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Deciphering Dimensions: A State-Wise Analysis Of Return To Scale In India During The 2020-21: Through The Lens Of The Cobb-Douglas Production Function

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Abstract: This study examines the returns to scale and the significance of input elasticities in shaping regional economic performance across Indian States and Union Territories for the year 2020–21. Employing a log-linear Cobb-Douglas production function, the analysis highlights the elasticity of capital expenditure (1.15) and labor force participation rate (0.24), leading to a combined input elasticity of 1.39. While this suggests increasing returns to scale. Hypothesis testing through Restricted Least Squares (F-test) indicates that the null hypothesis of constant returns to scale cannot be rejected at a 5% significance level. This finding underscores the statistical insignificance of the observed increasing returns, suggesting a constant returns to scale scenario during the study period.

These outcomes hold significant policy implications, advocating for strategic public investments and labor market interventions to optimize resource allocation and enhance economic performance. The research contributes to the literature on regional production efficiency, offering actionable insights for policymakers to foster sustainable and balanced growth.

KEYWORDS: Gross State Domestic Product, State-wise capital expenditure, State-wise Labor Force Participation Rate, Cobb-Douglas Production Function, Return to Scale, F-Test Approach

I. INTRODUCTION

"The notion of returns to scale has been central to economic theory since the development of production functions by Cobb and Douglas (1928). It provides insights into the relationship between input factors, such as labor and capital, and their combined impact on output. Empirical studies examining returns to scale often aim to determine whether increasing inputs leads to proportional, more-than-proportional, or less-than-proportional changes in output, thereby identifying increasing, constant, or decreasing returns to scale, respectively" (Samuelson & Nordhaus, 1989)

"In the context of regional economics, the assessment of returns to scale has particular relevance for policy formulation. Regions with increasing returns to scale can leverage complementarities between inputs to achieve higher growth rates". (Barro & Sala-i-Martin, 1995). "However, accurate measurement of input elasticities is critical to understanding the dynamics of capital and labor allocation, which can vary significantly across regions due to differences in economic structures, resource availability, and policy interventions" (Fujita et al., 1999).

The concept of returns to scale is fundamental in assessing production efficiency and regional economic performance. This research builds upon a well-established foundation of economic literature, which emphasizes the role of input elasticities and returns to scale in driving output growth across different regions.

The concept of returns to scale is central to understanding regional production dynamics. Increasing returns, as observed in this study, indicate that a proportional increase in inputs leads to a more than proportional increase in output. This finding has implications for designing policies that maximize economic output by leveraging complementarities between capital and labor inputs.

However, the significance of input elasticities is critical for policy formulation. Previous studies highlight the need for robust statistical validation to ensure the reliability of elasticity estimates. The present study addresses this by employing hypothesis testing and model validation to confirm the statistical significance of its findings, thereby strengthening its contributions to the literature.

II. Research Objective:

To Examine the Return to Scale of the Gross State Domestic Product (GSDP) across Indian States and Union Territories for the year 2020-21.

III. Literature Review:

“The Indian economy, characterized by its regional diversity, provides a rich context for examining returns to scale. Several studies have highlighted disparities in economic performance across states, often attributed to variations in capital investments, labor market conditions, and governance quality” (Ahluwalia, 2000; Sharma et al., 2012). “The elasticity of inputs, such as capital expenditure and labor force participation, has been a focal point in analyzing state-wise Gross State Domestic Product (GSDP)” (Dash & Sahoo, 2010).

“Numerous studies have been employed to analyze regional productivity differences, including applications in developing economies, where disparities in infrastructure and workforce participation often influence production outcomes” (Chatterjee, 2015; Mishra et al., 2017).

“However, findings regarding returns to scale in India have been mixed. While some studies suggest the presence of increasing returns to scale in states with higher infrastructure investments and industrial concentration, others highlight the prevalence of constant returns to scale in regions where input elasticities exhibit limited variability” (Mukherjee & Karmakar, 2019). These findings underline the importance of hypothesis testing to ascertain whether observed trends are statistically significant or simply reflective of random variations in the data.

“The interplay between capital and labor inputs has significant implications for regional development policies. Prior research suggests that increasing public investments in infrastructure and enhancing labor market participation can stimulate economic growth, particularly in states with underutilized resources” (Planning Commission of India, 2006). “However, the efficacy of such interventions depends on accurately estimating the returns to scale and understanding the complementarities between inputs” (Bhattacharya & Patel, 2020).

“Recent studies emphasize the need for robust statistical methodologies to validate the findings derived from the Cobb-Douglas model. For example, F-tests and Restricted Least Squares methods are commonly employed to test hypotheses concerning returns to scale, ensuring the reliability and statistical significance of estimated parameters” (Gujarati, 2003). This methodological rigor is particularly important for deriving actionable policy insights.

The current study's focus on testing the statistical significance of input elasticities and returns to scale contributes to this body of literature by providing robust empirical evidence for the year 2020–21. By employing the Cobb-Douglas production function and hypothesis testing through Restricted Least Squares, the study adds methodological rigor to the analysis of regional production efficiencies in India. Its findings, which suggest constant returns to scale, challenge the notion of increasing returns observed in raw input elasticities, thereby offering nuanced insights for policymakers aiming to achieve balanced and sustainable growth.

IV. Methodology:

The methodology for this study involves the following key components to analyze the Gross State Domestic Product (GSDP) elasticity of state-wise capital expenditure and labor force participation rates using the Cobb-Douglas production function:

1. **Research Design**

This research adopts a quantitative approach to find out the return to scale whether it is constant, increasing or decreasing. The log-linear Cobb-Douglas production function is used. To know if the finding is statistically significant or not, F-Test Approach is used. For F-Test approach Cobb-Douglas production function Model is modified as Unrestricted Least Square Regression Model and Restricted Least Square Regression Model.

Here in this analysis the log-linear form of Cobb-Douglas production function is considered as the Unrestricted Least Square Regression Model. After applying Linear Equality restriction i.e. ($ß_2 + ß_3 = 1$) to the log-linear form of Cobb-Douglas production function the modified model is called as Restricted Least Square Regression Model. Both The models are applied to data from 31 Indian States and Union Territories for the fiscal year 2020-21.

2. **Model Specification**

A) Unrestricted Least Square Regression Model:

$$\ln Q = ß_0 + ß_2 \ln K + ß_3 \ln L + u \quad \text{……… (6.2)}$$

B) Restricted Least Square Regression Model:

$$\ln (Q/L) = ß_0 + ß_2 (K/L) + u \quad \text{……………. (6.3)}$$

3. **Data Collection**

Data Sources: Secondary data of the year 2020-21 is used for this analysis. This data was published by the National Statistical Office, Ministry of Statistics and Program Implementation, Government of India, Reserve Bank of India and Ministry of Statistics and Program Implementation.

V. Data Collection and Source:

"The Indian economy, characterized by its regional diversity, provides a rich context for examining returns to scale. Several studies have highlighted disparities in economic performance across states, often attributed to variations in capital investments, labor market conditions, and governance quality" (Ahluwalia, 2000; Sharma et al., 2012). "The elasticity of inputs, such as capital expenditure and labor force participation, has been a focal point in analyzing state-wise Gross State Domestic Product (GSDP)" (Dash & Sahoo, 2010).

Table 5.1: Gross State Domestic Product, State-Wise Capital Expenditure and State-wise Labor Force Participation Rate of the period 2020-21.

Sr.No.	State/Union Territory	(Q) GROSS STATE DOMESTIC PRODUCT 2020-21 (₹ Lakh)	STATE-WISE CAPITAL EXPENDITURE 2020-21 (RE) (₹ Crore)	(K)STATE-WISE CAPITAL EXPENDITURE 2020-21 (RE) (₹ Lakh)	(L)State-wise Labor Force Participation Rate for age 15 years & above at usual status during the period 2020-21 (in %) All India (Rural + Urban) Persons
1	Andhra Pradesh	101437379	32478	3247800	61.1
2	Arunachal Pradesh	3127309	6689	668900	51.4
3	Assam	34017745	26330	2633000	52.7
4	Bihar	58715439	46032	4603200	41.9
5	Chhattisgarh	35026983	14807	1480700	65.2
6	Delhi	78534162	12785	1278500	45.6
7	Goa	7570540	4927	492700	48.5
8	Gujarat	163678141	37647	3764700	56.3
9	Haryana	75850653	23150	2315000	46.9
10	Himachal Pradesh	15667506	9875	987500	71.9
11	Jammu &Kashmir U.T.	17020073	40832	4083200	59.0
12	Jharkhand	30071593	12186	1218600	61.6
13	Karnataka	173099141	50230	5023000	56.9
14	Kerala	79957111	20315	2031500	51.3
15	Madhya Pradesh	97628148	43085	4308500	61.4
16	Maharashtra	271168512	101665	10166500	56.0
17	Manipur	3411021	4993	499300	43.4
18	Meghalaya	3471870	2830	283000	63.1
19	Mizoram	1802616	1792	179200	56.5
20	Nagaland	3042511	2708	270800	61.3
21	Odisha	53265168	30136	3013600	56.5
22	Puducherry	3568471	1209	120900	51.6
23	Punjab	53255526	20202	2020200	50.4
24	Rajasthan	101332301	34877	3487700	58.1
25	Sikkim	3180007	1778	177800	72.1
26	Tamil Nadu	180823943	60222	6022200	60.0
27	Telangana	96180037	32645	3264500	60.8
28	Tripura	5441512	2417	241700	55.6
29	Uttar Pradesh	164856708	94788	9478800	50.1
30	Uttarakhand	23466020	10152	1015200	52.3
31	West Bengal	130101677	36498	3649800	54.9

1. **Data Source:**
   i) *Gross State Domestic Product (Current Prices), National Statistical Office, Ministry of Statistics and Program Implementation, Government of India.*
   ii) *State-Wise Capital Expenditure 2020-21 (Re) (₹ Crore) 'Handbook of Statistics on State Government Finances-2010' and 'State Finances: A Study of Budgets', Reserve Bank of India, various issues.*
   iii) *State-wise Labor Force Participation Rate for age 15 years & above at usual status during the period 2017-18 to 2019-20: All India (Rural + Urban). Periodic Labor Force Annual Survey Reports, Ministry of Statistics and Program Implementation.*

2. **Data Note:**

   iv) *As of October 2021, India has 28 states and 8 union territories that is total 36. But the Data of Gross State Domestic Product is not available for four union territories: Andaman & Nicobar Islands, Ladakh, Dadra and Nagar Haveli and Daman and Diu, Lakshadweep. Furthermore, the Data of State-Wise Capital Expenditure is not available for five union territories: Andaman & Nicobar Islands, Chandigarh, Dadra and Nagar Haveli and Daman and Diu, Ladakh, Lakshadweep. Therefore, for the study, a dataset of 31 states and union territories is used.*
   v) *State-Wise Capital Expenditure data which was published by Reserve Bank of India in 'Handbook of Statistics on State Government Finances-2010' and 'State Finances: A Study of Budgets', Reserve Bank of India, various issues, was in Crore Rs. But Gross State Domestic Product data which was published by National Statistical Office, Ministry of Statistics and Program Implementation, Government of India, Was in Lakh Rs. we know that one crore is equal to hundred lakhs, therefore to convert State-Wise Capital Expenditure in the same unite as Gross State Domestic Product is, the State-Wise Capital Expenditure data is multiplied with hundred.*

VI. DATA ANALYSIS:

The famous Cobb-Douglas production function is as:

$$Q = \beta_1 K^{\beta_2} \times L^{\beta_3} \varepsilon^{\mu} \text{……………. (6.1)}$$

By taking Natural log on both side the function become as log-linear model as follows:

$$\ln Q = ß_0 + ß_2 \ln K + ß_3 \ln L + u \text{………… (6.2)}$$

This model is considered as the Unrestricted Least Square Regression Model.

Where $ß_0 = \ln ß_1$

This modification to the Cobb-Douglas production function allows for linear equality restrictions on the parameters of capital and labor. A common restriction in economic theory is constant returns to scale, which requires:

$$ß_2 + ß_3 = 1.$$

This implies that if capital and labor inputs double, output also doubles. This is an example of a linear equality restriction, as it expresses a linear relationship between parameters.

Under the linear equality restrictions on the parameters of capital and labor we have;

$ß_2 + ß_3 = 1$. This restriction can be written as $ß_2 = 1 - ß_3$. or $ß_3 = 1 - ß_2$.

Therefore, using either of these equalities, we can eliminate one of the ß coefficients in the log-linear model, that is:

$$\ln Q = ß_0 + ß_2 \ln K + ß_3 \ln L + u \text{………… (6.2)}$$

Now if we use $ß_3 = 1 - ß_2$, linear equality restrictions, we can write the log-linear model, that is:

$$\ln Q = ß_0 + ß_2 \ln K + ß_3 \ln L + u \ldots\ldots\ldots\ldots (6.2)$$

as follows,

$$\ln Q = ß_0 + ß_2 \ln K + (1 - ß_2) \ln L + u.$$
$$\therefore \ln Q = ß_0 + ß_2 \ln K + \ln L - ß_2 \ln L + u.$$
$$\therefore \ln Q = ß_0 + + \ln L + ß_2 \ln K - ß_2 \ln L + u.$$
$$\therefore \ln Q = ß_0 + \ln L + ß_2 (\ln K - \ln L) + u.$$
$$\therefore \ln Q = n L = ß_0 + ß_2 (\ln K - \ln L) + u.$$

$$\therefore \ln (Q/L) = ß_0 + ß_2 (K/L) + u \ldots\ldots\ldots\ldots\ldots\ldots (6.3)$$

This procedure is known as Restricted Least Square.

To compare the Unrestricted and Restricted Least Square regression or, to know that the restriction $ß_3 = 1 - ß_2$ is valid, the F-Test Approach is used. In other words, To Examine the Constant Return to Scale of the Gross State Domestic Product (GSDP) across Indian States and Union Territories for the year 2020-21, F-Test Approach is used.

$$F = \frac{(RSSS_R - RSS_{UR})/m}{RSS_{UR}/(n-k)}$$

This F-statistic Follows the F distribution with m degree of freedom in the numerator and (n-k) degree of freedom in the denominator.

Here;

1. RSS_R = Residual Sum Square of the Restricted Regression.
2. RSS_{UR} = Residual Sum Square of the Unrestricted Regression.
3. m = Number of Linear Restrictions.
4. k = Number of Parameters in the Unrestricted Regression.
5. n = Number of Observations.

1. Unrestricted Least Square Regression Model.

$$\ln Q = ß_0 + ß_2 \ln K + ß_3 \ln L + u \ldots\ldots\ldots\ldots\ldots\ldots (6.2)$$

Table 6.1.1: Regression Statistics

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.05969123	3.85385236	-0.01548871	0.987752125
ln K	1.146834929	0.090858351	12.62222913	0.0
ln L	0.240368941	0.869236710	0.276528749	0.784173021

The unrestricted least squares regression model estimates the relationship between output (Q), capital (K), and labor (L) using a log-linear specification:

$$\ln Q = -0.05969123 + 1.146834929 \ln K + 0.240368941 \ln L + u$$

The regression results indicate that the intercept ($ß_0$) is approximately -0.0597, but it is statistically insignificant with a very high p-value of 0.988, implying that it does not contribute meaningfully to the model. The coefficient of lnK (capital), estimated at 1.1468, is highly significant with a small standard error (0.0909) and a t-statistic of 12.6222, indicating a strong positive relationship between capital and output. This suggests that a 1% increase in capital leads to approximately a 1.15% increase in output, holding labor constant. On the other hand, the coefficient of lnL (labor) is 0.2404, but it is not statistically significant, given its large standard error (0.8692), a very low t-statistic (0.2765), and a high p-value of 0.7842. This implies that, in this model, variations in labor input do not significantly explain variations in output. The results suggest that capital plays a dominant role in determining output, while labor's contribution is not statistically discernible.

Table 6.1.2: ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	60.88906233	30.44453117	80.27315862	0
Residual	28	10.6193264	0.3792616572		
Total	30	71.50838873			

The ANOVA (Analysis of Variance) table for an Unrestricted Least Squares Regression Model decomposes the total variation in the dependent variable (lnQ) into two components: Regression Sum of Squares (SS) and Residual (Error) Sum of Squares (SS). The regression sum of squares is 60.89, which indicates the variation explained by the model, while the residual sum of squares is 10.62, representing the unexplained variation. The total sum of squares, which is the sum of these two components, is 71.51. The degrees of freedom (df) for regression are 2 (corresponding to the two explanatory variables, lnK and lnL), and for residuals, it is 28 (total observations n=30 minus the number of estimated parameters including the intercept). The mean square regression (MSR) is 30.44, and the mean square error (MSE) is 0.38. The F-statistic of 80.27 is used to test the overall significance of the model, and the associated Significance F value is 0, suggesting that the regression model is highly significant in explaining variations in lnQ.

2. Restricted Least Square Regression Model.

$$\ln (Q/L) = \beta_0 + \beta_2 (K/L) + u \ldots\ldots\ldots\ldots\ldots (6.3)$$

Table 6.2.1: Regression Statistics

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.580735638	0.8999524611	1.756465709	0.08956546787
ln (K/L)	1.138471164	0.08758394591	12.99862837	0

The regression results indicate that the intercept (β_0) is approximately 1.5808, which is statistically significant with a very low p-value of 0.089. The coefficient of ln (K/L) (Capital Labor ratio), estimated at 1.1384, is highly significant with a small standard error (0.0875) and a t-statistic of 12.9986, indicating a strong positive relationship between labor productivity and capital labor ratio. In other words, in the year 2020-21 in Indian States & Union Territories a 1 percent increase in the capital labor ratio led to on an average to about 1.14 percent increase in labor productivity.

Table 6.2.2: ANOVA

	df	SS	MS	F	Significance F
Regression	1	62.29614316	62.29614316	168.9643394	0
Residual	29	10.69212686	0.3686940296		
Total	30	72.98827002			

The ANOVA (Analysis of Variance) table of Restricted Least Squares model provides statistical insights into the model's fit. The regression sum of squares (SS) is 62.30, with 1 degree of freedom (df), indicating the explained variation in labor productivity due to the capital-labor ratio. The residual SS is 10.69, with 29 degrees of freedom, representing the unexplained variation. The total sum of squares is 72.99, which accounts for the total variation in the dependent variable. The Mean Square (MS) for regression is 62.30, while for the residuals, it is 0.37. The F-statistic of 168.96 is significantly high, and the Significance F (p-value) is 0, suggesting that the ln(K/L) has a highly significant effect on ln(Q/L). This implies a strong explanatory power of the model, affirming that variations in ln(K/L) play a crucial role in determining ln(Q/L).

VII. Hypothesis Testing:

From unrestricted least squares regression model, that is Log-linear Cobb-Douglas production function We see that in the Indian State & Union Territories for the year 2020-21, the Gross State Domestic Product elasticity of State-wise Capital Expenditure and State-wise Labor Force participation rate were 1.15 and 0.24, respectively.

In other words, over the 31 Indian States and Union Territories, holding the State-wise Labor Force participation rate constant, a 1 percent increase in the State-wise Capital Expenditure led to on the average to about a 0.15 percent increase in the Gross State Domestic Product. Similarly, holding the State-wise Capital Expenditure constant, a 1 percent increase in the State-wise Labor Force participation rate led on average to about a 0.24 percent increase in Gross State Domestic Product.

Adding the two input elasticities, we obtain 1.39, which gives the value of the returns to scale parameter. As is evident, the Indian States & Union Territories was characterized by increasing returns to scale in the year 2020-21. But the question arises that 'is this finding a significant one? To compare the Unrestricted and Restricted Least Square regression or, to know that the restriction ß3 = 1 - ß2 is valid, the F-Test Approach is used. In other words, To Examine the Return to Scale of the Gross State Domestic Product (GSDP) across Indian States and Union Territories for the year 2020-21, F-Test Approach is used.

1. ***Null Hypothesis:***

   H_0: $ß_3 = 1 - ß_2$

   In the year 2020-21 in Indian States & Union Territories there was constant return to scale.

2. ***Alternative Hypothesis:***

   H_1: $ß_3 \neq 1 - ß_2$

   In the year 2020-21 in Indian States & Union Territories there was not constant return to scale.

3. ***F-Test Approach:***

$$F = \frac{(RSSS_R - RSS_{UR})/m}{RSS_{UR}/(n-k)}$$

   1. RSS_R = 10.6921268597963 (Residual Sum Square of the Restricted Regression).
   2. RSS_{UR} = 10.6193264011342 (Residual Sum Square of the Unrestricted Regression).
   3. m = 1 (Number of Linear Restrictions).
   4. k = 3 (Number of Parameters in the Unrestricted Regression).
   5. n = 31 (Number of Observations).

$$F = \frac{(10.6921268597963 \ - 10.6193264011342)/1}{10.6193264011342/(31-3)} = 0.191953120710135$$

This F-statistic Follows the F distribution with 1 degree of freedom in the numerator and 28 degrees of freedom in the denominator. The P-value (i.e. the exact level of significance) is that if the null hypothesis were true, the probability of obtaining a F value of as much as 0.191953120710135 or greater (in absolute terms) is 0.664657568308864, which is indeed an extremely large probability, much larger than the artificially adopted of a = 5%. Accept the Null Hypothesis that is H_0: $ß_3 = 1 - ß_2$ and reject the Alternative Hypothesis.

In other words, in the year 2020-21 in India Indian States & Union Territories, was characterized by constant return to scale.

VIII. Conclusion:

By summing the two input elasticities, we obtain a value of 1.39, which represents the returns to scale parameter. This suggests that Indian States and Union Territories exhibited increasing returns to scale in 2020-21. However, the key question is whether this finding is statistically significant. To assess this, we compare the Unrestricted and Restricted Least Squares regressions using the F-Test Approach, which evaluates the validity of the restriction $ß_3 = 1 - ß_2$. Specifically, the F-Test is employed to examine the returns to scale of Gross State Domestic Product (GSDP) across Indian States and Union Territories for 2020-21. The p-value associated with the F-Test is 0.6647, which exceeds the 0.05 significance level. Consequently, we fail to reject the null hypothesis (H_0: $ß_3 = 1 - ß_2$) and reject the alternative hypothesis. This indicates that, despite the initial estimate, Indian States and Union Territories were actually characterized by constant returns to scale in 2020-21.

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