw treatment with urea, but very few farmers have adopted the technology on a continuous basis (Dolberg, 1992; O'Donovan *et al.,* 1997; Birthal and Rao, 2002; Rabbani *et al.*,2004; Nguyen, 2004). Urea treatment is not used on a wide scale by the farmers because of inadequate extension efforts to popularize the technology, non-availability of sufficient straw and the limited availability of liquid cash with farmers for purchase of urea (Walli *et al.*,1995., Badve, 1991., Nguyen, 2004). Despite efforts by various research and development agencies over the last 20-25 years with significant financial implications, urea treatment technology is largely considered a failure in India as far as its application in the field is concerned. Yet, its effective adoption by the smallholder dairy farmers has been reported in some pockets e.g. Mithila milkshed in the state of Bihar, where a sizeable number of farmers were found satisfied, thus, using it on a continuous basis (Roy and Rangnekar, 2006). No technology is worthwhile if it is not adopted by intended users. Urea treatment of straw is believed to be a proven technology but largely not used by the farmers. The limiting factors for poor adoption of this technology need to be explored through empirical research in different livestock zones in the country so as to analyze the field application status of this technology. Similarly, the other recommended technologies like deworming, A.I., vaccinations, fodder chaffing, feed supplementations etc can be mapped at field level for their adoption status across the country. It will help in, i. finding out the constraints faced by farmers with respect to adoption of selected technologies, ii. documenting farmers' feedback on recommended technologies and enlist their suggestions, iii. Determining extension gaps, extension needs of livestock farmers in different livestock zones in the country, iv. analyzing potential of different extension strategies including ICT application in narrowing the extension gaps with respect to identified technologies.

The National Bureau of Soil Survey and Land Use Planning (NBSS & LUP has mapped India's territorial space into 20 agro-ecological zones with their further classification into 60 sub-zones. However, taking into consideration topography, climatic conditions and cropping pattern of 60 sub-zones, country could be re-organized into 11 broad regions- 'livestock regions'. The status of application of technologies in these livestock regions may be analyzed against the predetermined indicators (Table1). Species and technologies prioritized for different livestock regions can be evaluated and the status of identified technologies can be determined by analyzing primary and secondary data. This exercise would result in a comprehensive document indicating the success, failures, shortcomings, need for refinement, future and possible remedies or alternatives with respect to various animal health and production technologies. This analysis will be useful in further refinement of technologies developed as also indicating the need for alternatives to the existing technologies.

Conclusion

This paper is motivated by the fact that in context of diffusion of livestock innovations, little research efforts are visible inspite of the economic, social and environmental implications of livestock technologies. Most of the literature that is available in the area of diffusion adoption research is focused on the diffusion of agricultural innovations at local scales (Black, 2000). If we look at the students' thesis done in Agricultural Extension subject in India, these are largely on crop varieties, fertilizers, pesticides and other innovations concerning crops. Livestock research leading to innovations and development of technologies suitable to local conditions is an area of growing interest, so is the increasing scope for diffusion and adoption research in livestock sector. The contribution of livestock within agricultural sector's contribution to the national economy is very high in any developed country as also it is progressively increasing in developing countries like India. It can be assumed that if a country is having a vibrant livestock economy, it stands better chance to be a developed one or vice versa.

Technology is the key to the growth in any sector including livestock. Over the years, many livestock technologies in the field of animal health and production have been developed by various institutions for different livestock/animal species, resulting in lots of promising technologies available at the level of research stations. The Planning Commission, Government of India (GOI) too, in its document, "Agriculture Strategy for Eleventh Plan: Some critical issues" has stated, 'Unfortunately, extension advice is almost totally absent in animal husbandry, special efforts need to be made in this area". A dedicated livestock extension service could boost diffusion and adoption of livestock technologies, but livestock extension activities are not very well organized into a well defined system in India (Chander *et al.*,2010).

The technologies offered by the livestock sector have yet to gain wider acceptance. Moreover, these technologies alone are not enough to bring about widespread change in livestock systems. For instance, crossbreeding technology in India despite better performance in select pockets, its widespread adoption is constrained for various reasons. In order to make the difference in production and productivity in livestock systems through these technologies, the diffusion and adoption theories need to be put into practice in right perspectives. These technologies are at various stages of diffusion- adoption process in different agro-ecological zones of the country. There is need to assess the technological gaps, actual adoption of these technologies, constraints faced by farmers in adoption of these technologies and way forward for these selected technologies. For instance, urea treatment of straw is considered one high potential technology by animal nutritionists, but it is rarely used by farmers in many parts of country. Yet there could be areas where it has shown good acceptance with reasons for this high acceptance. If we map the field spread of this technology, we would have a holistic picture on a national level-where does urea treatment of straw stand and what is its future? There is need to document the field experiences with respect to many such technologies, so as to have a comprehensive picture based on empirical evidences collected through systematic efforts. It is needed that the technologies are assessed by mapping them through diffusion-adoption stage and appropriate strategies are developed for needed interventions so as to have better impact of these technologies.

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Agriculture, manufactures, commerce and navigation, the four pillar of our prosperity, are the most thriving when left most free to individual enterprise. Protection from casual embarrassments however, may sometimes be seasonably interposed.

—Thomas Jefferson

Feature

Competitiveness of Indian States—2013

K.P. SUNNY AND DEEPAK GUPTA

During the last two decades some states have emerged as the most happening places in India. Competition can increase or decrease the inequalities in economic growth. Not all poor states are necessarily non-performers and competition allows the laggards the chance to catch up with the rich and thus bridge the inequality gap. Present study on Competitiveness of Indian states 2013 examines the dynamics of state level competitiveness and ranks the states in two groups such as bigger states and smaller states in terms of 52 data variables. Even though the states are quite diverse in terms of either area, population or resources they are operating under more or less the same policy environment and hence were endowed with almost equal opportunity to grow and prosper. The study uses the well-established methodology developed by International Institute for Management Development (IMD) (Switzerland) for the World Competitiveness Yearbook (WCY). There were wide variations among the bigger states in terms of the computed Standard Values of 'Overall Competitiveness'. Maharashtra came on the top of the list with a Standard Value of 0.221. Gujarat with a Standard Value 0.207 achieved second position followed by Punjab (0.151). The Standard Values of Rajasthan (-0.364) and Assam (-0.388) recorded at the bottom of the list. As in the case of the major states significant inter-state variations were observed among the smaller state with regard to 'Overall Competitiveness'. Delhi recorded the top ranking with a Standard Value of 0.923, followed by Goa (0.659) and Sikkim (0.559). Tripura (-0.314) and Nagaland (-0.361) were found at the bottom of the list.

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Section-I

The Rationale

India's development story is being scripted in the 29 states (including Delhi) and 7 Union Territories (UTs) across the country. The failure of one state will undermine the success of the others by pulling down the country's average. While there will always be high and low performing states, the country cannot progress unless the growing gap between the lives of people in different parts are bridged. Hence, it becomes pertinent to study the performance of the states in terms of recorded data variables so that the states can be ranked in terms of their relative position within the country's competitiveness landscape. More so because the edge of economic reform has increasingly being felt at the states since all factor markets are either in the state list or in the concurrent list of the Constitution and different states have reacted differently to economic reforms.

Competition gives participants a chance to perform to their potential, even as it allows non-performers to drift. Private investment has shied away from the poorly governed states and has flowed almost entirely to better-managed richer states. Not all mechanisms of transferring funds from the rich (often also better performing) to the poor (often also non-performing) have been given up. The Planning Commission and the Finance Commission still redistribute resources from the rich states to the poor states even now. Such redistribution has, however, shrunk a bit and private investment is free to go where it wants to.

There is increased realization among the states that they can make their own destiny. This prompted the Governments at the state level to initiate measures to attract more financial resources into the state including Foreign Direct Investments (FDIs). During the last two decades some of the states emerged as the most happening places in India. Thus competition is a double-edged weapon. It can increase or decrease the inequalities in economic growth. Not all poor states are necessarily non-performers and competition allows the laggards the chance to catch up with the rich and thus bridge the inequality gap. A significant part of the competitive advantage of states is believed to arise from far reaching incentive polices which are designed to attract both domestic and foreign investments.

The ability of a state to develop an excellent education system and to improve the knowledge of the labour force through training is vital to competitiveness. In addition to being competitive (temporarily) because of cheap labour, they aim to develop their competitiveness level so that it is based (permanently) on an educated workforce. Knowledge is perhaps the most crucial of the competitiveness criteria. As states move up the economic scale, the more they thrive on knowledge of the workforce higher will be their ability to compete in the fiercely competed world markets. How that knowledge is acquired and managed is almost entirely the state's responsibility.

Present study on Competitiveness of Indian states examines the dynamics of state level competitiveness and ranks Indian states in two groups such as 17 bigger states and 12 smaller states based on 52 identified hard data variables. Even though the states are quite diverse in terms of either area, population or resources they are operating under more or less the same policy environment and hence were endowed with almost equal opportunity to grow and prosper. In this study the ranking of the states has been made using a well-established methodology developed by International Institute for Management Development (IMD) (Switzerland) for the World Competitiveness Yearbook (WCY).[1]

Competitiveness: The Concept

Competitiveness is one of the most powerful concepts in modern economic thinking. Competitiveness encompasses the economic consequences of non-economic aspects, such as education, science, political stability or even culture and value systems. The present study looks at the relationship between the macro environment and wealth creation process by enterprises and individuals. In a market economy, individual firms and industries play a critical role in building and sustaining national competitiveness. A nation's competitiveness depends on the capacity of its organizations to innovate and upgrade. At micro levels, competitiveness is defined as the capacity to grow through market success and improved profits based on its perceived superiority over the competitors, which depends on the macroeconomic environment in which firms operate and compete with one another.

World Economic Forum (WEF), which has been ranking the leading nations of the world on a number of competitiveness criteria, defines national competitiveness as "the ability of a country to achieve sustained high rates of growth in GDP per capita."[2]

International Institute for Management Development (IMD), on the other hand, defines competitiveness as "the ability of a nation to create and maintain an environment that sustains more value creation for its enterprises and more prosperity for its people" *(Ref: World Competitiveness Yearbook 2013)*.

According to **Institute for Competitiveness**, India, Competitiveness is the productivity (value per unit of input) with which a nation, region, or cluster utilizes its human, capital, and natural resources. Productivity sets a nation's or region's standard of living (wages, returns on capital, returns on natural resources).[3]

While competitiveness of the nations is well understood, the same is still fuzzy at the sub-national state level. This is because competition among the states, which are part of the same nation, is limited in nature and magnitude, as compared to competition across the countries. States have to work under the socio-economic policies framed at the national level. This leaves a relatively smaller area of maneuverability on the part of individual states. This does not undermine the importance of competitiveness at the sub-national level.

State-level competitiveness ought to be understood within the context of National Competitiveness, because a state is a miniature version of the country. Therefore, definitions applied for measuring the country's competitiveness can be adopted for the states as well. Among the available definitions of national competitiveness, the one used by the IMD in its World Competitiveness Yearbook (WCY) appears to be broader in terms of application. The definition brings forth the role of the state in enhancing (or maintaining) competitiveness of the region. The state should provide the enabling environment to organizations and at the same time ensure prosperity to the people. This definition (of competitiveness) fits well within the functional autonomy enjoyed by the states in the federal framework of the country.

IMD's methodology is known for its simplicity and the direct approach while dealing with a large number of diverse indicators (333 in WCY 2013). The fundamental principle, which underlies the distinction between notions of National Competitiveness and Enterprise Competitiveness, focuses on where the creation of economic value takes place. A Nation's environment hinders or supports the wealth creation process through its policies. The State Competitiveness extends this principle within the states. State Competitiveness measures and compares how states are doing in providing an environment that sustains the Domestic and Global Competitiveness of the firms operating within their borders.

It is widely accepted in economic literature that state competitiveness cannot be reduced merely to its gross value of production or its productivity measured per person or per unit of capital. This is because firms must cope with the political, cultural, and educational dimensions of the geo-political entity. Therefore, the states provide firms with an environment, institutions and policies to make them competitive in the global place.

Section-II

Review of Competitiveness Studies in India

Experimental studies on competitiveness of Indian states have been pioneered by National Productivity Council (NPC) in 1992 when fifteen major Indian states were ranked based on their performance for Human Development Index (HDI). The four variables considered while ranking the states were life expectancy, literacy rate, per capita state domestic product (SDP) and population below poverty line. The study ranked Punjab at the top in terms of HDI followed by Kerala and Haryana.[4]

NPC followed this study with another study on the competitiveness of Indian States based on Infrastructure Development Index (IDI). In this study NPC the same fifteen major states were ranked. Six variables related to infrastructure were analyzed viz. road length, navigable waterways, railway route length, tele-density, electricity consumption and number of commercial bank branches. Based IDI Punjab was ranked at number one followed by Gujarat and Haryana. Bihar ranked last in both the studies.[5]

Further, in its third study a State Level Competitiveness Index was developed by NPC in the year 1994, covering a total of eleven variables including all those already considered in the HDI and IDI studies. The additional factors covered by the Competitiveness Index were the man days lost, political stability and state government taxes. Here the UNDP's methodology was followed in order to construct the Competitiveness Index for ranking the states. Punjab emerged as the most competitive Indian state followed by Kerala and Haryana. As in the case of earlier studies Bihar emerged as the lowest in terms of competitiveness.[6]

In 1995, Business Today (BT) carried out a survey on competitive advantage of Indian states. The main objective of the BT survey was three-fold viz. (i) identify, in order of importance, the parameters used by the corporate locating their projects (ii) rate the states on each of these parameters and (iii) combine the ratings into a composite rank for each state.[7]

In 1997, the BT conducted a second survey on best states to invest in. Besides relying purely on perception, an objective index was constructed, which ranked 26 Indian states. The objective index was arrived at based on 28 parameters belonging to four broad categories viz. physical infrastructure (18 parameters), government (3 parameters), labour (4 parameters) and social infrastructure (3 parameters). A state was thus evaluated on two dimensions viz. objective score, which comprised 28 parameters and a survey or perception score consisting of 19 parameters. To obtain a summary statistic for the state these two scores were averaged.[8]

BT's third study in the series published in 1999 introduced a marketing index besides the objective and the perception (survey) indices. The weights assigned to various factors while computing the objective rank of the states are as follows: physical infrastructure – 40%, quality of governance – 30%, financial infrastructure, labour and social infrastructure 10% each. The overall rank of a state was arrived at by averaging the scores in three different factors (objective, perception and marketing) with the objective score receiving 40% weight. The subjective score also received 40% weight while the marketing score was given a 20% weight. Maharashtra topped the list followed by Gujarat, Delhi, Tamil Nadu etc.[9]

National Council of Applied Economic Research (NCAER) undertook a study in year 2000 to find out the policy competitiveness of Indian states in attracting direct investment and the effects of this competition on economic development. The study found infrastructure as the most critical variable influencing the investors' decisions as compared to incentives offered by the state governments.[10]

In 2000 Confederation of Indian Industries (CII) commissioned the Rajiv Gandhi Institute for Contemporary

Studies (RGICS) to carry out a detailed study on the performance of the Indian states. The study was based on a detailed analysis of the Physical, Legal, Capital Market Infrastructure, Economic & Financial Performance, investment climate, labor force, law & order, level of human resource development and consumer demographics in each state. Based on the state's performance in terms of these criteria, an overall ranking was worked out using Principal Components Analysis. The study covered 18 states of India. Delhi was rated the best performing state, followed by Goa (2nd rank), Kerala (3rd rank), Punjab (4th rank) and Maharashtra (5th rank). Bihar was once again at the bottom of the list.[11]

India Today carried out a study to rank 19 Indian states according to what it called 'to live and work in'. The study noted that small states enjoyed inherent advantages over their big counterparts. Goa was found as the number one Indian state with Delhi and Punjab in second and third positions respectively. Bigger states like Madhya Pradesh and UP received lower ranks of 17 and 15 respectively.[12]

In the study on the State Competitiveness by the India Today 2004 (August 16), 35 Indian States were considered in three different categories such as Big States (20), Small States (10) and Union Territories (5). The bigger states were identified as the ones having more than 35000 sq.kms and with a population of over five million. Among the bigger states Punjab was ranked first, while Kerala got second rank and Himachal Pradesh got third rank while Bihar was ranked the last. Among the smaller states category Pondicherry was ranked first followed by Delhi while Meghalaya got the last rank. Among the Union Territories, Chandigarh was ranked first and Dadar & Nagar Haveli got the last rank. One major finding of the study was that the smaller states are relatively more competitive as compared to their bigger counter parts. This study considered 49 measures across eight broad macro economic performance parameters. Principal Components Analysis was used to generate weights for each of the measure.[13]

According to the State Competitiveness Report 2005 by National Productivity Council (NPC), Maharashtra was ranked the most competitive state among 15 major states in the country, followed by Punjab, Gujarat, Karnataka and Kerala, Among the larger states, Uttar Pradesh and Assam were found to be the least competitive. As far as smaller states are concerned, Goa was on top among 14 smaller states followed closely by Delhi. Meghalaya and Nagaland were at the bottom of this list.[14]

Recently Institute for Competitiveness has brought out India State Competitiveness Report 2013. The Report reflects the ability of states to utilize their factors of production (land, labour, capital) to gain optimal output. Delhi secured the overall top spot in the India State Competitiveness Report 2013. Maharashtra secured first rank in innovation driven economy category followed by Gujarat and Kerala. Tamilnadu stood first in transition economy category followed by Punjab and Himachal Pradesh. Andhra Pradesh came at first position in investment driven economy category followed by Karnataka and Uttarakhand.[15]

Section-III

Methodology of Estimation

Present study analyzes the micro and macro level aspects that govern the competitiveness dynamics of the states. The Report analyzes the competitiveness of 29 States with respect to 52 identified criteria grouped into Five factors or Pillars of Competitiveness such as:

- Economic Strength
- Governance Quality
- Business Efficiency
- Human Resources
- Infrastructure

The study assumes that healthy performance in these dimensions creates the environment that sustains the state's competitiveness. The list of 52 criteria used for competitiveness estimation is given in Appendix 1.

The study provides overall ranking and factor-wise ranking for both bigger states and smaller states.

Competitiveness Measurement

The quantitative data for all 52 identified criteria was collected from various published sources at national and state levels. All 52 criteria were grouped into five factors and each factor group given equal weightage in the estimation of overall rankings.

In the case of data that is volatile due to seasonal and cyclical factors (e.g. SDP, Per capita Income, Employment etc.) the averages values of the last five consecutive years based on its availability have been used. In most of the cases, a higher value is found better. For example, for State Domestic Product (SDP) the state with the highest standardized value is ranked first while the one with the lowest the last. However, in some cases, the lowest value is the most competitive, e.g. Number of Cognizable crimes per 1000 population. In such cases a reverse ranking is used, the economy with the highest standardized value receiving the last rank and the one with the lowest receiving the first.

Standard Deviation Method

As the criteria are scaled differently, a comparable standard scale is used to compute the overall factor results. The relative performance of each state in the final rankings is measured through the Standard Deviation Method (SDM). First, for each criterion, we compute the average value for all the states. Then the standard deviation is calculated using the following formula:

$$S = \sqrt{\frac{\Sigma(x-x)^2}{N}}$$

Finally, we compute each of the 29 states standardized values (STD) for the 52 ranked criteria by subtracting the average value of each criterion from the state's original value and then dividing the result by the standard deviation.

STD value = $x - \bar{x}$ S

Where:

x = original value

x= average value of for all the states

N = number of states

S = Standard Deviation

State Rankings

Using the above methodology, STD values are estimated for each of the criteria. Based on the results, the states are given ranking for each of the 52 criteria.

Factor-wise rankings are then determined by calculating the average of the STD values of all the ranked criteria which constitute the factor.

For arriving at the Overall Competitiveness rankings, the STD values of the Competitiveness Factors are then aggregated to determine the Overall Rankings.

For presentation of the ranks, the states are grouped into two broad categories based on the size of population: bigger states and smaller states i.e., bigger states (above 2.5 crores population) and the smaller states (less than 2.5 crores population).

Section-IV

Overall Ranking of Bigger States

There were wide variations among the bigger Indian states in terms of the computed Standard (STD) Values of 'Overall Competitiveness'. Maharashtra came on the top of the list with a STD Value of 0.221. Gujarat with a STD Value of 0.207 came at the second position followed by Punjab (0.151). The Standard Values of Rajasthan (-0.364) and Assam (-0.388) were reported at the bottom of the table (Table 1).

Table 1: Overall Ranking of Bigger States

State	STD value	Rank
Maharashtra	0.221	1
Gujarat	0.207	2
Punjab	0.151	3
Haryana	0.140	4
Kerala	0.117	5
Orissa	-0.027	6
Tamilnadu	-0.031	7
Karnataka	-0.058	8
Andhra Pradesh	-0.110	9
Jharkhand	-0.121	10
Chattisgarh	-0.163	11
West Bengal	-0.254	12
Madhya Pradesh	-0.266	13
Bihar	-0.283	14
Uttar Pradesh	-0.326	15
Rajasthan	-0.364	16
Assam	-0.388	17

Factor wise Ranking of Bigger States

Wide variations were noted among the bigger Indian states in the case of factorwise competitiveness ranking. Competitiveness factor 'Economic Strength', Gujarat reported on the top of the list with Standard Value as high as 0.679. The next in the list, Maharashtra, has a Standard Value of 0.445, followed by Kerala (0.239). Assam (-0.641) and Uttar Pradesh (-0.695) were at the bottom of the list. (Table 2)

Wide variations were found among the bigger states in the case of competitiveness factor 'Business Efficiency' too. Orissa on the top of the list recorded a Standard Value as high as 0.804. The next best state, Jharkhand has a Standard value, 0.799. Kerala (-0.527) and Assam (-0.675) were ranked at the bottom. (Table 2)

Table 2: Factor wise Ranking of Bigger States

S.No	State	Economic Strength		Business Efficiency		Governance Quality		Human Resource Development		Infrastructure	
		STD Value	Rank	STD Value	Rank	STD Value	Rank	STD Value	Rank	STD Value	Rank
1	Maharashtra	0.445	**2**	0.347	**4**	-0.122	**8**	0.498	**2**	-0.062	**9**
2	Gujarat	0.679	**1**	0.474	**3**	-0.170	**10**	-0.076	**8**	0.126	**8**
3	Punjab	-0.117	**8**	0.092	**7**	0.056	**4**	0.409	**3**	0.314	**4**
4	Haryana	0.171	**4**	-0.284	**12**	0.218	**2**	0.287	**4**	0.308	**5**
5	Kerala	0.239	**3**	-0.527	**16**	-0.256	**12**	0.812	**1**	0.316	**3**
6	Orissa	-0.581	**14**	0.804	**1**	0.228	**1**	-0.314	**12**	-0.275	**14**
7	Tamilnadu	-0.025	**5**	0.169	**5**	-0.873	**17**	0.257	**5**	0.318	**2**
8	Karnataka	-0.296	**10**	-0.102	**9**	-0.041	**6**	-0.005	**6**	0.156	**6**
9	Andhra Pradesh	-0.069	**6**	-0.057	**8**	-0.340	**14**	-0.242	**11**	0.156	**7**
10	Jharkhand	-0.626	**15**	0.799	**2**	-0.060	**7**	-0.168	**10**	-0.549	**17**
11	Chattisgarh	-0.435	**12**	0.102	**6**	0.070	**3**	-0.367	**14**	-0.183	**12**
12	West Bengal	-0.427	**11**	-0.255	**11**	-0.410	**15**	-0.111	**9**	-0.067	**10**
13	Madhya Pradesh	-0.115	**7**	-0.141	**10**	-0.145	**9**	-0.568	**15**	-0.360	**16**
14	Bihar	-0.239	**9**	-0.352	**13**	-0.026	**5**	-0.607	**16**	-0.193	**13**
15	Uttar Pradesh	-0.695	**17**	-0.400	**14**	-0.307	**13**	-0.647	**17**	0.420	**1**
16	Rajasthan	-0.516	**13**	-0.428	**15**	-0.551	**16**	-0.009	**7**	-0.315	**15**
17	Assam	-0.641	**16**	-0.675	**17**	-0.190	**11**	-0.323	**13**	-0.112	**11**

Significantly wide variations were observed among the bigger states with respect to 'Governance Quality'. On the top of the list was Orissa with Standard Value of 0.228, followed by Haryana with a standard value of 0.218 and Chattisgarh (0.070). Lowest Standard Values were achieved by Rajasthan (-0.551) and Tamilnadu (-0.873). (Table 2)

Significantly wide variations were observed among the bigger states in regard to competitiveness factor 'Human Resource Development'. The list was headed by Kerala with a Standard Value of 0.812 followed by Maharashtra (0.498) and Punjab (0.409). At the bottom of the list were Bihar (-0.607) and Uttar Pradesh (-0.647). (Table 2)

With regards to competitiveness factor "Infrastructure", Uttar Pradesh (0.420) headed the list followed by Tamilnadu (0.318), Kerala (0.316), Punjab (0.314) and Haryana (0.308). Madhya Pradesh (-0.354) and Jharkhand (-0.619) were at the bottom of the list. (Table 2)

Overall Ranking - Smaller States

As in the case of the major states, significant inter-state variations were reported for the smaller state as well in terms of 'Overall Competitiveness'. Delhi ranked at the top with a Standard Value of 0.923, followed by Goa (0.659) and Sikkim (0.559). Tripura (-0.314) and Nagaland (-0.361) were at the bottom of the list (Table 3).

Table 3: Overall Ranking of Smaller States

State	STD value	Rank
Delhi	0.923	1
Goa	0.659	2
Sikkim	0.559	3
Uttarakhand	0.414	4
Himachal Pradesh	0.235	5
Arunachal Pradesh	0.100	6
Mizoram	-0.045	7
Meghalaya	-0.066	8
Manipur	-0.181	9
Jammu& Kashmir	-0.203	10
Tripura	-0.314	11
Nagaland	-0.361	12

Factor wise Ranking of Smaller States

Vast variations were seen among the smaller states with regard to the competitiveness factor 'Economic Strength'. First in the list, Delhi with a Standard Value of 2.488, was far ahead of Goa (0.810) at the second and Uttarakhand (0.794) at the third position. Nagaland at the bottom of the list had a Standard Value of –0.521 followed by Manipur (-0.714) (Table 4).

Vast variations were observed among the smaller states in regard to 'Business Efficiency' too. Sikkim with a Standard Value of 0.980 came at the top of the list followed by Goa (0.628) and Himachal Pradesh (0.554) (Table 4).

With regards to 'Governance Quality', among the smaller states, Arunachal Pradesh topped with a Standard Value of 1.032 followed by Delhi (0.893) and Goa (0.867). At the bottom of the list came Jammu & Kashmir (-0.283) and Tripura (-0.853) (Table 4).

Smaller states showed significant variations among themselves with regard to the competitiveness factor 'Human Resources Development'. Uttarakhand reported at the top of the list with a Standard Value of 0.661 followed farther down by Goa (0.399) and Tripura (0.395). At the bottom of the list came Jammu & Kashmir (-0.019) and Meghalaya (-0.153) (Table 4).

Smaller states showed significant variations within themselves with regard to 'Infrastructure' too. Delhi with a Standard Value of 1.669 ranked at the top of the list followed by Goa (0.593) and Himachal Pradesh (0.515). Jammu & Kashmir (-0.457) and Nagaland (-0.477) were reported at the bottom (Table 4).

Table 4: Factor wise Ranking of Smaller States

S.No	State	Economic Strength		Business Efficiency		Governance Quality		Human Resource Development		Infrastructure	
		STD Value	Rank	STD Value	Rank	STD Value	Rank	STD Value	Rank	STD Value	Rank
1	Delhi	2.488	1	-0.491	8	0.893	2	0.054	9	1.669	1
2	Goa	0.810	2	0.628	2	0.867	3	0.399	2	0.593	2
3	Sikkim	0.455	4	0.980	1	0.835	4	0.325	4	0.199	4
4	Uttarakhand	0.794	3	0.391	4	0.110	8	0.661	1	0.115	5
5	Himachal Pradesh	-0.132	6	0.554	3	-0.071	10	0.310	5	0.515	3
6	Arunachal Pradesh	-0.173	7			1.032	1	-0.007	10	-0.354	9
7	Mizoram	-0.098	5			-0.059	9	0.156	8	-0.222	7
8	Meghalaya	-0.252	8	0.329	5	0.148	6	-0.153	12	-0.401	10
9	Manipur	-0.714	12	-0.298	7	0.129	7	0.288	6	-0.310	8
10	Jammu& Kashmir	-0.401	10	0.147	6	-0.283	11	-0.019	11	-0.457	11
11	Tripura	-0.302	9	-0.617	9	-0.853	12	0.395	3	-0.194	6
12	Nagaland	-0.521	11	-1.193	10	0.172	5	0.212	7	-0.477	12

Appendix 1: Factors & Criteria

S.No	Factor and Criteria	Units	Sources of data
1	**Economic strength**		
1.1	Per Capita Income (Constant prices 2004-05)	Rs	Economic Survey, Ministry of Finance
1.2	Growth of GSDP (Constant prices 2004-05)	%	Economic Survey, Ministry of Finance
1.3	Growth in per capita income	%	Economic Survey, Ministry of Finance
1.4	Per capita monthly consumption expenditure	Rs	Ministry of Statistics & Programme Implementation
1.5	Investment as per IEMs implemented per 1000 population	Rs Lakhs	Department of Industrial Policy & Promotion
1.6	Deposits in scheduled commercial banks per 1000 population	Rs crore	Reserve Bank of India
1.7	Credit disbursement of commercial banks per 1000 population	Rs crore	Reserve Bank of India
1.8	Number of commercial bank offices per 1000sq.kms	No.	Reserve Bank of India
2	**Business efficiency**		
2.1	Registered factories per'000 population	nos	Annual Survey of Industries
2.2	capital intensity(Mfg.) (Fixed capital per worker)	Rs Lakhs	Annual Survey of Industries
2.3	Labour wages per annum per person	Rs	Annual Survey of Industries
2.4	Growth in employment(Mfg.)	%	Annual Survey of Industries
2.5	Profit per Factory	Rs Lakhs	Annual Survey of Industries
3	**Governance Quality**		
3.1	Cognizable Crimes Per'000 Population	nos	National Crime Record Bureau
3.2	Minimum wages (unskilled workers) per worker	Rs	Ministry of Labour & Employment
3.3	Fiscal Deficit as % of GSDP	%	Planning Commission
3.4	Revenue Receipts Per Capita	Rs lakhs	Reserve Bank of India & Economic Survey of Delhi
3.5	State Annual Plan Expenditure Per Capita	Rs lakhs	Planning commission
4	**Human Resource**		
4.1	Birth Rate per 1000 Population (-)	Nos	Ministry of Health and Family Welfare
4.2	Death Rate per 1000 population (-)	Nos	Ministry of Health and Family Welfare
4.3	Number of Industrial workers per '1000 population	Nos	Annual Survey of Industries
4.4	Female Labour Force Participation Rates	%	Ministry of Labour & Employment
4.5	Life Expectancy at Birth-Male	years	Office of the Registrar General, Ministry of Home Affairs
4.6	Life Expectancy at Birth-Female	years	Office of the Registrar General, Ministry of Home Affairs
4.7	Child Mortality (under 5 years) per '000 births(-)	%	data.gov.in (Data Portal NIC)
4.8	Average population served per Govt. hospital Bed	Nos	Ministry of Health and Family Welfare
4.9	State Expenditure on Health services Per capita	Rs	Ministry of Health and Family Welfare
4.10	Households with access to toilet facilities	%	data.gov.in (Data Portal NIC)
4.11	Literacy Rate (Total)	%	Census 2011, Registrar General of India

S.No	Factor and Criteria	Units	Sources of data
4.12	Enrolment Ratio, Primary Schools	%	Ministry of Human Resource Development
4.13	Pupil Teacher Ratio (Primary Schools)(-)	nos	Ministry of Human Resource Development
4.14	Public Expenditure on Education as % of Budget Expenditure	%	Ministry of Human Resource Development
4.15	Mandays Lost in Industrial disputes per '000 Population (-)	Nos	Labour Bureau, Ministry of Labour & Employment
4.16	Population Below Poverty Line (Tendulkar methodology)	%(URP)	Planning Commission
4.17	Average Calorie Intake Per Capita	Kcal	National sample Survey Organisation, Ministry of Statistics & Programme Implementation
4.18	Average Protein Intake Per Capita	gm	National sample Survey Organisation, Ministry of Statistics & Programme Implementation
5	**Infrastructure**		
5.1	Rail Route Kms (per 1000 Sq. Kms area)	Kms	Ministry of Railways
5.2	Road Kms (per 1000 Sdq. Kms area)	Kms	Ministry of Road Transport and Highways
5.3	Length of National highways (per 1000 sq. Kms area)	Kms	data.gov.in (Data Portal NIC)
5.4	Telephone Lines per household	Nos	Census 2011, Registrar General of India
5.5	Cellular Subscribers (% of population)	Nos	Census 2011, Registrar General of India
5.6	Electricity Generation per capita per month	Kwh	Central Electricity Authority
5.7	Average Tariff on Electricity (industry)(-)	Rs/KWh	Central Electricity Authority
5.8	Electricity Connected Villages as % of Total no. of villages	%	data.gov.in (Data Portal NIC)
5.9	T&D Losses of Electricity (-)	%	Planning Commission
5.10	Availability of Electricity per capita per month	Kwh	Central Electricity Authority
5.11	Degree Colleges per 1000 sq km	Nos	University Grant Commission
5.12	Secondary and senior secondary Schools per 1000 sq km	Nos	Ministry of Human Resource Development
5.13	Primary and upper primary Schools per 1000 sq km	Nos	Ministry of Human Resource Development
5.14	Primary/Village Health Centres per 1000 sq km	Nos	Ministry of Health and Family Welfare
5.15	Households with access to Safe Drinking Water	%	Planning Commission
5.16	Forest Area as % of total area	%	Ministry of Environment and Forests

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Whenever you are asked if you can do a job, tell èm, 'certainly I can!' Then get busy and find out how to do it

—Theodore Roosevelt

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