Efficiency and agglomeration economies in India: An industry level analysis across states

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Abstract

This paper examines how efficiency of various industries are linked to presence (or absence) of agglomeration economies. Using the state level data for various industry groups in India, it estimates technical efficiency of industries at state level based on the stochastic frontier framework. Significant urbanisation economies are found in all analysed groups while localisation economies are found in three out of five industry groups. Role of infrastructure, particularly highways and railways network is critical for all industries in improving efficiency and productivity. This suggests that measures against urbanisation can be counterproductive and production incentivising schemes should be industry specific and should aid in utilisation of agglomeration economies.

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Introduction

The Starrets's Spatial Impossibility Theorem (Starrett, 1978) states that an economy with a finite number of locations and a finite number of consumers and firms, in which space is homogenous and transport is costly, no competitive equilibrium exists in which actual transport takes place. It follows that agglomeration might thus be due to externalities (or increasing returns) arising from scale.

Agglomeration economies are the benefits that come when firms and people locate near one another, in large cities and industrial clusters. In India only 4% of the landmass is categorised as urban while it hosts 31% of the total population (census 2011) and contributes to around 60% of GDP. Despite the wide availability of open spaces, almost all development is centred around these areas. Such a pattern of development makes sense only when there are localised aggregate increasing returns. Theory points toward geographical clustering of economic activity as an important determinant of efficiency. Urbanisation and industrialisation have a close nexus, and with increasing urbanisation agglomeration clusters create spillover effects that augments productivity in form of increased output from inputs, or lower costs for a given output.

Marshall (1890) identifies links between concentration of population, industrial activities, infrastructure and human capital in a nearby area, with efficiency and productivity arising from trinity of outcomes. First is labour market interactions where a local pool of skilled labour develops, second is from linkages between intermediate- and final-goods suppliers, and third from local knowledge spill-overs. Labour market pooling in economic clusters leads to a better match between an employer's demand and skilled worker's supply and reduces risks for employers and labourers. Spillovers in knowledge takes place when an industry is localized by allowing workers to learn from each other, switch jobs, imitate and implement new and better technology. Other sources include market size effects, when large demand from the city or urban cluster leads to agglomeration, and economies in consumption, whereby cities exist and expand as people like entertainment, night outs, tech-savvy gadgets etc.

Factors such as immobile factors of production, higher rents particularly land rents, and pure external diseconomies lead to elimination of agglomeration economies. Immobile factors, particularly land and natural resources act as constraints to agglomeration as they prevent firms from clustering. Clustering in urban areas and highly industrialised areas push up rents and reduce agglomeration economies from playing out. Also clustering can lead to higher congestions, increased crimes, higher demand for limited local resources, price competition among producers, increase in price of inputs, etc., producing external diseconomies.

Today when large scale capital expansion and incentive based production schemes are budgeted lakhs of crores of public money, policymakers need to recognize impacts of agglomeration economies in different industry groups so as to target industries and regions differently. Rather than treating urban and concentrated areas as an ill, a more refined and evidence based approach for expansion and development of urban and peri-urban areas should be undertaken. However, urban development and industrial location policies in India have yet not considered the differential and significant impacts of agglomeration on various industry groups.

Literature review

The productivity and efficiency advantages of industrial clusters with a high density of firms and workers have been perceived for a long time, and already received the attention of Smith (1776) and Marshall (1890). In the past 30 years, urban economists have successfully quantified and documented these advantages. Broad approaches for empirical analysis have been used however the most direct approach has been to analyse systemic variations in productivity across space. Empirically, the ideal process to estimate agglomeration economies is by identifying production functions for individual firms. Given the constraints in availability of firm level data on value added, labour and capital usage, many studies use growth rate of employment, density of employment, wages, rents, or density of population as an alternative. In this section studies that deploy some of these measures to estimate agglomeration economies are summarised.

Impacts of localisation and urbanisation on two digit industry is studied by Nakamura (1985) for Japan and Henderson (1986) for USA and Brazil. Total employment in the city is used as a measure of urbanisation while employment in the industry is used as a measure of localisation. Localisation economies are found in more number of industries while urbanisation in fewer, and some industries do not exhibit any external economies. Nakamura empirically estimates that a doubling of industry scale leads to a 4.5% increase in productivity, while a doubling of city population leads to a 3.4% increase. Henderson finds almost no evidence of urbanization economies but significant evidence of localization economies. To sum up, Henderson and Nakamura find more presence of localization economies than urbanization, while inter-industry variation is present in impacts of agglomeration economies.

Inter industry variations in agglomeration economies are also identified by Mitra and Sato (2007) for Japan. They use a two-step approach, calculating technical efficiency of two digit industry groups at prefecture level, using stochastic frontier based production function, and then relate technical efficiency with agglomeration specific variable(s), growth indicator (per capita income), and welfare indicator (the unemployment rate) using factor analysis. They find weak association of agglomeration variables with technical efficiency however for few industry groups, such impact is stronger than for others. Food (industry group 09), beverages (10), textiles (11), lumber and wood (13), furniture (14), non-ferrous metals and products (24) and electronic parts and devices (29) have relatively stronger agglomeration effects than other industry groups. For British firms in the manufacturing and services industry, Graham (2007) estimated positive localisation economies for 13 of the 27 sectors examined while significant localisation diseconomies are estimated in few sectors. Moreover where localisation economies are found, they tend to decrease rapidly with distance. For urbanisation economies, Graham(2007) estimated its presence only in 14 out of 27 sectors of the British economy.

In contrast, Fritsch and Wyrwich (2021) find that for 14 OECD economies agglomeration economies in large cities offer some advantage for innovation and research activities, however such advantages are not significantly different from a small area. They conclude that popular theories overemphasize the importance of agglomeration and large cities.

In Indian context, using panel data for 15 major states in India over the period 1976/77 to 1992/93, Mitra (2014) estimates total factor productivity growth for each of the seventeen two-digit level industries. They conclude that more than half of the industry groups have presence of urban agglomeration economies in determining TFPG. Large urban settlements are created out of concentration of economic activities, which leads to higher productivity. Similarly Dwivedi and Arora (2020) finds a strong and statistically significant effect of the agglomeration variables on innovative activities at district level in India. Institutions, infrastructure and local socio-economic conditions increase innovative activities and the spillover effects are visible in form of higher output and productivity.

Many studies have empirically observed the positive relationship between agglomeration and productivity, however the literature has struggled to isolate the sources of such benefits.

Perspective on agglomeration economies in India

Two agglomeration economy concepts are localisation economies and urbanisation economies. Together they constitute economies of scope for industries. Localisation economies is an intra-industry concept whereby they are external to firms but internal to the industry. Whereas urbanisation economies are inter-industry; external to the firm and the industry but internal to states or cities.

Localization economies refers to efficiency gains that accrue from increased scale of a particular industry operating or located closely in a state or city. Efficiency gains can arise in three ways. First from technological spillovers between firms of an industry arising from increased communication between firms and workers. Second from high quality of inputs at a lower cost due to growth of ancillary and subsidiary trade. And, third from development of the local skilled labour pool. Localization economies, in this paper, is measured as the proportion of industry k's employment in state j as a share of total industrial employment in state. It is calculated as

$$state\_emp\_share_k = \frac{employment\ in\ industry\ k_j}{total\ industrial\ employment\ in\ state\ j}$$

Urbanisation economies refer to a large urban population base nearby an industrial area which acts as a source of human capital, a hub of innovation as well as provides a market for industrial goods, high quality infrastructure and public services. In India 31% of total population lives in urban areas (census 2011) while urban areas constitute less than 5% of landmass.

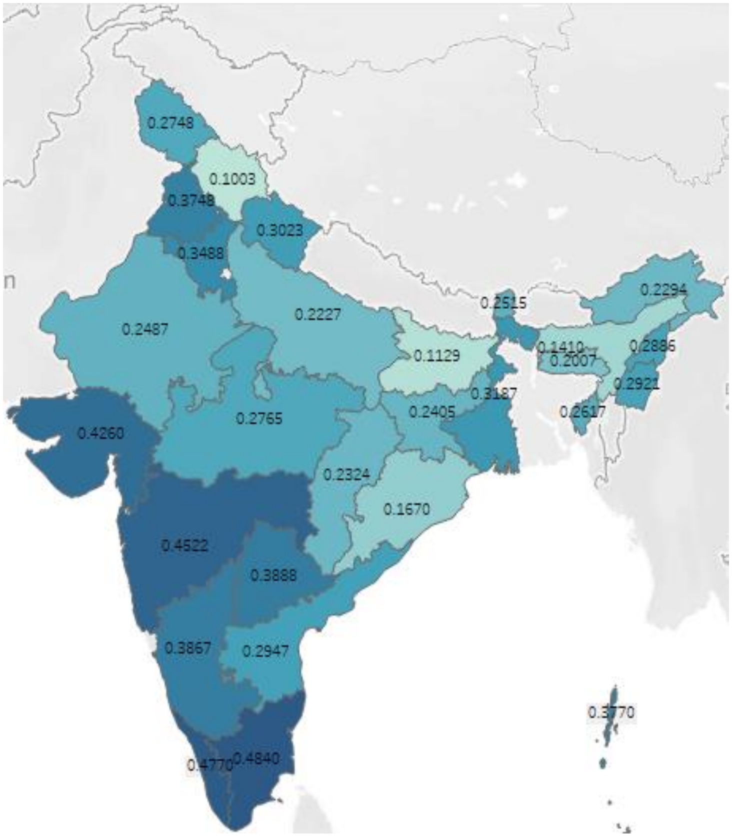

Fig 1, share of urban population in states (based on census 2011)

India's fastest growing states, such as Maharashtra, Gujarat, Southern states of Karnataka, Tamil Nadu, Kerala and Telangana have high share of urban population. Urbanised states of India are also industrially diverse with presence of diverse industrial capacities. Coefficient of correlation between industrial concentration and urban population share is negative (-0.3) and statistically significant. Although not all firms in a given industry may be located in the urban areas, urbanization economies, if they exist, are assumed to benefit them irrespective of their location within the state

Industrial concentration/diversity in a region reflects the economic geography of the region. Industrial concentration or economic diversity in the region is measured as the sum of squares of employment shares of all industries in a state. This is basically the Herfindahl index for calculating concentration of economic activities. The largest value for Herfindahl index is 'one', when the entire state economy is dominated by a single industry while smaller values represent the presence of a larger number of industries in the state.

Industrial Concentration in state j can be calculated as

$$industrial\ concentration_j = \sum_k \left(\frac{employment\ k_j}{employment\ j}\right)^2$$

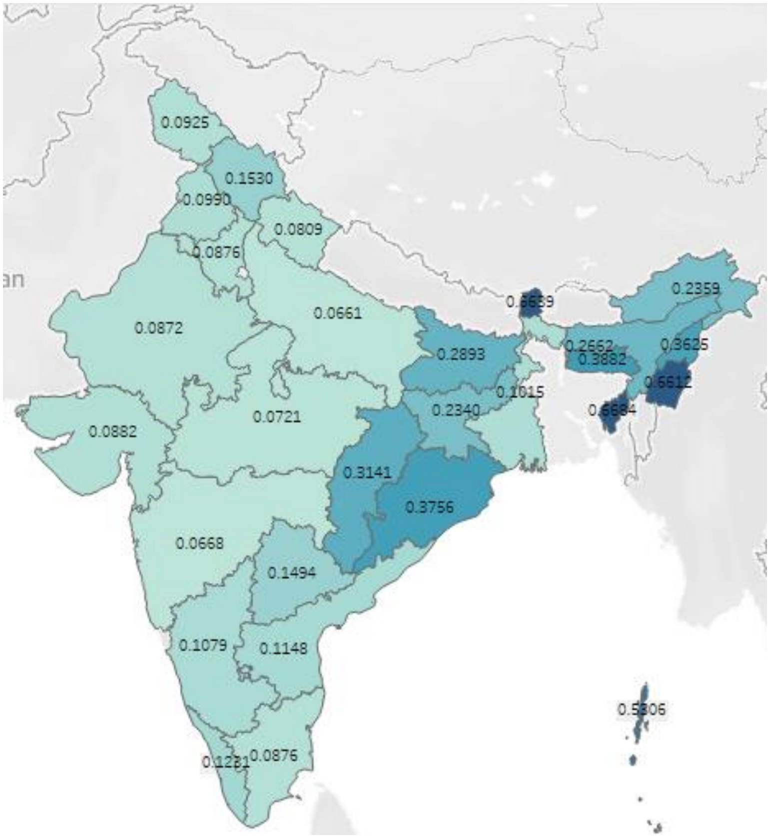

Fig 2, industrial concentration across Indian states

Industrial concentration across states shows that industrially large and advanced states such as Gujarat, Maharashtra, Tamil Nadu, Uttar Pradesh, Rajasthan, and Madhya Pradesh have large industrial diversity with its workforce employed in diverse sets of industries. Smaller states such as Uttarakhand, Himachal Pradesh, Punjab and Haryana also show high industrial diversity. Whereas industrial diversity in Eastern states of India is starkly low (except for West Bengal) with north eastern states having presence of a few industries on the states. Sikkim has a dominant presence of pharmaceutical industry (employing 81% of its industrial workforce), while other north eastern states have a dominant presence of other non-metallic mineral products such as clay, limestone, cement, plaster etc. (NIC code 23) industry. The eastern states of Bihar, Chhattisgarh, Jharkhand and Odisha are endowed naturally with ferrous and non-ferrous minerals and thus here industrial diversity is low with basic metal industry (NIC Code 24) employing majority of its industrial workforce.

Share of the state in total exports is another measure for identifying the openness and competitiveness of the state. A state with higher exports will have exposure to competition from foreign markets as well will have adapted the given technology with optimum usage. In other words such a state would lie closer to the production frontier. However exports data at state level is skewed as a few states with major ports process all the exports from India.

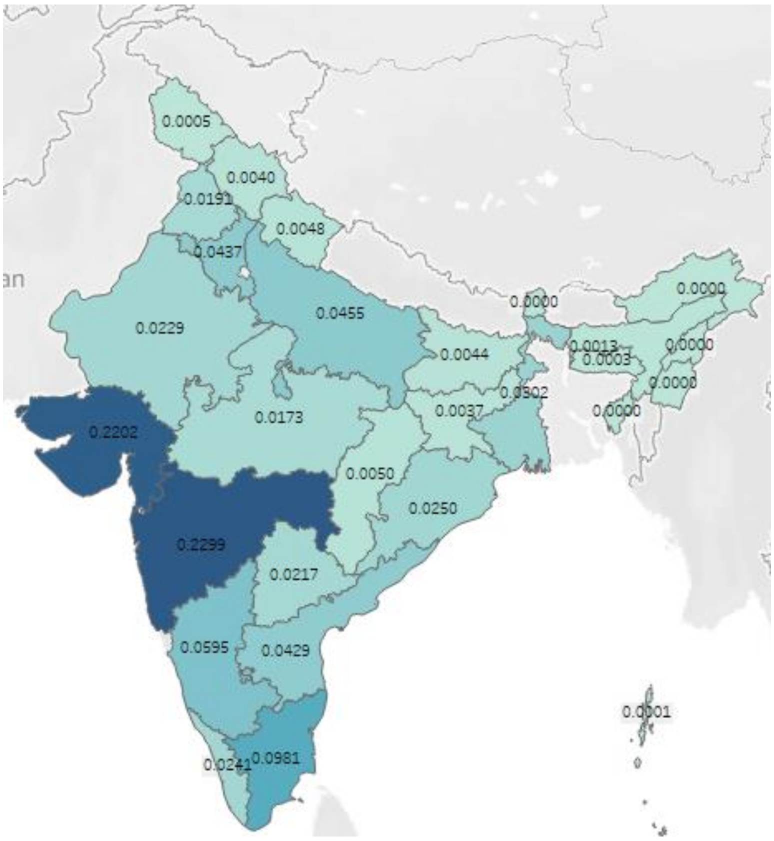

Fig 3, state wise proportion of exports

As seen from the exports heat map, the port states of Gujarat, Maharashtra, Tamil Nadu and Karnataka together export 60% of Indian exports in 2017-18. This is because the origin state for export products is difficult to identify and most of the exports are tagged to the exporting state. So export share was not used as a determining factor in the analysis of (in)efficiency across states.

Per capita availability of infrastructure, particularly length of highways and railways network in states are also used as factors in the determination of efficiency across states. In the next section we discuss the methodology used for estimation of our analysis.

Empirical model and methodology

Technological (in)efficiency is calculated using a stochastic frontier model (SF Model). The SF model captures the idea that an economic agent cannot exceed the ideal "frontier", and deviations away from this frontier represents individual inefficiencies. Empirically, by formulating a regression model with a composite error term consisting of measurement error and other classical noise along with a one sided disturbance representing efficiency.

$$y_i = \alpha + x_i'\beta + \epsilon_i$$

$$\epsilon_i = v_i - u_i$$

$$v_i \sim N(0, \sigma_v^2)$$

$$u_i \sim F$$

Where y_i represents the log of the value added of the i^{th} industry group, x_i is a vector of inputs (log of employment and log of capital), and β is the vector of technology parameters. The composite error term $\in_i$ is the sum (or difference) of a normally distributed disturbance, v_i, representing measurement and specification error, and a one-sided disturbance, u_i, representing inefficiency. Moreover, u_i and v_i are assumed to be independent and identically distributed across observations. The last assumption is about the distribution of the inefficiency term, which is needed to make the model estimable. Inefficiency term (u_i) can follow a truncated normal distribution, half normal distribution, exponential distribution or gamma distribution.

In general, SF analysis is based on two sequential steps: in the first, estimates of the model parameters $\hat{\theta}$ are obtained by maximizing the log likelihood function $l(\theta)$, where $\theta = (\alpha, \beta', \sigma_u^2, \sigma_v^2)$. In the second step, point estimates of inefficiency can be obtained through the mean (or the mode) of the conditional distribution $(u_i / \hat{\epsilon_i})$, where $\hat{\epsilon_i} = y_i - x_i'\hat{\beta}$

A very important issue in SF analysis is the inclusion in the model of exogenous variables that are supposed to affect the distribution of inefficiency. These variables, which usually are neither the inputs nor the outputs of the production process but nonetheless affect the productive unit performance. Researchers have often incorporated exogenous effects using a two-step approach. In the first step, estimates of inefficiency are obtained without controlling for these factors, while in the second, the estimated inefficiency scores are regressed (or otherwise associated) with them. Wang and Schmidt (2002) show that this approach leads to severely biased results. Thus in this analysis of efficiency of industries, a model based on simultaneous estimation of frontier and inefficiency would be used.

To model exogenous variables in determination of inefficiency of industries, we assume the following for the inefficiency parameter:

$$u_i \sim N^+(\mu_i, \sigma_u^2)$$

$$u_i = z_i'\psi$$

where u_i is a truncated normal random variable, z_i is a vector of exogenous variables (with constant term), and ψ is the vector of unknown parameters to be estimated.

In this paper, Annual Survey of Industries (2017-18) data for state and industry level value added, fixed capital and employment is used. For agglomeration economy variables data from Annual Survey of Industries (2017-18), Census (2011) and Handbook of Statistics on Indian Economy (RBI) is used. Eight industries (based on NIC 2008 classification), which are focussed by Government of India for production linked incentive scheme (PLI) are selected for analysis of efficiency and agglomeration economies. Details of selected industry are:

NIC 2008 Code	Description of Industry
10	Manufacture of food products
11	Manufacture of food beverages
20	Manufacture of chemicals and chemical products
21	Manufacture of pharmaceuticals, medicinal chemical and botanical products
24	Manufacture of basic metals

26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment
29	Manufacture of motor vehicles, trailers and semi-trailers

Input Variables and their computation

Category	Variable	Symbol	Calculation Method
Input in Production	Capital	l_capital	Log of fixed capital
	Labour	l_employees	Log of number of employees
Agglomeration Variables	Industrial Concentration	industrial_concentration	Sum of squares of employment shares of all industries in a state
	Localisation Index	state_emp_share (for industry)	Ratio of employment in an industry and total industrial employment in state
	Urbanisation Index	share_urban_pop	Proportion of urban population in state
	Industrial Employment in State	industrial_emp_share	Ratio of industrial workers to total population of state
Infrastructure variables	Length of highways per 1000 people	highways_per1000	Total length of highways (national + state) *1000/population of state
	Length of railways per 1000 people	railways_per1000	Total length of railways network *1000/population of state

Results

For each of the industry groups at state level, Cobb-Douglas production function in terms of value added is estimated in a stochastic frontier framework by applying the MLE method. As cross sectional data is used for estimation distributional assumptions about the efficiency component in error term is to be made. It is assumed that errors representing the efficiency (inefficiency) follow a truncated-normal distribution.

For three industry groups, production frontier with significant differences in efficiency across states could not be estimated. These industry groups are 24 (Manufacture of basic metals), 26 (Manufacture of computer, electronic and optical products), and 29 (Manufacture of motor vehicles, trailers and semi-trailers). This is due to very skewed production at state level, majorly concentrated in a few states (case for industry group 24 and 29), heavy reliance on imports and not much value added in India (case industry group 26) as well as aggregation of firm level data to state level whereby aggregation reduces differences in productivity across states.

The results of frontier production function for each of the two digit industry groups are presented in Table 1. The log of gross value added has been regressed on log of employment and log of capital. The coefficient represents the elasticity of value added with respect to employment and the elasticity of value added with respect to capital. Both elasticities are positive for all the industry groups, also implying that the marginal productivity of labour and capital are positive. Both in terms of z-ratios corresponding to the coefficients and the chi-square values representing the overall goodness of fit of the equations, are significant in all the frontiers.

The results presented in table 1 have some interesting features. Urbanisation economies are significantly present for all industry groups, though the significance is low for Manufacture of chemicals and chemical products (Industry group 20). This may be because the industry produces more intermediate and industrial goods and the market for its products is more in industrial areas than in urban areas.

Localisation economies, represented by the share of concerned industry in the total industrial employment of the state, is a significant determinant of efficiency of industries, except for industry group 10 (Manufacture of food products). Except for Manufacture of beverages (industry group 11), increased presence of an industry in the state, i.e., more localisation, leads to higher efficiency of that industry. For the Manufacture of beverages (industry group 11), there is evidence of localisation diseconomies. Here the density of own industry employment leads to lowering of efficiency.

Industrial diversity (or concentration) is a significant determinant of efficiency in industry groups 10 (Manufacture of food products) and 20(Manufacture of chemicals and chemical products). In Manufacture of food products (10), increasing industrial concentration increases inefficiencies or decreases efficiency, or higher the industrial diversity in state in form of large and diverse manufacturing base, efficiency of food products industry increases. This is perhaps due to higher forward and backward linkages of FPIs as well as requirement of diverse labour skill set from various types of manufacturing facilities. In contrast, for Manufacture of chemicals and chemical products (20), increasing industrial concentration (presence of few specific industries in state) reduces inefficiencies or increases efficiency. This is perhaps due to limited raw materials requirements as well as limited and specialised market for final products.

Availability of infrastructure is a significant determinant of industrial technical efficiency for all analysed industrial groups, except 21 (Manufacture of pharmaceuticals, medicinal chemical and botanical products). This suggests that states with higher per capita availability of national highways or railway tracks will nurture more efficient industries and thus would be more productive and have higher growth.

Table 1, frontier for industry groups

Industry Group	10	11	20	21	27
l_capital	0.53* (5.42)	0.33* (4.34)	0.37* (1.1e+05)	0.43* (3.41)	0.28* 2.46)
l_employees	0.33* (3.1)	0.84* (5.81)	0.31* (6.2e+04)	0.67* (4.29)	0.50* (3.21)
cons	2.22* (4.96)	0.786** (1.86)	5.51* (2.3e+05)	1.55* (3.65)	3.92* (4.79)
obs	22	27	23	24	25
wald chi2	645	8.71E+09	1.85E+11	994	116
Determinants of inefficiency for each industry group					
share_urban_pop	-0.55** (-1.83)	-1.46* (-3.38)	-	-0.47*** (-1.59)	-
ln_urban_pop	-	-	-0.28*** (-1.45)	-	-0.69* (-3.14)
industrial_concentration (Herfindahl Index)	1.32* (2.75)	-	-2.48 (-1.19)	-	-
state_emp_share(for industry)	-	18.58* (3.72)	-27.33* (-2.51)	-2.63* (-3.85)	-72.5* (-4.09)
industrial_emp_share	-	8.76*** (1.45)	-	-	-
highways_per1000	-1.21* (-2.16)	-0.58* (-2.13)	-2.79* (-1.91)	-	-2.33* (-3.85)
railways_per1000	-	-	-	-	-38.45* (-3.65)

*Here, * p < 5%, ** p < 10%, *** p < 15%*

z values are represented in parenthesis

Looking at industry as a whole, food products (10) and beverages (11) industries experience significant urbanization economies, with efficient industries located in urbanised states. However efficiency of food product manufacturing (87%) is in general higher than beverages (47%) in India. Food products industry includes manufacturing/processing of meat products, fishery products, fruits and vegetables, vegetable and animal oil, dairy products etc.

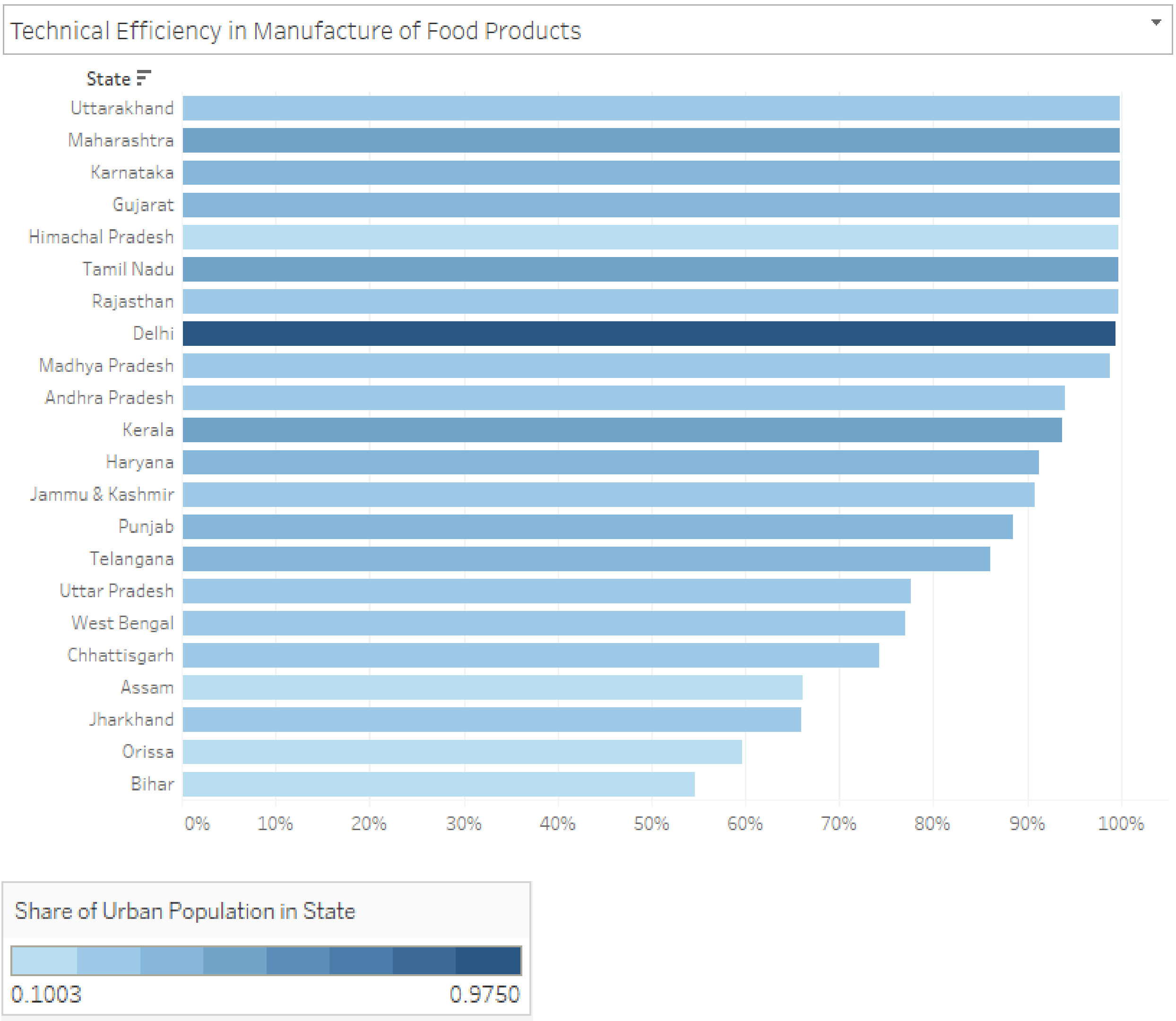

Figure 4, State level technical efficiency in Manufacture of food products (10)

Food products manufacturing (10) in India is widely dispersed and is centered in and around the primary sector of the economy. While urbanisation economies are found in the industry, localisation economies are not present. Primary activities are just not a mode of earning but a way of life in India, whereby Manufacture of food products (10) drives its backward linkages from omnipresent primary sector is not constrained by localisation factors. It however requires good infrastructure, primarily highways network for marketing of its products that have low shelf life.

Manufacture of Beverages (11) include alcoholic and non-alcoholic beverages manufacturing. The Beverage industry experiences localisation diseconomies possibly because of many reasons. One, the small scale local country liquor (NIC Code 11012) manufacturing units aim to serve a market dispersed according to the population. So they will benefit more from concentrations of people rather than their own manufacturing activities. This is consistent with the fact that industry has negative localisation economies but experiences positive urbanisation economies. Second, possibly because industrial concentration in larger alcoholic and non-alcoholic manufacturing leads to more intense price competition for bulky and local raw material.

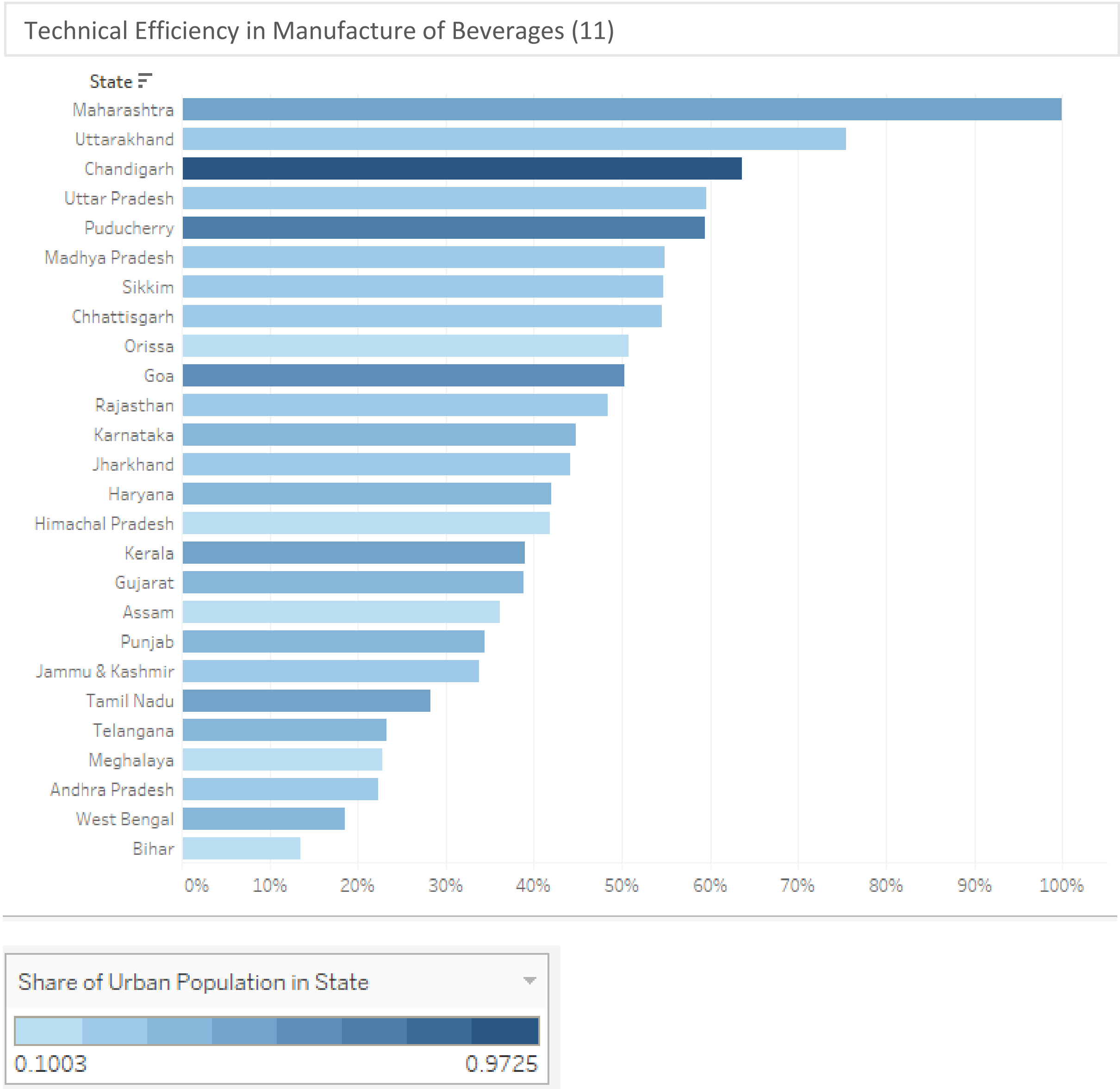

Figure 5, State level technical efficiency in Manufacture of Beverages (11)

Maharashtra has the most efficient beverages manufacturing industry with presence of manufacturing of wine, Manufacture of distilled, potable, alcoholic beverages such as whisky, brandy and gin as well as Manufacture of soft drink. While Bihar, West Bengal, Andhra, Meghalaya, Assam have the lowest efficient industries (Group 11). This is because of the large presence of Manufacture of country liquor (NIC Code 11012) which are primarily small scale units, catering to a small area and using obsolete technology.

Manufacture of Chemicals Industry (20) includes manufacturing of fertilizers, pesticides, industrial or medical gases, paints and varnishes, plastic, rubber, soap and detergents, man-made fibres, etc. The industry experiences significant external economies in form of localisation and urbanisation. Industry is efficient when located around certain specific industries with which it shares backward and forward linkages, while in states that have high diversity in industrial presence, the efficiency is low. Infrastructure, especially the presence of national highways is critical for efficient functioning of industry.

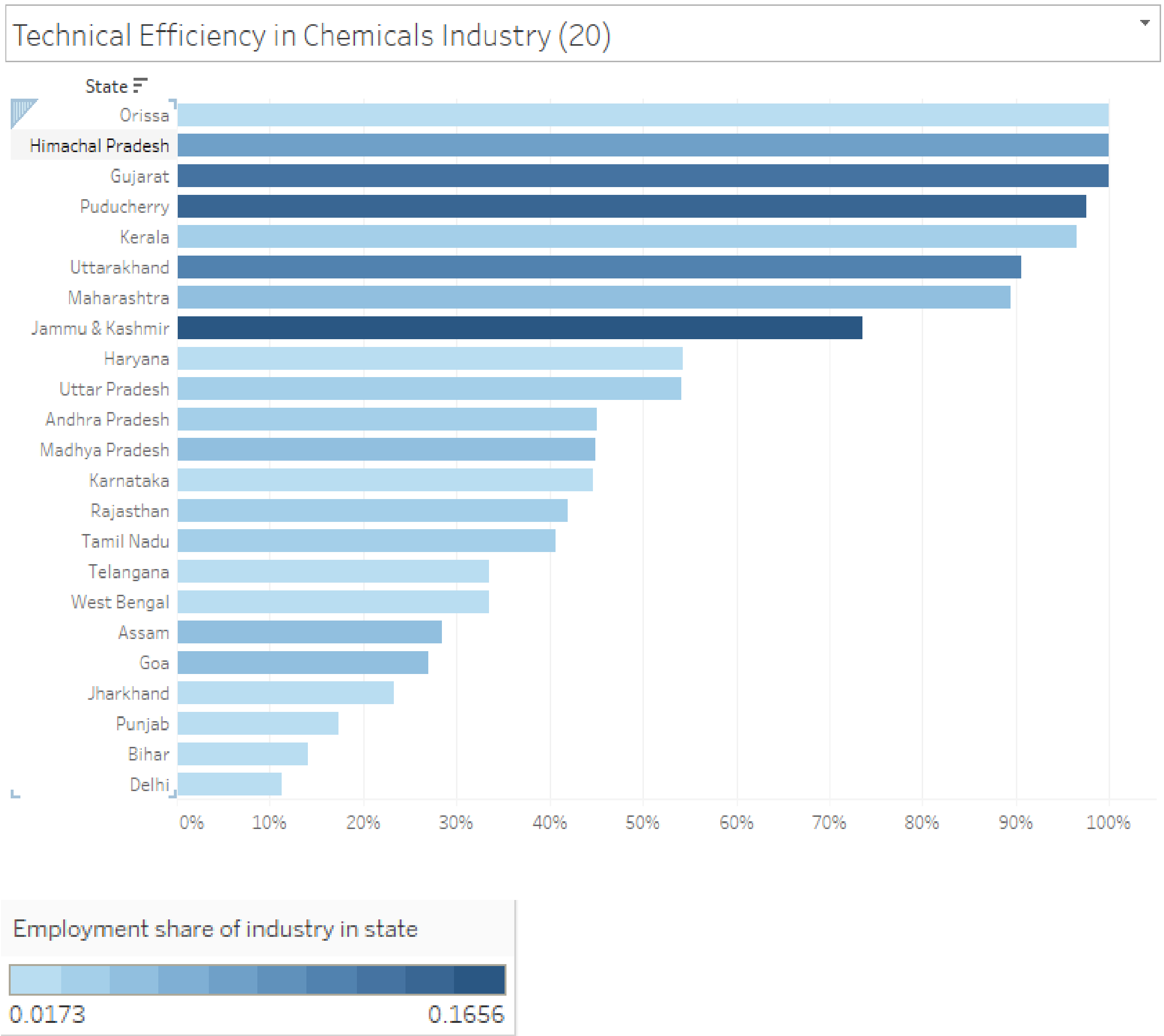

Figure 6, State level technical efficiency in Manufacture of chemicals and chemical products (11)

On average, the industry is 55% efficient. The largest manufacturers, Gujarat and Maharashtra are operating at high efficiency levels (95% average efficiency). While the states operating at lower scale, viz Bihar, Delhi, Jharkhand, have industries operating at lower efficiency.

Looking at Manufacture of pharmaceuticals, medicinal chemical and botanical products (21), India is the world's third-largest pharmaceutical producer and is considered 'pharmacy to the world'. It is the largest provider of generic drugs globally. Empirical analysis shows that the pharma industry experiences external economies arising from urbanisation and localisation. Presence of railways and highways is not a significant constraint in efficiency of industry, and thus the industries are promoted in hilly Himalayan and north eastern states where they operate at relatively high efficiency levels.

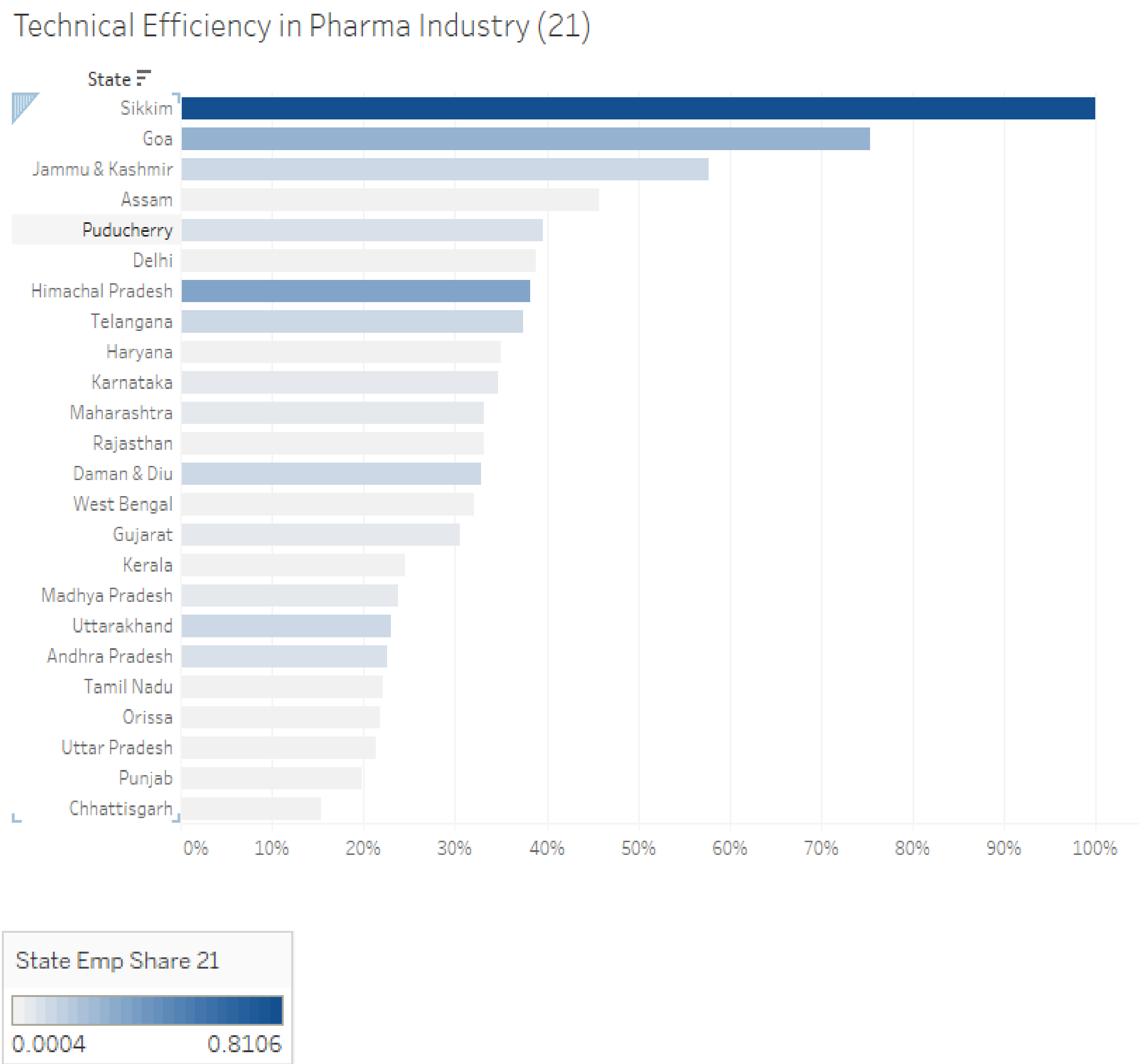

Figure 7, State level technical efficiency in Manufacture of pharmaceuticals, medicinal chemical and botanical products *(21)*

Sikkim, most efficient of states in the pharma industry, is India's fifth largest producer, and has offered a host of tax benefits to the industry and has attracted an investment of over $400 million from 22 major pharma companies in the last three years (2014-17). Many pharma companies and their ancillary units have migrated from Baddi in Himachal Pradesh and Uttarakhand to Sikkim, as the excise duty exemption given to these states will soon expire. Sikkim has emerged as a major pharma hub in the North Eastern with tax incentives, low manufacturing and labour costs and a pollution free environment. Largest manufacturing states, Gujarat, Telangana, Maharashtra and Himachal Pradesh are found to be operating lower efficiency levels.

Manufacture of electrical equipment (27) includes electric motors, generators, batteries, wires and cables, electric lighting equipment, domestic appliances, etc. The industry experiences significant urbanisation and localisation economies. Moreover efficiency of industry is critically dependent upon availability of quality infrastructure, particularly highways and railways networks.

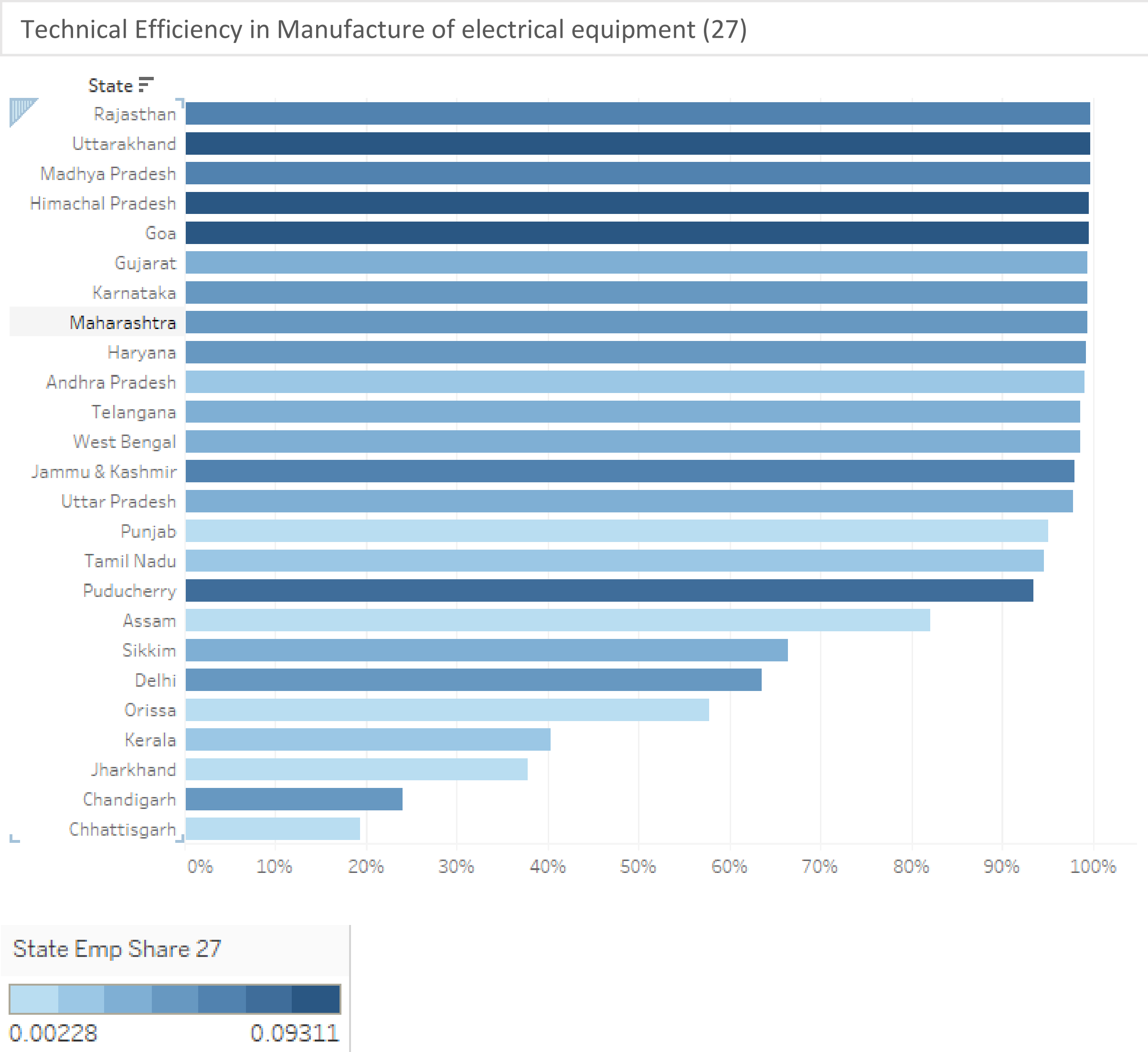

Figure 8, State level technical efficiency in Manufacture of electrical equipment *(27)*

Manufacture of electrical equipment (27) industry on an average is 83% efficient. Top five producer states, Maharashtra, Karnataka, Gujarat, Tamil Nadu and Haryana, are highly efficient (98% efficiency, on average), while the efficiency of bottom five producing states(and UTs), Delhi, Sikkim, Jharkhand, Chhattisgarh and Chandigarh, is low (42% on average).

Conclusions

This paper highlights the central role of agglomeration economies in differential output or costs between industries in different states. Industries in some states can produce higher than others with the same input and technology, due to external economies generated through agglomeration. While at the same time there are differential impacts of agglomeration economies in industry groups. Urbanisation economies are present for all five industry groups, which reflects the wide scope of increasing output and productivity in India as only a small proportion of India is yet urbanised. Urban planning, thus, becomes a necessity in achieving the objectives of National Manufacturing Policy, 2011. This close relation of urbanisation and efficiency is generally neglected and planning for each is done in silos.

Localisation of industries also leads to productivity boost in industry groups 20, 21, and 27 while not in groups 10 and 11. Localisation of industrial activities is less beneficial for industries associated with primary activities and this calls for development of FPI industries in all corners of India whereby they can add value to farm products at high efficiency levels. Evidence of localisation economies in industry groups such as 20, 21 and 27 calls for identifying specialisation at state level.

Role of infrastructure, primarily highways and railways network becomes critical in increasing productivity of industries and complements external economies arising out of localisation and urbanisation. Productivity of some industries are however not critical upon availability of highways and railways network, which calls for push for such industries in areas where development of highways and railways network is difficult or is slow, example hilly areas, ecologically sensitive areas, north eastern region, etc.

As the policy preference shifts towards capital expenditure over revenue expenditure and new flagship government schemes incentivise greenfield and brownfield investments in industrial sectors, and indicative planning is adopted in the economy, utilising external economies generated from agglomeration can significantly shoot up returns on every rupee of public money invested.

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Appendix

Snapshot of SF Model for Industry group 10

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Log likelihood =     8.0460

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          l_grossvalueadded |      Coef.   Std. Err.       z    P>|z|     [95% Conf. Interval]
----------------------------+----------------------------------------------------------
Frontier                    |
              l_fixedcapital |   .5319525   .0980687     5.42   0.000     .3397414    .7241636
        l_numberofemployees |   .3285074     .10586     3.10   0.002     .1210256    .5359891
                      _cons |   2.222064   .4477308     4.96   0.000     1.344527      3.0996
----------------------------+----------------------------------------------------------
Mu                          |
            share_urban_pop |  -.5546326   .3039057    -1.83   0.068    -1.150277    .0410116
 industrial_concentration   |   1.324584   .4808591     2.75   0.006     .3821178    2.267051
       highways_per_1000ppl |  -1.211569   .5603006    -2.16   0.031    -2.309738   -.1134001
                      _cons |   .3871717   .2135685     1.81   0.070    -.0314148    .8057582
----------------------------+----------------------------------------------------------
Usigma                      |
                      _cons |  -8.501776   5.301447    -1.60   0.109    -18.89242    1.888869
----------------------------+----------------------------------------------------------
Vsigma                      |
                      _cons |  -3.594015   .3004943   -11.96   0.000    -4.182973   -3.005057
---------------------------------------------------------------------------------------
            sigma_u |   .0142516    .037777     0.38   0.706      .000079     2.57136
            sigma_v |   .1657943   .0249101     6.66   0.000     .1235034    .2225667
             lambda |   .0859594   .0438251     1.96   0.050     .0000638    .1718549
------------------------------------------------------------------------------
```

Snapshot of SF Model for Industry group 11

```
Iteration 41:  Log likelihood = -6.4908972

Stoc. frontier normal/tnormal model                 Number of obs  =        27
                                                    Wald chi2(2)   =  8.71e+09
                                                    Prob > chi2    =    0.0000

Log likelihood =    -6.4909

------------------------------------------------------------------------------------
   l_grossvalueadded |      Coef.   Std. Err.       z    P>|z|     [95% Conf. Interval]
---------------------+--------------------------------------------------------------
Frontier             |
      l_fixedcapital |   .3307995   .0762902     4.34   0.000     .1812735    .4803254
 l_numberofemployees |   .8409924   .1448279     5.81   0.000     .5571349     1.12485
               _cons |    .786115   .4219785     1.86   0.062    -.0409476    1.613178
---------------------+--------------------------------------------------------------
Mu                   |
     share_urban_pop |  -1.461788   .4330112    -3.38   0.001    -2.310475   -.6131021
   state_emp_share_11 |   18.57712   4.993899     3.72   0.000     8.789258    28.36498
highways_per_1000ppl |   -.584017   .2738166    -2.13   0.033    -1.120688   -.0473464
industrial_emp_share |   8.764219   6.062397     1.45   0.148     -3.11786     20.6463
               _cons |   1.086031   .1968282     5.52   0.000     .7002549    1.471807
---------------------+--------------------------------------------------------------
Usigma               |
               _cons |   -2.17936   .3159455    -6.90   0.000    -2.798602   -1.560118
---------------------+--------------------------------------------------------------
Vsigma               |
               _cons |  -34.28101   1501.281    -0.02   0.982    -2976.738    2908.176
------------------------------------------------------------------------------------
            sigma_u |   .3363241     .05313     6.33   0.000     .2467694    .4583789
            sigma_v |   3.60e-08    .000027     0.00   0.999            0           .
             lambda |    9349419   .0531301   1.8e+08   0.000      9349419     9349419
------------------------------------------------------------------------------
```

Snapshot of SF Model for Industry group 20

Stoc. frontier normal/tnormal model

Number of obs = 23
Wald chi2(2) = 1.85e+11
Prob > chi2 = 0.0000

Log likelihood = -5.9277

l_grossvalueadded	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
l_fixedcapital	.3736656	3.49e-06	1.1e+05	0.000	.3736588	.3736725
l_numberofemployees	.3118445	5.05e-06	6.2e+04	0.000	.3118346	.3118544
_cons	5.518474	.0000238	2.3e+05	0.000	5.518427	5.518521
Mu						
state_emp_share_20	-27.33774	10.53939	-2.59	0.009	-47.99457	-6.680904
highways_per_1000ppl	-2.786147	1.458576	-1.91	0.056	-5.644903	.0726099
ln_urban_pop	-.2874706	.198878	-1.45	0.148	-.6772643	.102323
industrial_concentration	-2.479432	2.082538	-1.19	0.234	-6.561132	1.602268
_cons	7.40664	3.616067	2.05	0.041	.3192793	14.494
Usigma						
_cons	-1.178824	.4438819	-2.66	0.008	-2.048817	-.3088317
Vsigma						
_cons	-37.46054	677.0466	-0.06	0.956	-1364.448	1289.526

sigma_u	.5546533	.1231003	4.51	0.000	.3590088	.8569156
sigma_v	7.34e-09	2.48e-06	0.00	0.998	5.2e-297	1.0e+280
lambda	7.56e+07	.1231003	6.1e+08	0.000	7.56e+07	7.56e+07

Snapshot of SF Model for Industry group 21

Stoc. frontier normal/tnormal model

Number of obs = 24
Wald chi2(2) = 994.02
Prob > chi2 = 0.0000

Log likelihood = -1.6613

l_grossvalueadded	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
l_fixedcapital	.4293982	.1258096	3.41	0.001	.182816	.6759804
l_numberofemployees	.6665888	.1554088	4.29	0.000	.3619931	.9711845
_cons	1.554089	.4257533	3.65	0.000	.7196277	2.38855
Mu						
state_emp_share_21	-2.663645	.6913582	-3.85	0.000	-4.018682	-1.308608
share_urban_pop	-.4691094	.2959473	-1.59	0.113	-1.049155	.1109367
_cons	1.544934	.1836775	8.41	0.000	1.184933	1.904936
Usigma						
_cons	-2.550883	.2956521	-8.63	0.000	-3.13035	-1.971415
Vsigma						
_cons	-31.8828	856.2928	-0.04	0.970	-1710.186	1646.42

sigma_u	.2793077	.041289	6.76	0.000	.2090514	.3731751
sigma_v	1.19e-07	.0000511	0.00	0.998	0	.
lambda	2340695	.041289	5.7e+07	0.000	2340695	2340695

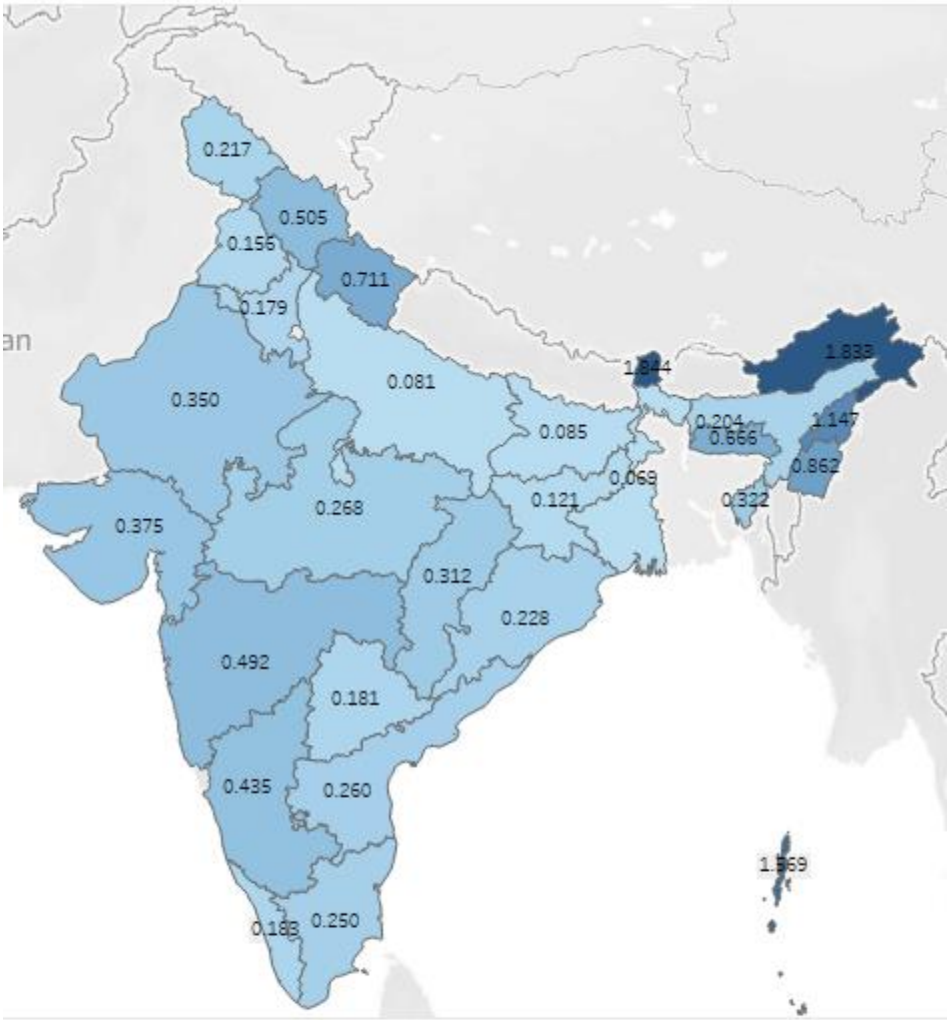
Snapshot of SF Model for Industry group 27

```
Stoc. frontier normal/tnormal model                  Number of obs =        25
                                                     Wald chi2(2)  =    116.26
                                                     Prob > chi2   =    0.0000

Log likelihood =     -3.2624
```

l_grossvalueadded	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
l_fixedcapital	.2783976	.1129834	2.46	0.014	.0569542	.499841
l_numberofemployees	.5006973	.1561188	3.21	0.001	.1947101	.8066844
_cons	3.926809	.8196714	4.79	0.000	2.320283	5.533336
Mu						
ln_urban_pop	-.6920921	.2204826	-3.14	0.002	-1.12423	-.2599541
ind_emp_share_27	11.79396	13.57235	0.87	0.385	-14.80737	38.39528
state_emp_share_27	-72.52084	17.75288	-4.09	0.000	-107.3158	-37.72584
highways_per_1000ppl	-2.339524	.6072338	-3.85	0.000	-3.52968	-1.149367
railways_per_1000ppl	-38.45518	10.53315	-3.65	0.000	-59.09978	-17.81059
_cons	15.24378	4.297299	3.55	0.000	6.821225	23.66633
Usigma						
_cons	-4.486787	3.052701	-1.47	0.142	-10.46997	1.496398
Vsigma						
_cons	-2.574807	.3484459	-7.39	0.000	-3.257748	-1.891865
sigma_u	.1060978	.1619425	0.66	0.512	.0053269	2.113191
sigma_v	.2759865	.0480832	5.74	0.000	.1961503	.3883172
lambda	.3844313	.1867638	2.06	0.040	.018381	.7504817

State wise length of highways (KM) per 1000 people



State wise length of railways (KM) per 1000 people