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A.M. Swaminathan
Mayank Gupta
Abhishek Tiwari
Navagat Prakash

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CONCENTRATION AND EFFICIENCY IN INDIAN MANUFACTURING: A REGIONAL STUDY

A. M. Swaminathan[1]
Mayank Gupta[2]
Abhishek Tiwari[3]
Navagat Prakash[4]

Abstract

Regional concentration of firms has several effects on the development of firms. While theories indicate different relations between firm's efficiency and regional concentration, this study employs data envelopment analysis and a Tobit model to analyse such relationships for 9 Indian manufacturing industries located in 17 Indian states. Results on efficiency reveal that technical efficiency is better than allocative efficiency, indicating betterment of technology along with excess use of resources in Indian industries. Besides, a negative relationship exists between regional concentration of industries and efficiency, which supports 'Quiet Life Hypothesis' of Hicks. Tobit analysis also indicates prevalence of negative relations between efficiency and concentration in Indian industries. Just-in-time management of inventories could be encouraged, and reforms should ensure measures such that this is successfully implemented in industries.

Key words: Data Envelopment Analysis, Tobit, Regional Concentration

JEL Codes: R3, L6.

[1] Associate Professor, Department of Economics, University of Mumbai, Mumbai-400 098.
E-mail id: swaminathanuma25@gmail.com

[2] Ph. D. Student, Department of Economics, University of Mumbai, Mumbai-400 098.
E-mail id: mayank_g24@yahoo.co.in

[3] Ex-student, Department of Economics, University of Mumbai, Mumbai-400 098.
E-mail id: abhishektiwari005@gmail.com

[4] Ex-student, Department of Economics, University of Mumbai, Mumbai-400 098.
E-mail id: navagatprakash@gmail.com

1. INTRODUCTION:

New trade theory approach explains that regional growth should be based on the proposition such that a firm's location is influenced by the existence of economies of scale, barriers to trade and agglomeration economies. The interaction of these three factors is considered to determine the geographical distribution of the industry. Besides, these industries located in different regions are considered to play a major role in the development of the region. Clearly, the words of Kaldor (1967) indicate that industry is considered to be the main 'engine of growth'. However, with studies indicating a positive relation between the size of firms, profits and their efficiency (Demsetz[1], 1973) and a negative relation between the concentration of firms and their efficiency (Gumbau-Albert and Maudos, 2002), the link between regional productivity of industry, efficiency in production and agglomeration economies is a matter of concern in regional economics. Though numerous studies have explored regional productivity analysis, regional concentration of industry and the influence of local factors, only few studies have linked industrial location, concentration and economic efficiency of regions. Prominent among them is the study by Bannister *et al* (1995), which explores the link between regional concentration, industry location and economic efficiency in the manufacturing industries of Mexico. Besides, while Gumbau-Albert and Maudos (2002) focus on the relation between efficiency of firms and various determinants of efficiency in a study on Spanish industry, Setiwan *et al* (2012) employs firm-level data to investigate the relation between technical efficiency and regional concentration in Indonesian food and beverage sectors. In addition, it is found that while Beeson and Husted (1989) examine the relation between productive efficiency in the US manufacturing sector and the regional differences in labour, urbanisation and industrial structure, Patibandla (1998) examines the link between production efficiency, organizational behaviour and structural conditions of large and small firms in the Indian context. Studies such as those by Driffield and Kambhampati (2003) and Bhaumik and Kumbhakar (2010) focus on an indirect relation between manufacturing efficiency and its determinants. Besides, other studies[2], focus on total factor productivity growth and agglomeration without involving efficiency. All these clearly indicate that no study has used Annual Survey Industries[3] (ASI) data to examine the relation among industrial location, concentration and economic efficiency of industry in regions in the Indian context. Thus, the fact that industry location plays a major role in the development of regions and that simultaneously concentration of these industries affects efficiency of these industries is well known. Therefore, this study employs ASI data for 2008-09 to analyse the link among industry location, concentration and efficiency of nine[4] manufacturing industries across seventeen[5] states in India. Since no such study exists in the Indian context to the best of our knowledge, we presume that this study is new in the Indian context.

Observing the developments in India, we find that the reform process during the last two decades have induced several changes in the field of industry in India, leading to the development of numerous industries both in the private and public sectors. The disinvestment policy has given an added advantage to this development. The central government has been reducing its control in many areas; as such, the states have been getting greater opportunities to take up initiatives to attract both domestic and foreign investments. This has developed several indigenous as well as multinational industries or, in some cases, collaboration between the two in different states of the country. Moreover, several states compete among themselves to give concessions to industries to ensure that their respective states get the benefit of new industry or expansion of the existing industry owing to the benefits of the liberalisation process. In addition, unlike in the past, the infrastructural facilities such as power and highways are also being supplied by the private sector along with the government-owned organizations to these industries. This has further given incentives to industries to locate at places where most of the benefits are available. Linking these developments to theory, the location and relocation of the industries in different states/regions of India should have benefitted from the concentration of industries in specific states/regions. Thus, the impact of policy measures gives additional reason to examine the extent to which the location and concentration of selected industries in different states benefited those industries in the respective states in attaining high efficiencies.

Efficiency results indicate that technical efficiency in industries under study is better than allocative efficiency[6], clearly indicating the betterment of technology and simultaneously the prevalence of over investment in inventories in Indian industries. Furthermore, regional concentration has a negative relation with efficiency for the nine industries under study. This supports the 'Quiet Life Hypothesis' of Hicks, which indicates a negative relation between the two. However, going against the Efficient Structure hypothesis, it is seen that Indian manufacturing neither supports the positive relation between efficiency and profit nor the positive relation between efficiency and size. Besides this, the pre-regression data and tobit analyses also indicated that the 'Quiet Life Hypothesis' could be true to a certain extent. This is because the estimates of concentration - 0.07 (though very small) related to average scale of industry (a concentration index) was inversely related to efficiency.

Thus, while Section 2 presents the literature review, Section 3 focuses on the approach followed in this study. Section 4 describes the methodology followed, the data used and adjustments made to make data workable. While, Section 5 presents empirical results and analysis, Section 6 provides policy implications. Finally, Section 7 concludes the study.

2. REVIEW OF LITERATURE:

Reviewing the literature on studies using efficiency or productivity, it is found that these could be divided into those that link efficiency with its determinants or otherwise. Numerous studies have explored the link between efficiency or productivity and its general and specific factors that determine them. The leading among them are the studies by Beeson and Husted (1989), Bannister and Stolp (1995), Murali Patibandla (1998), Gumbau-Albert and Maudos (2002) and Setiwan *et al* (2012).

Beeson and Husted (1989) examine the relation between productive efficiency in the US manufacturing sector and the regional differences in labour, urbanisation and industrial structure. They used the Annual Survey of Manufacturers for 1959-1973 and stochastic frontier to measure productivity efficiency. These productivity efficiencies were compared with numerous determinants of which labour force, level of urbanization and industrial structure were found to be related to the variations in productive efficiency across states.

Bannister and Stolp (1995) investigate the link between concentration, industrial location and economic efficiency in Mexican manufacturing. The efficiency is examined using a linear programming approach for seven industries in different regions of Mexico for 1985. They find that most industrially concentrated regions consistently play decreasing returns, and this is because the concentration process results in diseconomies of scale. In their econometric analysis, they find that scale, urbanization and agglomeration economies are positively related to overall and technical efficiency at the regional level.

Patibandla (1998) examines the link between production efficiency, organizational behaviour and structural conditions of large and small firms in the Indian context. He uses parametric production function approach to measure efficiency to firm-level survey data on Indian industries to examine technical efficiency, influenced by organizational factors, technology gap between firms, product and factor prices and economies of scale. He uses the Tobit model to analyse the same and finds that lower efficiency in larger firms was due to loss of organizational control.

Gumbau-Albert and Maudos (2002) focuses on the relation between efficiency of firms and various determinants of efficiency in a study on the Spanish industry. They use stochastic frontier analysis to measure efficiency for the data from the Survey of Business Strategies of the Ministry of Industry and Energy for 1991-1994 and analyse whether efficiency can be explained by factors external to the firm. These relate to the degree of competition, size, organization, location *etc*. They use an econometric model and find that technical progress and gains in efficiency influences production, efficiency increases with increase in size and investment, and competition also increases efficiency. Lowest level of efficiency was found among firms in more concentrated areas *i.e.* less competition.

Mamman *et al.* (2012) investigates the relation between technical efficiency and regional concentration in Indonesian food and beverage sectors using firm-level data from the Annual Manufacturing Survey published by the Indonesian Bureau of Central Statistics. The data is for a period of 10 years. Knowing the importance of the said industry, the authors have attempted to find how the industry's efficiency is helping in ensuring competitive prices and product quality for consumers. They have examined the relation between concentration and technical efficiency considering

Quiet Life and Effective Structure hypotheses. The relation between technical efficiency and concentration is examined using the granger causality test. The results were in support of the Quiet life hypothesis in the selected industry.
Others which focus on efficiencies and its specific determinants like infrastructure relate to the study by Mitra *et al*. (2002).

Mitra *et al.* (2002) use the production function approach to focus on the role of core infrastructure like per capita industrial consumption, road density, postal system educational development, *etc.* influencing the total factor productivity of Indian manufacturing for 1976-92. Calculating the technical efficiency of the Indian manufacturing industries, they have used an econometric model to find whether infrastructure influences technical efficiency. They use annual industrial survey data for Indian manufacturing industries and numerous government documents for different infrastructure data and find that some sectors are observed to have large discrepancies in relative total factor productivity along with differences in the level of development. They attribute this to the industrial concentration in those sectors and the benefits these sectors derive from economies of scale and externalities. However, their study does not analyse the role of these economies of scale or externalities but concludes by indicating that differences in industrial performances are significantly explained by differences in infrastructure endowments across Indian states. Furthermore, it suggests enhancement of equipment infrastructures which would constitute a powerful engine for industrial progress.

Mitra *et al.* (2012) focus on the estimation of impact of infrastructure on productivity and efficiency of Indian manufacturing. Working along the same lines as the above study, the authors use Prowess database created by the Centre for Monitoring Indian Economy for 1994-2008. The conclusion reveals the prevalence of infrastructure bottlenecks in Indian manufacturing and suggests that the removal of these bottlenecks would help Indian manufacturing in international competition.

Others studies that focus on efficiencies and its determinants indirectly relate to those by Driffield and Kambhampati (2003) and Bhaumik and Kumbhakar (2010). They are considered indirectly as they focus on the effects of liberalization or reforms and then study efficiency.

Driffield and Kambhampati (2003) find whether efficiency of firms in India improved since liberalization in 1991 using production frontier model for RBI data on industries related to transports, textiles, metals, machine tools, food and chemicals for 1987 to 1994. They analyse firm-level efficiency in the above six manufacturing sectors in India by examining the effects of liberalization and domestic competition. Results revealed that efficiency increased in five out of the six sectors. Imports did not improve efficiency.

Bhaumik and Kumbhakar (2010) have investigated whether the reform process instigated competition and whether efficiency has actually improved using ASI plant level data for 14 industries between 1989-90 and 2000-01. Efficiency has been measured using stochastic frontier analysis. Relation between total factor productivity and other influencing factors are examined using augmented Cobb-Douglas production function. Chi-square test statistics for likelihood ratio test is used for identifying the link between efficiency and the production function estimates. Results indicate that increase in competition increased plant- and industry-level total factor productivity. No proper link is found between changes in productivity or technical efficiency and industrial growth.

Besides, other studies have focused on comparative industry efficiency between states in India as well as the US without considering its determinants. These relate to the studies by Ray *et al.* (2004), Mukerjee (2008) and (2011) and Trivedi *et al.* (2009).

Ray *et al.* (2004) in their study on the efficiency in state level Indian manufacturing data focuses on the efficiency dynamics. Using the state-level data from the manufacturing sector in India for 1986-87 to 1999-00, the study analyses the efficiency dynamics of a typical firm in individual states during the pre- and post-reform years. The efficiency is measured using DEA. Besides, the authors use super-efficiency models to rank the states in terms of their performance and investigate the dynamics of the efficiency rankings over time. They find no major changes in the efficiency ranking of states after the reforms nor any evidence of convergence in the distribution of efficiency in the post-reform period.

Mukerjee (2008) focuses on efficiency on energy use in US manufacturing sectors for 1970-2001. Energy efficiency is measured using DEA. This is split into four models. While the first two focus on potential reduction in energy use with given output and no additional input, the third relates to cost minimization. The fourth focuses on capacity output and energy utilization. Her results indicated that efficiencies were higher for later years. Besides, production process in manufacturing faced difficulties in making rapid adjustments to input proportions to energy shocks. However, it was found that they adjust to price changes over time.

In another study, Mukerjee (2011) focuses on efficiency on energy use in Indian manufacturing sectors for 18 major states for 2000-01 to 2004-05. This was aimed at energy conservation and output growth. Here, she uses Nerlove-Luenberger measure[7] of efficiency for a typical firm. The results revealed that by reducing energy input by 14.08 % on an average, the given output could still be produced.

Trivedi *et al.* (2009) focuses on comparative efficiencies, total factor productivity and competitiveness of selected industries in states in India over a time series data from RBI and ASI. Results reveal that estimates of productivity are sensitive to methodology used. Variations in results were also found in the usage of both Stochastic Frontier analysis and DEA.

However, other studies have explored total factor productivity growth and agglomeration without involving efficiency. These relate to the studies by Chaudhary (1989), Lall *et al*. (2004), Goldar (2004), Fritschn and Slavtcher (2008), Agarwalla (2011), Lin *et al.* (2011), Papola *et al.* (2011) and Drucker and Feser (2012).

Chaudhary (1989) studied the link between agglomeration economies and productivity growth in Pakistan manufacturing. Applying a CES production function to 1984-85 data on few industries from the Census of Manufacturing Industries, Islamabad, the author finds that agglomeration economies exist even in less developed countries and that increasing returns to scale is a phenomena for concentration of industries in Pakistan.

Lall *et al*. (2004) try to examine how far agglomeration economies influence economic productivity. They use three sources of agglomeration economies one at the firm level, industry level and regional level. At the firm level, it is the improved access to market centres; at industry level, it is intra industry localization economies; and at regional level, it is inter industry urbanization economies. Using production function framework in the empirical analysis, they allow for non-constant returns to scale and agglomeration economies to be factor augmenting. The data used relates to plant-level data for 11 industry sectors from the Annual Survey of Industries for 1994-95. They find considerable variations in the sources and effects of agglomeration economies among sectors. It is also found that location of industries in dense urban areas does not offset associated costs. This could be because of inequality in spatial distribution.

Goldar (2004) focuses on total factor productivity growth in Indian manufacturing considering economic reforms. Estimating total factor productivity growth for Indian manufacturing for last two decades, he finds a slowdown in Indian manufacturing in the post reform period which is largely attributable to deterioration in capacity utilization.

Fritschn and Slavtcher (2008) focus on the link between industrial specialization and regional innovation system. For this, the study investigates the effects of a regions specialization in certain industries on its producing knowledge. They apply a simultaneous quantile regression technique for 93 German regions over a four-year data collected from patent applications between 1995 and 2000.

Agarwalla (2011) examines the link between agglomeration economies and productivity growth in India. She uses total factor productivity and agglomeration distinguished by localization at industry level and urbanization at regional level to investigate the above relation for four sectors: manufacturing, transport, storage and communication and other services for 25 states over 27 years by working on a panel data regression. Results revealed that urbanization economies tend to exist, but its magnitude varied over sectors. Regional diversity was more supportive than localization across sectors.

Lin *et al.* (2011) have examined the link between spatial concentration and firm-level productivity in China's textile industry. They find whether firm productivity is influenced by spatial concentration of manufacturing activities. In other words, they examine the dynamics of industrial agglomeration and its impact on firm-level labour productivity in China's textile industry for nine sub-groups within the textile industry between 2000 to 2005. Using an econometric model with relative labour productivity as a dependent variable and Ellison-Glaeser index of industrial agglomeration, firm age, size, capital intensity, per capita GDP, RandD, FDI as independent variables, the study finds industrial agglomeration to significantly positively impact firm-level labour productivity.

Papola *et al.* (2011) examine inter-regional disparity in industrial growth and structure. Analysing the level of industrialization and economic development across states in India, they assessed the industry distribution across states, growth performance in industry, technical ratios and impact of reforms or industrial performance of different states. Furthermore, they concluded that inter-state variations in performance could be due to capital investment, human resources, regulatory framework and infrastructure during the post-reform period.

Drucker and Feser (2012) investigate the link between productivity, regional concentration, size of firm and agglomeration economies for three industries using establishment-level data. Examining the relation between concentrated regional industrial structure and agglomeration economies of small firms, the authors use econometric model for three specific years-1992, 1997 and 2002 and find concentrated regional industrial structure to be directly associated with lower productivity. Accordingly, agglomeration economies are not an important mediating mechanism for productivity effect associated with local industry structure.

The literature review clearly indicates that no study has linked industrial location, concentration and economic efficiency of industry in regions in the Indian context using Annual Survey Industries (ASI) data. Thus, this study examines these links using ASI data for the year 2008-09.

3. APPROACH TO THE STUDY:

Researchers have approached the work on efficiency invariably by using non-parametric programming and data envelopment analysis (DEA) pioneered by Farrell 1957. There are exceptions[8] to these (Patibandla, 1998). However, this study also falls in line with most of those who have used DEA in calculating efficiency of firms of different industries in different states. Scitovsky (1955) discusses concentration measurements of industry under different economic conditions. However, regional economic theory links benefits of firms to scale, localisation and urbanisation economies. Within the firm, scale economies result due to increase in production level, and these are enhanced when firms are located in places where other firms of the same industry are located (Bannister *et al.* 1995). At the industry level, firms get the benefit of scale economies because of the size of the industry in a particular location (Lall, 2004). These benefits refer to the localisation economies and relate to the sharing of specialized labour or information on techniques, production *etc.* related to the industry. In addition, when large number of firms belonging to different industries are located at close proximity to one another in a particular location, firms get the benefit of physical and financial infrastructure, larger pools of labour with general skills, entrepreneurial talents *etc.* These benefits which are outside the industry are referred to as agglomeration/urbanisation economies. Though these benefits help the firms in reducing cost, diseconomies like higher wage bills, rising land values, traffic congestion *etc.*, are associated with concentration of firms in a location. Certainly, firms that are able to see that economies of regional concentration outweigh these diseconomies, would be able to produce more efficiently (Bannister *et al.* 1995). Thus, this study finds the extent to which efficiency of firms in different industries in different regions is influenced by the localisation and urbanisation factors using an econometric model. Since both localisation and urbanisation relate to regional concentration, this study uses five indicators relating to them. These indicators are represented by LQO–Location Quotient for Output, LQF – Location Quotient for number of factories in operation in each industry, LQS – Location Quotient for average scale of industry, LQU - Location Quotient for urbanisation and AGG/ DIV – Agglomeration or Diversity. While LQO is an average measure of size of the industry using output in comparison to that at the national level, LQF is a measure of average size of the industry using factories in operation in comparison to that at the national level. While LQS is a measure of average scale of regional industry in relation to the average scale at the national level, LQU is a measure of the effects of urbanisation economies enjoyed by all the firms in the region.

The first three of these four indicators represent localisation and the last one refers to urbanisation. Agglomeration (AGG/DIV) is measured as one minus Herfindahl -Hisrchman index[9]. Since diversity could be used to capture the effects of inter-industry agglomeration, the study measures it by (1- (Herfindahl-Hirschman index)) which is a measure of specialization and concentration.

4. MODEL AND DATA:

Since the study has used both DEA and econometrics, this section initially describes the DEA model followed by the econometric model.

4.1 DEA model:

There are numerous approaches, which could give a fair idea about the inter-state variations in industrial efficiency. The prominent among them are the econometric approaches using the Cobb-Douglas and CES production functions and the modified econometric approach called the SF A (Kumbhakar, S C and Lovell, C A K, 2000). While the SFA is classified under the parametric approach, off late DEA, a non-parametric approach is gaining prominence. This is because such studies while calculating efficiency, focus on relative efficiency[10] rather than absolute. Since this study examines the inter-state or regional variations, such comparative or relative efficiency could suit the situation better. The technique is identified as one, which uses least number of assumptions as compared to other parametric approaches (Balk, Boer, Greve, 2000).

Studying the performance of an industry by recognizing the divergence of both inputs and output is quiet important. DEA is a methodology (Ramanathan, 2003 and Ray, 2004) in which linear programming is interestingly applied, resulting in comparative efficiency. Generally, DEA is used for assessing relative performance of a set of firms called a decision-making unit (DMU). These units use identical inputs to produce various identical outputs. Similarly, here the study considers the firms belonging to an industry using identical inputs and producing identical outputs across states. The DEA which uses linear programming helps in bringing out the comparative efficiency, the wastage of resources and the optimal output related to these firms in an industry in the different states they operate. As such, the study initially examines the inter-state variations in industrial efficiency.

Discussing the working process under DEA, the study considers each industry in the 17 states. Here, the industrial output considered relates to one single output for each industry in a state. Besides, these industries in the 17 different states are considered to use four inputs to produce a single output. The efficiency of conversion here is measured for a particular state by a fractional program. This program maximizes the ratio of weighted outputs to weighted inputs for the state considered, subject to the condition that the similar ratios for all states be less than or equal to one. Weights here are considered to be non-negatives. (See Appendix for the mathematical formulation of the DEA model).

4.2 Econometric model:

As the study analyses the extent to which the concentration indices influence the efficiency of industries in each state/region, an econometric model is considered. Further, since it is hypothesized that efficiencies of industry in each state are considered to be positively influenced by localisation and urbanisation economies, efficiencies of different states under each industry are considered to be dependent variables and the five indicators relating to localisation, urbanisation and agglomeration are used as independent variables. Moreover, since the use of OLS for a dependent variable ranging from zero to one would give biased results (Wooldridge 2011), the study uses maximum likelihood estimation. Thus, a two-limit Tobit model is used to analyze the econometric model. These models have been used for three different efficiencies: the first related to technical, second related to allocative and third related to economic. The above model is defined as follows:

$$EFF_{ij}=f\ (LQO_{ij},\ LQF_{ij},\ LQS_{ij},\ LQU_{ij},\ AGG/DIV,\ D1\ to\ D8) \qquad \ldots\ldots\ldots\ldots\ (1)$$

Here, the EFF_{ij} represents technical, allocative and economic efficiency for industry i in region *j*. The independent variables have been classified into three groups. The first is a set of variables LQO, LQF, and LQS explained in section 2 which are the location quotients capturing localisation economies, the second group constituting one variable (LQU) captures urban economies while the third group also constituting one variable (AGG/DIV) comprises agglomeration economies. These are technically defined as follows:

$$LQO_{ij}= (O_{ij}/\sum O_{ij})/ (NO_i/\sum NO_i)$$

O_{ij} is the total output in industry *i* and state/region *j* while NO_i is the national output in industry *i* for all states/regions.

$$LQF_{ij}= (F_{ij}/\sum F_{ij})/ (NF_i/\sum NF_i)$$

F_{ij} is the number of factories in operation of industry *i* in state/region *j* while NF_i is the number of factories in operation of industry *i* in all states/regions.

$$LQS_{ij}= (LE_{ij}/\sum LE_{ij})/ (F_{ij}/\sum F_{ij})$$

LE_{ij} is the labour employed by industry *i* and region *j* while Fij is the factories in operation of industry *i* in state/region *j*.

$$LQU_{ij}= (U_j/P_j)/ (NU/NP)$$

U_j is the urban population in state *j* while Pj is the total population of state *j*. NU is the national urban population while NP is the total national population.

Besides these localisation and urbanisation indicators, the study uses another indicator representing agglomeration economies *i.e.* AGG/DIV

$$AGG/DIV = (1 – (\text{Herfindal-Hirschman index}))$$

According to the Tobit model, one industry is considered to be a benchmark, and other industries have been compared with this benchmark industry. As such, dummy variables (D1 to D8) are used to represent different industries to suit the Tobit model.

4.3 Data Base and Adjustments:

The disaggregated[11] statewise data on industries in Volume I of ASI for the year 2008-09 is used. A set[12] of sub-industries have been clubbed to form nine industries in each state. Under these industries data on number of factories in operation, invested capital, interest paid, total output, fuels consumed, materials consumed available in Table 2 of the ASI volume I and workers employed, employees other than these workers and wage and salaries available in Table 4 of the same volume and Electricity purchased available in Table 6 also in the same volume are used for the 17 states considered in this study. To capture the efficiency of a typical firm, all outputs and inputs are divided by the number of factories in operation in each industry under each state.

Besides, statewise and national urban population figures and total population for each state and the nation are collected from the Census 2011[13] to calculate the urbanisation ratios.

5. EMPIRICAL RESULTS AND ANALYSIS:

Since the study involves the use of two different methodologies: one the DEA and the other the econometric model, both the methodologies have been solved using different software. The results arrived at while using the two software are presented in subsections below.

5.1 Results on Efficiency:

Initially, the model on DEA is solved using the DEAP[14] package. Comparative efficiencies have been calculated for all the 17 states for each of the nine industries. These efficiencies are split into two *i.e.* technical efficiency (TE) and allocative efficiency (AE). While TE is calculated in DEAP using one output and four inputs: capital, labour (labour constitutes workers and employees other than workers), fuels consumed and materials consumed, AE is calculated by considering one output and three inputs: capital, labour and fuel consumed and their respective prices. Average wage per industry per state has been considered to be the price of labour. This is calculated by dividing wages by labour. Though, real interest rate plays an important role in calculating price of capital, we have used the simplest form of interest and depreciation as a cost of capital and its corresponding price is calculated as interest plus depreciation per unit of capital *i.e.*, interest plus depreciation is divided by invested capital. Besides, though all capital need not be borrowed, we understand that the owned capital has an opportunity cost as such we use the invested capital as the denominator in the calculation of price for capital. In the case of price for fuel consumed we use the factory sector data on fuel consumed given in Table 6 of the ASI Volume I and use the electricity purchased as a proxy for all fuel consumed. This is selected because electricity purchased is available in both quantity and value and forms the largest share in the total of all fuels having both quantity and value. Materials consumed invariably involve the use of large number of items, so we assume its price to be equal to one across states.

Economic efficiency (EE) is calculated as the product of TE and AE. These three efficiencies have been taken separately to form three different econometric models, as shown in model I.

The results on efficiency indicate that industries in states/regions are more efficient technically as compared to their optimal utilization of resources. Observing Tables 1(A) and 1(B) on technical efficiency and allocative efficiency respectively, it is seen that while more than half of the 17 states show more than 50% of their industries to be technically efficient, only approximately 18% of the states show more than 50% of their industries to be using their resources optimally.

On the other side, while large scale manufacturing units using heavy machinery like Chemical and Chemical products, Paper and Paper products, Transport and Transport equipment, Wood and Wood products, Non-Metallic Mineral products and Metal and Metal products are found to be technically efficient in almost 60% of the states they operate, the Textiles, Electrical and Electrical component and the General and Specific Purpose Machinery industries (which to a greater extent are under the small scale industries) are efficient only in few states where they operate. Thus, indicating that more the mechanisation, more is the technical efficiency and vice versa. Observing the AE, it is observed that on an

TABLE 1A

TECHNICAL EFFICIENCY										
STATE	FREQUENCY	TEX	CCP	PPP	EEC	TTE	WWP	GPM	NMMP	MMP
GUJRAT	3	0.7770	0.8820	1.0000	0.7250	1.0000	1.0000	0.9870	0.6370	0.7660
MAHARAHSTRA	6	1.0000	0.9780	1.0000	0.8400	1.0000	0.9950	1.0000	1.0000	1.0000
WEST BENGAL	6	0.4100	1.0000	1.0000	0.8300	0.8130	1.0000	1.0000	1.0000	1.0000
ODISHA	9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
JHARKHAND	6	0.8990	1.0000	1.0000	0.9370	1.0000	1.0000	0.7070	1.0000	1.0000
HARYANA	3	0.6940	0.9720	0.9630	1.0000	1.0000	0.9640	0.6750	0.9270	1.0000
HP	4	1.0000	1.0000	0.9880	0.7220	0.8300	0.9970	0.5670	1.0000	1.0000
PUNJAB	5	0.8900	0.6790	0.9510	0.7910	1.0000	1.0000	1.0000	1.0000	1.0000
RAJASTHAN	5	0.9260	1.0000	1.0000	1.0000	1.0000	0.5940	0.8140	1.0000	0.9080
UP	3	1.0000	0.9500	1.0000	0.7440	0.9330	0.7820	0.9450	1.0000	0.8030
UTTARAKHAND	9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
AP	0	0.5520	0.9310	0.8120	0.7380	0.9580	0.8680	0.7490	0.9540	0.8610
CHATTISGARH	5	0.5860	1.0000	0.8440	1.0000	1.0000	1.0000	0.6810	0.8770	1.0000
KARNATAKA	3	0.8810	1.0000	0.8380	0.7090	1.0000	0.9960	0.7850	0.9530	1.0000
KERALA	6	1.0000	0.9460	1.0000	0.7190	1.0000	1.0000	0.7170	1.0000	1.0000
MP	4	0.7820	1.0000	1.0000	0.7770	0.9250	1.0000	0.8570	0.8070	1.0000
TAMIL NADU	4	0.9360	1.0000	1.0000	0.6230	0.9580	1.0000	0.7600	0.8030	1.0000
	FREQUENCY	6	10	11	5	11	10	5	10	13

NB: The nine industries relate to TEX-Textiles, CCP- Chemical and Chemical Products, PPP- Paper and Paper Products, EEC – Electrical and Electrical component, TTE- Transport and Transport Equipment, WWP- Wood and Wood Products, GPM- General and Specific Purpose, NMMP- Non-Metallic Mineral Products and MMP- Metal and Metal Products

TABLE 1B

ALLOCATIVE EFFICIENCY										
STATE	FREQUENCY	TEX	CCP	PPP	EEC	TTE	WWP	GPM	NMMP	MMP
GUJRAT	0	0.3770	0.3980	0.6150	0.8720	0.2400	0.7970	0.6840	0.5550	0.5280
MAHARAHSTRA	0	0.4960	0.5150	0.6880	0.8850	0.9380	0.4790	0.7890	0.9210	0.7940
WEST BENGAL	2	0.7450	0.4570	0.4240	0.9110	0.8820	1.0000	0.8600	1.0000	0.9950
ODISHA	6	1.0000	1.0000	1.0000	0.8800	1.0000	0.4730	1.0000	0.9650	1.0000
JHARKHAND	3	0.6540	0.5420	1.0000	0.4380	0.8900	1.0000	0.5330	0.8940	1.0000
HARYANA	2	0.7300	0.4550	0.7140	0.0610	1.0000	0.5170	0.5810	0.8030	1.0000
HP	2	1.0000	0.9460	0.7240	0.9700	0.8230	0.6390	0.7890	1.0000	0.9400
PUNJAB	0	0.4450	0.2660	0.3070	0.8070	0.8510	0.7550	0.7120	0.9960	0.9680
RAJASTHAN	1	0.4650	0.2420	1.0000	0.9940	0.8010	0.9050	0.6320	0.6130	0.7430
UP	1	1.0000	0.3860	0.5700	0.8710	0.8820	0.7000	0.7450	0.9110	0.8140
UTTARAKHAND	7	1.0000	0.7180	0.6720	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
AP	0	0.6880	0.5810	0.4940	0.9850	0.8780	0.7820	0.8650	0.5460	0.8200
CHATTISGARH	5	0.3520	1.0000	0.3840	1.0000	1.0000	1.0000	0.7090	0.9860	1.0000
KARNATAKA	1	0.6470	0.2630	0.5660	0.9600	0.9740	0.7990	0.8270	0.7760	1.0000
KERALA	1	0.8790	0.4860	0.4050	0.9500	0.9540	0.8530	0.8310	1.0000	0.4950
MP	0	0.4570	0.2750	0.4580	0.8500	0.9320	0.7430	0.8420	0.9600	0.9210
TAMIL NADU	3	0.7140	1.0000	0.4600	0.9620	0.8700	1.0000	0.7990	0.8600	1.0000
	FREQUENCY	4	3	3	2	4	5	2	4	7

NB: The nine industries relate to TEX-Textiles, CCP- Chemical and Chemical Products, PPP- Paper and Paper Products, EEC – Electrical and Electrical component, TTE- Transport and Transport Equipment, WWP- Wood and Wood Products, GPM- General and Specific Purpose, NMMP- Non-Metallic Mineral Products and MMP- Metal and Metal Products average, a little more than 30% of the states in which all these industries (*i.e.* both large scale and small scale) are found to be using resources optimally. The EE which is considered to be a product of TE and AE would have the influence of both. Observing the EE in Table 1(C), it is seen that traditionally dominant industrial states like Maharashtra, Gujarat and Tamil Nadu do not get a top place in efficiency. Surprisingly, traditionally backward state like Odisha, and newly created states like Uttarakhand and Chattisgarh have large number of industries which are highly efficient.

TABLE 1C

ECONOMIC EFFICIENCY										
STATE	FREQUENCY	TEX	CCP	PPP	EEC	TTE	WWP	GPM	NMMP	MMP
GUJRAT	0	0.2929	0.3510	0.6150	0.6322	0.2400	0.7970	0.6751	0.3535	0.4044
MAHARAHSTRA	0	0.4960	0.5037	0.6880	0.7434	0.9380	0.4766	0.7890	0.9210	0.7940
WEST BENGAL	2	0.3055	0.4570	0.4240	0.7561	0.7171	1.0000	0.8600	1.0000	0.9950
ODISHA	6	1.0000	1.0000	1.0000	0.8800	1.0000	0.4730	1.0000	0.9650	1.0000
JHARKHAND	3	0.5879	0.5420	1.0000	0.4104	0.8900	1.0000	0.3768	0.8940	1.0000
HARYANA	2	0.5066	0.4423	0.6876	0.0610	1.0000	0.4984	0.3922	0.7444	1.0000
HP	2	1.0000	0.9460	0.7153	0.7003	0.6831	0.6371	0.4474	1.0000	0.9400
PUNJAB	0	0.3961	0.1806	0.2920	0.6383	0.8510	0.7550	0.7120	0.9960	0.9680
RAJASTHAN	1	0.4306	0.2420	1.0000	0.9940	0.8010	0.5376	0.5144	0.6130	0.6746
UP	1	1.0000	0.3667	0.5700	0.6480	0.8229	0.5474	0.7040	0.9110	0.6536
UTTARAKHAND	7	1.0000	0.7180	0.6720	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
AP	0	0.3798	0.5409	0.4011	0.7269	0.8411	0.6788	0.6479	0.5209	0.7060
CHATTISGARH	5	0.2063	1.0000	0.3241	1.0000	1.0000	1.0000	0.4828	0.8647	1.0000
KARNATAKA	1	0.5700	0.2630	0.4743	0.6806	0.9740	0.7958	0.6492	0.7395	1.0000
KERALA	1	0.8790	0.4598	0.4050	0.6831	0.9540	0.8530	0.5958	1.0000	0.4950
MP	0	0.3574	0.2750	0.4580	0.6605	0.8621	0.7430	0.7216	0.7747	0.9210
TAMIL NADU	3	0.6683	1.0000	0.4600	0.5993	0.8335	1.0000	0.6072	0.6906	1.0000
	FREQUENCY	4	3	3	1	4	5	2	4	7

NB: The nine industries relate to TEX-Textiles, CCP- Chemical and Chemical Products, PPP- Paper and Paper Products, EEC – Electrical and Electrical component, TTE- Transport and Transport Equipment, WWP- Wood and Wood Products, GPM- General and Specific Purpose, NMMP- Non-Metallic Mineral Products and MMP- Metal and Metal Products

Overall, TE in industries is better than AE. The results clearly indicate the betterment of technology and simultaneously prevalence of over-investment in inventories in Indian industries. This is because more than half of the industries under study show that 80% of the states where they are located are allocatively inefficient. This implies that resources are not optimally used. *i.e.* there is either wastage of resources or over investment in them. This is supported by recent studies (Swaminathan *et al*. 2013) in selected Indian industries. However, the reform process led to the liberalisation of the economy away from the 'Permit Quota Raj'[15].

Liberalisation helped industrialists or entrepreneurs to choose products and production system which has helped in showing a better technical efficiency in the different industries in different states.

Since the study analyses the link between industry location, concentration and efficiency of nine manufacturing industries across 17 states in India using ASI data for the year 2008-09, we try to analyse these links in the following sub-section.

5.1.1 Links between Industry Concentration and Efficiency:

As per the Quiet life hypothesis -Hicks 1935, referred in the study by Setiawan *et al* 2012, high industrial concentration lowers competition among firms, which in turn reduces incentives for the firms to maximize their efficiency. This clearly indicates a negative relation between industrial concentration and efficiency, and this has been proved by studies like that by Gumbau-Albert and Maudos, 2002. The current study also experiences a similar negative relation between industrial concentration and efficiency[16]among the selected manufacturing industries in India, for, it is observed that (by considering concentration to be a share of at least 10% and high efficiency as EE = 0.70 and above) only 11 out of 17 states *i.e.* Gujarat, Maharashtra, Tamil Nadu, Uttar Pradesh, Haryana, West Bengal, Uttaranchal, Kerala, Rajasthan, Chattisgarh and Andhra Pradesh which form 65% of states considered in the study, experience high concentration (10%). Of these, while two states, Gujarat and Maharashtra experience heavy concentration in 7 out of 9 industries, Tamil Nadu experiences heavy concentration in 4 out of 9 industries. Uttar Pradesh and Haryana experience heavy concentration in 2 out of 9 industries. The others *i.e.* West Bengal, Uttaranchal, Kerala, Rajasthan, Chattisgarh and Andhra Pradesh, experience heavy concentration only in 1 out of 9 industries. From these, 15 cases of concentration out of 28 show efficiency below 0.70. In other words, a number of concentrations (13) or 46% of the cases show equally high efficiency *i.e.* above 0.70. All these indicate that with increase in concentration, efficiency is affected or diseconomies of concentration is experienced by more than half of them. Thus, in the Indian case for the nine industries under study, regional industrial concentration has a negative relation with efficiency, as proposed in the Quiet Life hypothesis of Hicks which indicates a negative relation between the two.

5.1.2 Links between Industry Efficiency and Profit:

As per the efficient structure hypothesis, firms with higher efficiency produce at lower cost per unit of output, which in turn leads to higher profits and larger market share (Setiawan *et al* 2012). This indicates that with higher efficiency, profits start increasing showing a positive relation between efficiency and profits. Examining the same for the selected industries in this study, in 6 out of 9 industries, at least 40% of the states have economic efficiency above 70% and 4 out of 9 industries have almost 60% of the states having 70% efficiency. However, in the case of the Wood and Wood Products and Metal and Metal Products industries, 50% and 38% of the states, respectively, showing high efficiency, have equally high above average profit. In the case of Non-Metallic Mineral Products industry, Transport and Transport Equipment industry, the Electrical and Electrical component industry and General and Specific Purpose Machinery industry, 23%, 20%, 25% and 29%, respectively of the states showing high efficiency, have equally high above average profit. Since only less than one-third of the states in 6 out of 9 industries have the positive relation, the Indian manufacturing data does not support the positive relation between efficiency and profit.

5.1.3 Links between Industry Efficiency and Size:

According to the above said efficient structure hypothesis, high efficiency firms are able to earn high profit, and it also causes them to grow rapidly in size (Setiawan *et al* 2012). This again indicates a positive relation between efficiency and size of the firms in an industry. Considering the average size of firms in each state under each industry and comparing them with the high efficiency, only one-third of these states showing high efficiency have equally high above average size with an exception of four industries. These relate to the Textiles, Chemical and Chemical Products, Paper and Paper Products and Metal and Metal Products industries where 40, 60, 50 and 38 percent, respectively of the states have more than average size along with high efficiency. However, since 5out of 9 industries do not show more than average size along with high efficiency, here again the positive relation between efficiency and size is not supported by Indian manufacturing industries.

5.2 Results of the Tobit model:

Next, the econometric model is solved using 'R''[17].27 regressions with 153 observations each have been run by keeping each industry as a benchmark. Since the study considers 9 industries, therefore 9 runs for each one of the three efficiencies (TE, AE and EE) have been made. The results of 4 industries as benchmark, which have given larger number of statistically significant results, relate to Electrical and Electrical component industry, Transport and Transport Equipment industry, General and Specific Purpose Machinery industry and Metal and Metal products industry. However, since the Tobit estimates are almost same for all the models, the study presents only one Table *i.e.* Table 2.

TABLE 2

	TE	AE	EE
	ESTIMATE	ESTIMATE	ESTIMATE
(Intercept)	0.8988**	0.6925*	0.6268
LQO	0.0282	0.0103	0.0227
LQU	-0.0251	-0.1123	-0.1265
LQS	-0.0755**	0.0174	-0.0253
LQF	0.0110	-0.0098	-0.0121
UA	0.0183	0.2827	0.2359
D1	0.1990**	-0.2847***	-0.1448
D2	0.1916**	-0.2247**	-0.1004
D3	0.1068	-0.1704.	-0.0634
D4	0.2703***	0.0430	0.1976*
D5	0.1246.	-0.0224	0.0641
D6	0.0343	-0.0760	-0.0299
D7	0.1463*	0.0444	0.1377
D8	0.2487***	0.0882	0.2229*

Significance codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1 The variables are as described in the text and the D's refer to the dummies representing different industries. Like Textiles, Chemical and Chemical Products, Paper and Paper Products, Electrical and Electrical component, Transport and Transport Equipment, Wood and Wood Products, General and Specific Purpose, Non-Metallic Mineral Products and Metal and Metal Products

The pre-regression data analysis shows high correlation between AE and EE as compared with TE and EE for all industries, except General and Specific Purpose Machinery which show a marginally high correlation between TE and EE as compared with AE and EE. The correlation between TE and AE for all the industries is very poor. This shows that EE is largely influenced by AE and by TE to a lesser extent.

The Tobit results could be categorised into two: the use of benchmarking of industry and the influence of the independent variables on the efficiency. Thus, we have two sub-sections below which relates to industry bench marking and the general results.

5.2.1 Tobit Results using industry as benchmark:

Considering Electrical and Electrical component industry as a benchmark in Tobit analysis, it is found that in the case of the two efficiencies: AE and EE, presented in Table 2 Metal and Metal products industry is the most efficient with estimated coefficients of 0.0882 and 0.2229, respectively above the benchmark industry. In the case of TE, Transport and Transport Equipment industry is most efficient with an estimated coefficient of 0.2703 above the bench mark industry. On the other hand, while General and Specific Purpose Machinery industry has been found to be the least efficient with estimated coefficient of 0.0343 above the benchmark industry in case of TE, Chemical and Chemical Products industry with an estimate of -0.2847 and-0.1448, respectively, below the benchmark industry, under the two efficiencies AE and EE. It has also found that nearly six, three and two industries under each of Tobit-runs on TE, AE and TE have statistically significant results (the degree of significance is different).

5.2.2 General Results of Tobit Analysis:

In the analysis on concentration and efficiency, it was found that the Indian data used in this study affirmed the ‘quiet life hypothesis’ which says that higher concentration results in lower economic efficiency. This was also supported by the pre-regression analysis of the data, and the regression results affirmed the same to a certain extent. This is because in all the nine models, it is found that among the concentration indices used in our study, average scale of industry *i.e.* LQS shows a negative relation with technical and economic efficiency, LQU a measure of the effects of urbanisation economies shows the same relation for all efficiencies and

LQF a measure of average size of the industry using factories in operation for both allocative and economic efficiencies. However, LQO –an average measure of size of the industry using output shows a positive relation with all these efficiencies and LQF – measure of average size of the industry using factories in operation shows a positive relation to technical efficiency and negative relation to allocative and economic efficiencies. Only in the case of TE, LQS is found to be statistically significant at 1% in all the models run in this paper, indicating that localisation economies inversely influence TE. No other variable is found to be significant in all the models *i.e.* surprisingly, none of the urbanisation and agglomeration economies were significant factors in influencing any of the efficiencies.

The sensitivity of the estimated parameters has been verified by conducting the Leverage and Cooks test (Faraway John,2005) which checks for outliers and influential observations for the results presented in Model I and all the models worked on. The models are robust to these diagnostic tests as it has been found that even by removing the outliers and influential observations, no significant change was reported in the parameters estimates.

As there have been arguments in favour of OLS (McDonald John,2009), the study has 27 OLS runs with 153 observations each, by keeping each industry as a benchmark *i.e.* as already mentioned, since the study considers 9 industries, there were 9 runs for each one of the three efficiencies (TE, AE and EE). It has been observed that the OLS and Tobit results are not identical.

6. POLICY IMPLICATIONS:

With technical efficiencies for the nine industries selected in the study being better than allocative efficiencies, the data and results affirm the positive effects of liberalisation in upgrading technology in Indian industries. *i.e.* the reform process has helped in attracting FDIs to almost all the industries under study, and this has helped the respective industries to upgrade their technology. Use of these new technology over the years has helped in developing skill of the labour in these industries. This development in skill is reflected in the technical efficiency, and all these have happened only because of the liberalization policy.

Simultaneously, as allocative efficiency is bad in more than half of the industries under consideration and in more than 80% of the states where these industries are located, this requires improvement in use of resources by industries. For this, the country needs to speed up the reforms relating to efficient use of resources and supply chain management. This indicates the need for more reforms to see that over investment in inventories are reduced. (Over investment could be due to delay in availability of resources or constant rise in prices of resources). Besides, the prevalence of a supply chain mismanagement requires strengthening the existing reforms on industrial linkages or introducing new reforms to see a high degree of coordination between sectors such that interdependencies between sectors are solved in the best manner possible. Just-in-time management of inventories could be encouraged, and measures to see that this is successful in industries should be the aim of reforms. India, which is already in its second stage of reforms, is focussing on such aspects discussed above. Therefore, if the reforms persist, it could be expected in future that allocative efficiency in Indian industries are equally high as the technical efficiency.

7. CONCLUSION:

The study finds that the TE in industries are good, indicating that the industries under study, have benefitted technically due to the liberalization process. However, with allocative efficiency showing a bad result, there is an indication of need for more rigours reforms to overcome over investment in raw-material/inventories in selected industries under study. Though, over inventory is considered to be an indicator for inefficiency in allocation, possibly there could be other factors responsible. Another study is exploring this topic. Though, the efficiency and concentration figures showed a positive relation, tobit analysis showed the possibility of inverse relation between the two.

END NOTES:

1. Demsetz 1973, "Industry Structure, Market Rivalry and Public Policy", is a reference presented in the paper of Setiwan *et al*, (2012).

2. These studies relate to those of Choudhary (1989), Lall *et al* (2004) and Agarwalla (2011) given in the references.

3. Annual Survey of Industry (ASI) Volume Ideals with industries data published by Central Statistics Office, Government of India. This volume, consist of mainly three tables related to state wise data. The first table provides state wise industry wise factories in operation, invested capital, interest paid, total output, fuel consumed, materials consumed, total inputs, gross value added, addition in stocks of material consumed, fuel, semi-finished goods, finished goods, gross capital formation, income, profit *etc*. The second table deals with number of persons engaged *i.e.*, workers, employees other than workers, unpaid family members/proprietor, total man days employed and wages and salary including employer's contribution. The third table deals with type of fuel.

4.The study deals with the Textile, Chemical and Chemical products, Paper and Paper products, Electric and Electrical components, Transport and Transport equipments, General and Specific Purpose Machinery, Wood and Wood products, Non-Metallic Mineral products and Metal and Metal products for they cover more than 90% of industrial output and are prevalent in all the 17 states considered. Each one of these have been formed by summing up related industries for *e.g.*, Textiles (*e.g.*, Textiles comprises of spinning, weaving and finishing of Textiles, manufacturing of other Textiles, manufacturing of wearing apparel except fur apparel, manufacture of knitted and crocheted apparel). In order to reduce the bulk of the paper the other sets could be given to interested readers.

5. The seventeen states considered for the study are as follows: Gujarat, Maharashtra, West Bengal, Odisha, Jharkhand, Haryana, Himachal Pradesh, Punjab, Rajasthan, Uttar Pradesh, Uttarakhand, Andhra Pradesh, Chattisgarh, Karnataka, Kerala, Madhya Pradesh and Tamil Nadu.

6. Allocative efficiency is the ratio of cost efficiency to technical efficiency.

7. This method is the directional distance function introduced by Chamber *et al* 1996

8. Patibandla in his paper has assumed production efficiency to be synonymous to technical efficiency.

9. We measure the concentration of industries as well as specialization and diversity of region using Herfindahl-Hirschman index. The Herfindahl-Hirschman index is given by,
$H_j^c=\sum_{i=1}^{n}(g_{ij}^c)^2$ and $H_j^s=\sum_{i=1}^{m}(g_{ij}^s)^2$
where: $g_{ij}^c=X_{ij}/X_j$ and $g_{ij}^s= X_{ij}/X_i$
i: region (1 to 17), j: industry (1 to 9), X: Total output, Xij: Total output in industry j in region i,

Xj: Total output of industry j, Xi: Total output in region i, H_j^s: The Herfindahl-Hirschman index for specialization, H_j^c: The Herfindahl-Hirschman index for concentration., g_{ij}^c: the share of industry i in the total national output of region j,g_{ij}^s: the share of region j in the total national output of industry i.

10. As the Technical Efficiency is a ratio of its actual output to maximum output producible from its observed inputs defined by the production frontier function.

11. Refer to end note 2and3.

12. Refer to end note 3.

13. Census 2011 is the latest census data available and since it is close to 2008-09, we have preferred to use it instead of Census 2001.

14. DEAP stands for Data Envelopment Analysis (Computer) Programme which is used to conduct Data Envelopment Analysis for the purpose of calculating efficiencies in production. It is designed by Tim Coelli, Centre for Efficiency and Productivity Analysis, Department of Econometrics, University of New England, Armidale, NSW, Australia. Data Envelopment Analysis uses non-parametric linear programming method to calculate efficiencies.

15. 'Permit Quota Raj' refers to the period between post-independence and pre-liberalisation or pre-reforms in India. India for a long time, followed the mixed economy process where investment decisions for a large number of manufacturing sectors were taken up by the private sector. It is a well-known fact that private sector investment is motivated by profitability and the allocation of resources could be different from social optimal allocation. Thus in order to regulate private sector investments, the Indian government used permits or licences and quotas as a weapon during the pre-liberalisation period.

16. Table not presented. Data could be given to interested readers on request.

17. R is an open source programming language used for statistical and computational data analysis.

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Appendix 1

$$MaxE_m = \frac{\sum_{j=1}^{1} v_{jm} y_{jm}}{\sum_{i=1}^{4} u_{im} x_{im}}$$

Subject to

$$0 \le \frac{\sum_{j=1}^{1} v_{jm} y_{jn}}{\sum_{i=1}^{4} u_{im} x_{in}} \le 1$$

$n = 1., ...m, ...17,$ $v_{jm}, u_{jm} \geq 0$ $i = 1 \ldots 4,$ $j = 1$

The variables v_{jm}, u_{jm} are the weights to be determined by the above mathematical program. Though the weights are considered non-negative, in some DEA programs it would be shown as $v_{jm}, u_{jm} \geq \varepsilon$, where ε is an arbitrary small positive number. This is just done to ensure that all inputs and outputs have positive weights. The m^{th} state is the base state in the above model. The optimal value of the objective function is said to be the DEA efficiency score of the m^{th} state. If this is equal to one then the m^{th} state satisfies the necessary condition to be DEA efficient, if not it is DEA inefficient. Surely, this efficiency is relative to the performance of other 16 states considered here.

Since it is not easy to solve such a fractional objective function, this could be converted into a linear problem by either converting the numerator or denominator to unity. By setting the denominator to unity in the above model, the output maximization linear programming problem can be obtained. On the other hand, by setting the numerator to unity the input maximization problem can also be obtained *i.e.*,

$$MaxE_m = \sum_{j=1}^{1} v_{jm} y_{jm}$$

Subject to

$$\sum_{i=1}^{4} u_{im} x_{im} = 1$$

$$\sum_{j=1}^{1} v_{jm} y_{jn} - \sum_{i=1}^{4} u_{im} x_{in} \leq 0$$

$n = 1, ...m.., 17,$ $v_{jm}, u_{jm} \geq 0$ $i = 1 \ldots 4,$ $j = 1$

A complete DEA model involves solutions of n such programs, each for a base state *i.e.* 17 in this study. This gives 17 different sets of weights in each program. Though, the constraints remain the same, the ratio to be maximized changes. Generally, the dual of the above model is used for the computation of the efficiency score, which is

$$Min\, \vartheta_m$$

Subject to

$$\sum_{n=1}^{17} y_{jn} \lambda_n - S_j = y_{jm}$$

$$\vartheta_m x_{im} - \sum x_{in} \lambda_n - S_i = 0$$

$\lambda n, S_j, S_i \geq 0$ $i = 1 \ldots 4,$ $j = 1$

This dual rates a particular state *i.e.* the m^{th} state. This state is relatively efficient if and only if the optimal values of its efficiency ratio, θ_m, equals unity and the optimal values of all the slack variables S_i and S_j are zero for all i and j. This model assumes constant returns to scale. But, by appending the constraint

$$\sum_{n=1}^{17} \lambda_n = 1$$

variable returns has been incorporated in the model.

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410, Gemstar Commercial Complex, Ramchandra Lane Ext, Kachpada,
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