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Assessing The Role Of Technology In The Cobb-Douglas Production Function: Evidence From India's Major Industries

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ABSTRACT

The paper aims to estimate the Cobb- Douglas production function for major industries, as given in ASI (An- nual Survey of Industries India). The function was assessed for twenty-nine (two-digit) Industries from 2011 to 2021 with time trend and without time trend. It is observed that (a) there are inter-industry differences in efficiency parameters, the highest efficiency was observed in other non-metallic mineral products industry in both cases, (b) more than sixty per cent of industries observed with positive exponents of labour and capital in contrast to approximately forty-one per cent in production function with time trend(c) except eight industries in total, remaining all the industries exhibiting increasing returns in Cobb – Douglas production function without technological change. Only eight industries indicated strong returns with the technological change (time trend).
(d) the upper three industries with the highest growth rate of technological change were showing decreasing returns to scale.

KEYWORDS

Industries, Cobb-Douglas production function, returns to scale, Total Factor Productivity

1. *Introduction*

There are many studies related to the estimation of production function. However, the Cobb-Douglas function is widely adopted in economics due to its simplicity and possession of essential properties praised by economists. The Douglas-type production remained a good fit for the Indian Industrial data and was used in empirical studies.[1] Despite its perception as a simplification in economic theory, it proves highly robust across diverse applications (Brown, 2018). Generally, Cobb-Douglas functions as a utility function; when labour and capital are chosen as inputs, it gives us a production function, and when adjusted for normalized prices, it transforms into an indirect utility function. An impressive feature of this function is that its coefficients are related to the degree of homogeneity computed by aggregating the output elasticities of inputs. This function's unitary substitution elasticity characteristic makes it commendable for growth models.

Moreover, it mandates that each production factor is important, preventing complete substitution between factors and thus restricting the function's domain to strictly positive real numbers. Fluctuations in the total factor productivity parameter A indicate technological changes in the Cobb-Douglas function. The hick's neutral function considers this technological change. The unit elasticity of substitution imposes constraints by not accommodating technological progress, which alters the ease of substituting production factors.

2. *Objective*

- To evaluate the Cobb-Douglas production function with and without technological change
- To analyze the estimates of output elasticity of inputs, returns to scale, efficiency parameter, and rate of growth of technological change

[1]*For example, see Murti and Sastry [1]*

3. *Methodology*

Most empirical studies[2] applied Cobb- Douglas production function on a particular segment of the industry or industries of a special region. However, our study examines each industry separately, covering all the major (two-digit) industries given in the ASI (Annual Survey of Industries). The Ministry of Statistics and Programme Implementation (MoSPI), Government of India published the data. To compute the Cobb-Douglas production function, the paper required time series data on the value of the output (Q), number of workers (L), and fixed capital (K) for the period 2011-12 to 2021-22. The Cobb-Douglas production function was used with constant technology and with a rate of growth in technological change (Hick's neutral).

1. Cobb-Douglas production function (without time trend) mathematically can be expressed as: -

$$X = A.L^{b1}.K^{b2} \quad (1)$$

Where X represents the output value, L shows the number of workers, and K illustrates fixed capital. This form facilitates the conversion of the algebraic expression into a log-linear form, illustrated as follows:

$Ln (X) = ln(A) + b_1 \, Ln (L) + b_2 \, Ln (K)$

The estimation of this production function involved linear regression analysis. It operates as a homogeneous production function, with its degree determined by the sum of the values of b_1and b_2. The function represents the following types of scales:

- if, $b_1 + b_2 > 1$ (Increasing returns)
- if, $b_1 + b_2 = 1$ (Constant returns)
- if, $b_1 + b_2 < 1$ (Decreasing returns)

Then, after taking the logarithmic form of the production function, the OLS (ordinary least square) method was used. we computed the values of the following variable by using SPSS: -

A = Total factor productivity

b_1 = Output elasticity of Labor

b_2 = Output elasticity of Capital

$b_1 + b_2$ = Degree of homogeneity or Returns to Scale

2. Cobb-Douglas production function (with time trend): - Technology is not constant in this case and can take various forms.[3] The study used the Hicks neutral disembodied exponential technical change production function. Mathematically, the function can be expressed in the form: - with

$A_t = A_0 e^{\lambda t}$ therefore, equation becomes: -

$$X_t = A_0 e^{\lambda t} L^{b1}.K^{b2} \quad (2)$$

Here, t represents the year and A_0 is another constant parameter. The rate of growth of technological change[4] is λ, which grows exponentially over time, affecting output levels without changing the relative marginal products of labour and capital. This feature makes the Hicks neutral production function useful for analyzing long-term economic growth trends and productivity changes in an economy.

Results and Estimation of Cobb- Douglas Production Function

From equations (1) and (2) parameters A, b_1, b_2 and λ were estimated with the help of the ordinary least squares (OLS). Table 1 gives the names and codes of the major industries. Until 2012-13, the industries under codes 01 and 08 were named 'crop & animal production, hunting & related service activities' and 'other mining and quarrying'. Afterwards, the names were changed, as shown in Table 1.

[2] *For example, see Iyer [2], Ulveling and Fletcher [3], and Narayana [4]*

[3] *For example, see Bhasin and Seth [5]*

[4] *For time (t) we will take values 1, 2, ……. Up to eleven, and will regress Ln(Xt) on t, Ln(L), and Ln(K) to get the value of λ, ,A0, ,b1, and ,b2,*

TABLE 1

Annual Survey of Industries -2008 (Major industries)

S. No.	Name of the Industry	Group No
1	other industries	Ot
2	cotton cleaning, ginning, and bailing; seed processing for propagation	1
3	salt production by saline waters or by evaporation	8
4	pharmaceuticals, botanical products, and medicinal chemicals	21
5	other manufacturing	32
6	tobacco products	12
7	electrical equipment	27
8	wearing apparel	14
9	printing and reproducing recorded media	18
10	repair and installation of equipment and machinery	33
11	beverages	11
12	leather products	15
13	motor vehicles semi-trailers, and trailers	29
14	chemical products and chemicals	20
15	food products	10
16	transport equipment (other)	30
17	plastic and rubber products	22
18	basic metals	24
19	coke and refined petroleum products	19
20	computer, optical products and electronic	26
21	textiles	13
22	equipment and machinery	28
23	non-metallic mineral products (other)	23
24	fabricated metal products (except machinery and equipment)	25
25	waste collection, disposal activities and treatment; materials recovery	38
26	paper products and paper	17
27	manufacture of furniture	31
28	publishing activities	58
29	products of wood and cork, and wood (except furniture)	16

Source: MoSPI

The results of the estimates are presented in Table 2 and Table 3, respectively. The unrestricted form of the Cobb-Douglas with constant efficiency parameter showed positive results of output elasticity of labour and capital in the case of Pharmaceuticals, botanical products, medicinal chemicals, Other manufacturing, Tobacco products industry, Wearing apparel, Printing and reproducing recorded media, Repair and installation of equipment and machinery, beverages, leather, food products, Plastic and rubber products, Basic metals, Coke and petroleum industry, Textiles, Equipment and machinery, Fabricated metal products, Waste collection, treatment & disposal activities; materials recovery, Paper products and paper and products of wood and cork and wood (except furniture). The output elasticity of capital turned out positive for industries except for industries such as Salt production by saline waters or by evaporation, Electrical equipment, Motor vehicles, semi-trailers and trailers, Chemical products and chemicals, Computers, optical products, and electronic and Publishing activities. The output elasticity of labour was negative for Cotton cleaning, ginning, and bailing; seed processing for propagation; salt production by saline waters or by evaporation; transport equipment (other); non-metallic mineral products (other); manufacture of furniture and was positive for remaining twenty-four industries.

In these industries, the coefficient of labour was found statistically significant for other manufacturing, Tobacco manufacturing, wearing apparel, Printing and reproducing recorded media, Repair and installation of equipment and machinery, Basic metals, Textiles, Machinery and equipment, Waste collection, disposal activities, and treatment; materials recovery, and Products of wood and cork, and wood (except furniture). The exponent of capital was found statistically significant for Pharmaceuticals, botanical products, medicinal chemicals, Other manufacturing, Tobacco, Wearing apparel, Repair and installation of equipment and machinery, Plastic products and rubber, Paper products and paper, and Products of wood and cork and wood (except furniture).

The exponent of both inputs was statistically significant in the case of other industries, other manufacturing, tobacco products industry, apparel wear, and repair and installation of equipment and machinery. Moreover, in some industries- Cotton cleaning, ginning, and bailing; seed processing for propagation; Salt production by saline waters or by evaporation; transport equipment (other), Non-metallic mineral products (other); manufacture of furniture – the exponent of labour was negative but statistically insignificant while in industries- Other industries, Salt production by saline waters or by evaporation, chemicals Chemical products and chemical, Computer, optical products and electronic, Publishing activities- the exponent of capital was statistically insignificant and negative.

TABLE 2

Estimates of Cobb- Douglas Production Function (Without trend)

S. No	b_1	b_2	b_1+b_2	R^2	A
1	0.81	-0.22	0.59	0.64	10.75
2	-0.15	0.32	0.17	0.16	13.21
3	-0.10	-1.50	-1.6	1.96	4.22
4	0.30	0.95	1.25	0.99	-1.77
5	0.55	0.74	1.29	0.99	-1.91
6	0.71	0.83	1.54	0.79	-5.09
7	3.84	-0.61	3.23	0.99	-26.69
8	1.35	0.33	1.68	0.92	-7.25
9	0.62	0.37	0.99	0.89	2.43
10	0.32	0.87	1.19	0.87	-0.62
11	1.05	0.14	1.19	0.92	0.87
12	0.64	0.56	1.2	0.43	-0.44
13	0.27	-0.08	0.19	0.01	16.66
14	1.62	-0.06	1.56	0.90	-2.50
15	0.14	0.92	1.06	0.94	0.31
16	-0.10	0.98	0.88	0.95	2.68
17	1.35	0.88	2.23	0.73	-16.25
18	1.89	0.45	2.34	0.88	15.55

19	0.97	0.49	1.46	0.41	-3.11
20	1.33	-0.04	1.29	0.60	1.18
21	1.45	0.07	1.52	0.86	-2.89
22	1.21	0.06	1.27	0.91	0.12
23	-5.97	3.74	-2.23	0.36	36.44
24	1.29	0.25	1.54	0.83	-3.38
25	1.14	0.07	1.21	0.77	0.95
26	0.26	0.50	0.76	0.88	6.32
27	-0.20	1.31	1.11	0.47	-1.07
28	1.14	-0.03	1.11	0.82	3.46
29	1.14	0.08	1.22	0.45	1.50

The time trend variable as a proxy of technological change provided the rate of technological change λ in Cobb Douglas production function but also led to a change in the coefficients of capital and labour. In Table 3 the coefficients inputs improved in Other industries, Publishing activities and Products of wood and cork, and wood (except furniture industries); a decrease in the exponent of both was observed in Tobacco products, Chemical products and chemicals, Food products, Plastic products and rubber, Basic metals, Coke and refined petroleum products industry, Computer, optical products and electronic, Textiles, Equipment and machinery, Non-metallic mineral products (Other), Fabricated metal products (except machinery and equipment), Waste collection, disposal activities and treatment; materials recovery, and paper products and paper industries.

The sum of two exponents or return to scale showed improvement in other industries, Salt production by saline waters or by evaporation, Pharmaceuticals, botanical products, medicinal chemicals, Leather products, Publishing activities, and products of wood and cork, and wood (except furniture) industries. The returns to scale were the same in cotton cleaning, ginning, and bailing, as well as seed processing for the propagation industry. In all the remaining twenty-three industries, the sum of exponents was lower in Table 3 than in Table 2. While observing Table 3, it was found that the rate of technological change was positive in all industries except Salt production by saline waters or by evaporation and Transport equipment (other) industries. The industries were classified into three categories3: above average ($\lambda > .10$), below average ($\lambda < .05$), and average ($.05 < \lambda < .10$). it was observed that the rate of technological change was in the above-average category for Printing and reproducing recorded media, Food products, and Non-metallic mineral products (other) industries. for Repair and installation of equipment and machinery, Motor vehicles, semi-trailers and trailers, Chemical products and chemicals, Plastic products and rubber, Basic metals and computers, optical products and electronic industries λ come within the average category. For the remaining twenty industries, the rate of technological change was below average.

TABLE 3

Estimates of Cobb- Douglas Production Function (With time trend)

S. No	b_1	b_2	b_1+b_2	R^2	A	λ
1	0.90	-0.19	0.71	0.66	9.32	0.005
2	0.12	0.05	0.17	0.36	13.51	0.03
3	-1.50	1.96	0.46	0.97	4.22	-0.10
4	0.74	0.57	1.31	0.99	-1.86	0.02
5	0.82	0.37	1.19	0.99	0.36	0.02
6	0.51	0.71	1.22	0.88	-0.94	0.02
7	3.50	-0.50	3	0.99	-23.68	0.009
8	0.91	0.41	1.32	0.93	-2.45	0.01
9	1.88	-1.26	0.62	0.92	8.78	0.99
10	0.83	-0.59	0.24	0.90	12.83	0.08
11	0.46	0.34	0.8	0.98	4.70	0.05
12	1.82	0.31	2.13	0.62	-10.69	0.03
13	0.67	-0.99	-0.32	0.58	27.16	0.10

14	0.70	-0.31	0.39	0.93	13.49	0.07
15	-0.79	0.16	-0.63	0.96	24	0.12
16	0.48	-2.03	-1.55	0.95	-8.59	-0.07
17	-0.30	0.01	-0.29	0.92	20.57	0.08
18	1.18	-0.5	0.68	0.90	12.16	0.06
19	0.84	-0.34	0.5	0.85	10.76	0.04
20	0.01	0.13	0.14	0.90	13.84	0.09
21	0.35	-0.01	0.34	0.92	12.36	0.04
22	0.97	-0.29	0.68	0.93	8.94	0.04
23	-7.60	2.59	-5.01	0.37	76.58	0.16
24	0.60	-0.05	0.55	0.96	9.60	0.05
25	0.46	0.06	0.52	0.92	8.14	0.05
26	0.22	0.49	0.71	0.88	6.96	0.00
27	-0.01	0.77	0.76	0.53	3.79	0.04
28	1.83	0.06	1.89	0.85	-3.82	-0.08
29	1.25	1.19	2.44	0.45	-0.84	0.00

4. Conclusion

The results pointed out that there were only two industries in which output elasticities of capital and labour were positive and statistically significant in both the forms of Cobb Douglas production function, and these industries were the other manufacturing and Tobacco products industries. The industry with the highest returns to scale was electrical equipment, and the one with the lowest returns but highest total factor productivity was the other non-metallic mineral products industry. with the rate of technological growth, which was λ, the Printing and reproduction of recorded media industry was at the top. Overall, sixty-one per cent of industries had positive output elasticities of capital and labour. the percentage was close to forty-one in the Cobb-Douglas production function with a time trend significantly lower than in the previous case. The sum of exponents (returns to scale) except for eight industries was more than one, demonstrating increasing returns. In contrast, only eight industries indicated increasing returns for Cobb–Douglas with time trend production function.

5. *Scope of the study*

The production function (Cobb-Douglas) assumes that the elasticity of substitution is one. Therefore, it would be interesting to know the different elasticities of substitution for all the twenty-nine Indian industries with the help of other production functions like C.E.S. Another interesting question is that despite the high rate of technological change and high factor productivity in Printing and reproducing recorded media, Food products, and Non-metallic mineral products (other) industries, these industries follow decreasing returns to scale. Does the high rate of productivity with decreasing returns to scale reflect inefficiency? More than half of Indian industries with a rate of technological growth were negative in at least one of the exponents of capital and labour. Therefore, there is still a lot of scope to analyze this study further to understand Indian industries in depth and to make policy implications.

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