Cointegration Test between Industrial Value Addition and Factors of Production

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Abstract

Purpose of the study: In this study, an initiative has been taken to understand relationship of capital and labour input with the industrial value addition.

Study design/ methodology/approach: To understand such relationship, yearly time series data from 1981 to 2017 have been taken in the Cobb-Douglas production function. Empirical statistical analyses have been made on the basic Cobb-Douglas production function in regression equation form, and auto regressive distributed lag method has been applied to understand the long-term relationship between dependent and independent variable.

Findings: The study shows that in the basic model, capital has significant positive impact and labour input has no significant impact. But in case of long-run, capital input has negative relationship with the industrial value addition.

Keywords: *Industrial Value Addition, India, ARDL Approach, Cobb-Douglas, Cointegration*

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Introduction: The Government of Indian publishes 'Survey of Industries' report on regular. The industrial sector plays an important role in the Indian economy and the Government makes policies to improve performance of this sector. The report contains all the input factors and output information on yearly and quarterly basis. The industrial value addition is a vital data to measure the amount of contribution generation made to the Indian economy. This can be found from the 'Handbook of Statistics of India' published by the Reserve Bank of India on annual basis. The industrial value addition means value added by the industries of a private or government sector to overall GDP. Considering it as a production output and applying Cobb-Douglas production function, the relationship between input factors like labour and capital has been tested.

Thus, after brief introduction in this section, literatures have been reviewed briefly in section two, and then objectives of the study have been mentioned in section three. Section four deals with research methodology, findings have been discussed in section five and in section six conclusions have been made.

Literature Review: Several of the eeconomic literatures provide different outcomes on output and domestic production with respect to the increasing capital and productivity factors. There are numerous factors, which can impudence productivity. The improvement of country level productivity includes productivity of the business and industries. The increasing rate of industrial productivity is related to the increase in employment growth rate. The aim for each country's policy is to achieve economic growth, business and industry level productivity and employment with the help of necessary capital.

In this section, some studies regarding such labour and capital inducement with respect to the industrial productivity, have been examined. The findings of some select literatures on this issue are produced below.

The wage-productivity relationship of Indian manufacturing industries was checked by Jain (2019) by using cointegration methods and he found that there exits discrepancy between wages and productivity among the states. But, the study have found that a long-run relationship subsist between wages and productivity.

Dritsaki & Stamation (2018) have conducted a study to realise the relationships among trade, financial and economic development with the help of Cobb-Douglas production function (CDF). The results show that both long and short term equilibrium relationships are available among the variables. However, capital seems to be the main driver of economic growth and labour is found to have negative impact.

In the study of Yusof (2008), a long-run relationship had been found out between employment and real productivity with the real wages being the main cointegration factor.

Geda & Zerfu (2006) have conducted CDF model cointegration test of capital stock and labour factors. The Ethiopian data were used in first and second difference cointegration test and they found that none of the results were satisfying long-term relationship. So, they have suggested a polynomial model for long-term cointegration relationship.

Cointegration study of output, capital, labour and energy was conducted by Stresing et. al. (2008) on the basis of log transformed time series data from three developed countries. Here, the results show that labour is having less powerful cointegration with output against energy factor. In addition to this, the capital factor is found to be less significantly cointegrated with the output in USA within the period of 1960-78.

Several researchers have been considering the output as a result of physical factors' accumulations. Followers of this issue argue that more inputs produce more output. The studies conducted by Young (1992, 1994, 1995), Kim & Lau (1994) and Collins & Bosworth (1996) are some of the studies which support this opinion.

Therefore, these literatures have discussed on the productivity issue of countries at macro level and some of them have shown the necessity of

long-run relationship of input factors with the output. Considering these, the objectives of the present study have been specified in the next section.

Objective of the study: The main objectives of the present study are to understand the relationship of factor of production with the output level in the form of industry value addition and testing cointegration of those input factors.

Research design & methodology: This methodology part consists of sample, variables and statistical tools for analysis.

i) *Sample*: The study is based on time series data on yearly basis from 1981 to 2017. Secondary data have been collected from the reports of 'Annual Survey of Industries' and 'Handbook of Statistical Report' issued by the Reserve Bank of India.

ii) *Variables*: There are some selected variables. These are annual industrial output or production units (OUTP), industries value addition at constant price (INVACO), man-days worked by the total workers and other employees (MDE), total amount of invested capital (ICAP) and total number of workers (WORK).

iii) *Equations*: Considering the traditional theories in economics, there are popular models on the estimation of production, based on some specific input factors. Among which, Cobb-Douglas production function (CDF) is very much popular. It is basically a non-liners multiple regression model with two main factors of production and with constant return to scale assumption. There are other production functions, which are closely related with CD's, like Translog production function (TLF) and Polynomial or cubic production function (PCF). Considering widely use of CDF, it has been reformed in regression model and has been tested accordingly in this paper. These three production functions are shown below in mathematical form.

CDF: $Y=AK^{\alpha}L^{\beta}$ $\alpha+\beta=1$ ---------- (1)

TLF: $\ln Y = \alpha_1 \ln K+\alpha_2 \ln L+\beta_{11}(\ln K)^2+\beta_{12}\ln K.\ln L+\beta_{22}(\ln L)^2$ ----------(2)

PCF: $Y = \alpha_1 K + \alpha_2 K^2 + \alpha_3 K^3 + \beta_1 L + \beta_2 L^2 + \beta_3 L^3$ ----------(3)

Here, 'ln' is natural log transformation, 'Y' is to indicate output value or in quantity as INVACO, 'K' is the amount of capital invested as ICAP and

'L' is to indicate amount of labour or MDE (Man-days worked by total employees). 't' is time in year. The production function in Eq-1 is based on constant returns to scale. It indicates that change in input factors by positive amount has change in output by the same amount. Therefore, $\alpha + \beta = 1$ to denote the constant return the scale, $\alpha + \beta > 1$ to show increasing returns to scale and $\alpha + \beta < 1$ for diminishing returns to scale. The CDF in Eq-1 has been transformed into linear form in the Equation-1.1 and represented here:

$\ln INVACO_t = C + \alpha \ln MDE_t + \beta \ln ICAP_t$ -------- (1.1) {putting 'log' in both side, C: Constant}

Besides estimating relationship between input and output from Eq-1.1, the α and β relationship is to be checked. Cointegration analysis is also made to know long-term relationship among the dependent and independent variables. For statistical analysis purpose SPSS and EVIEWS software have been used.

The ARDL (p,q,r) technique of cointegration can be presented through the following equation:

$$LNINVACO_t = \varphi_0 + \varphi_1 t + \sum_{i=1}^{p} \theta_i \, LNINVACO_{t-i} + \sum_{i=0}^{q} \propto_i LNMDE_{t-i} + \sum_{i=0}^{r} \beta_i \, LNICAP_{t-i} + \varepsilon_{it} \quad \text{--(2)}$$

where θ, α and β are coefficients; φ_0 is constant; φ_1 is for trend; i=0, 1, ... k in time; p,q,r are optimal lag orders; ε_{it} is the error term.

Now, for bound test of cointegration, the Eq. 2 can be specified as in Eq. 3 given below :

$$\Delta LNINVACO_t = \varphi_0 + \varphi_1 t + \theta_{1i} LNINVACO_{t-i} + \propto_{1i} LNMDE_{t-i} + \beta_{1i} LNICAP_{t-i} + \sum_{i=1}^{p} \theta_{2i} \, \Delta LNINVACO_{t-i} + \sum_{i=1}^{q} \propto_{2i} \Delta \, LNMDE_{t-i} + \sum_{i=1}^{r} \beta_{2i} \Delta \, LNICAP_{t-i} + \varepsilon_{it} \quad \text{----------} \quad (3)$$

Considering Eq. 3 for cointegration through error correction model (ECM), the same equation can be represented as in the Eq. 4 below:

$$\Delta LNINVACO_t = \varphi_0 + \varphi_1 t + \sum_{i=1}^{p} \omega_{1i} \, \Delta LNINVACO_{t-1} + \sum_{i=1}^{q} \omega_{2i} \Delta \, LNMDE_{t-1} + \sum_{i=1}^{r} \omega_{3i} \Delta \, LNICAP_{t-1} + \lambda ECT_{t-1} + \varepsilon_{it} \quad \text{----------(3)}$$

Where, λ is the speed of adjustment parameter with a significant negative sign; ECT is the error correction term ; ω_{1i}, ω_{2i}, ω_{3i} are short-run dynamic coefficient of the model's adjustments of long-run equilibrium.

Results & Findings: Although, there is little need of correlation analysis, as the nature of relationship among these variables are already known theoretically and in applied economics. These are re-presented here in support of that classic relationship. Table-1 shows that OUTP has highly significant and positive correlations with ICAP, MDE, WORK and GDP. The INVACO has also the same nature of relationships with ICAP, MDE, WORK and GDP. Now, the combined impact of labour and capital inputs are being tested in the regression results, which have been shown in Table-2.

Table 1 : Pearson's bi-variate Correlations

		OUTP	ICAP	INVACO	MDE	WORK	GDPCON
ICAP	Cor	0.995**	1				
	Sig	0.000					
INVACO	Cor	0.979**	0.972**	1			
	Sig	0.000	0.000				
MDE	Cor	0.958**	0.962**	0.935**	1		
	Sig	0.000	0.000	0.000			
WORK	Cor	0.971**	0.972**	0.947**	0.995**	1	
	Sig	0.000	0.000	0.000	0.000		
GDPCON	Cor	0.979**	0.976**	0.999**	0.930**	0.942**	1
	Sig	0.000	0.000	0.000	0.000	0.000	
GDPGRO	Cor	0.317	0.317	0.364*	0.317	0.314	0.364*
	Sig	0.056	0.056	0.027	0.056	0.059	0.027

******. Correlation is significant at the 0.01 level &*****. is significant at the 0.05 level (2-tailed).

Source: *Author's computation based on secondary data*

Considering Eq. 1.1, the regression results and test statistics are shown in the Table-2. Here the R^2 is above 90% and very low standard error and F-statistic value highly significant at p<1%. These results are validating the

model fundamentally. In case of regression coefficients, it can be seen that the constant and LNICAP are positively significant. But, the LNMDE is negative and insignificant. The $\alpha + \beta$ value is 0.454 (0.515-0.061), which is showing a diminishing return to scale.

Table 2: Regression Results of Equation-1.1

Eq.	R^2	Adj R^2	SE Reg.	F	Const.	MDE	ICAP	BPG	JB	VIF	DW	α+β
1.1	0.981	0.980	0.095	899.43	21.877	-0.061	0.515	0.268	2.945	4.461	0.148	0.454
P Val				0.000	0.000	0.679	0.000	0.766	0.229			
BPG: Breusch Pagan Godfrey				JB: Jarque-Bera			DW: Durbin-Watson					

Source: *Author's computation based on secondary data*

However, the BPG test and JB test statistics are showing that there is no heteroscedasticity and non-normality issues in the regression results. The VIF is showing that multicollinearity exists at marginal level and DW test result is showing some positive correlation among the variables. So, the study results are showing the validity of CDF model with diminishing return or contribution of the input factors in the industrial value addition. To understand long term relationship of these input factors with the industrial value addition, cointegration test are made on the CDF Eq. 1.1 on the basis of ARDL technique.

To consider ARDL test, the selected variables must be tested against existence of unit root level or at first difference. If any of the variables is not stationary at level or first difference then the ARDL test cannot be applicable. Therefore, the Table-3 is showing the ADF test of unit root existence. It is showing that LNINVACO has unit root at level and no unit root at first difference and same results are found for LNMDE, whereas LNICAP has no unit root at level value. These test results are allowing for ARDL test to be applicable on Eq. 1.1.

Table-3: Unit Root Test

Augmented Dickey-Fuller (ADF) Unit Root Test			
Variable	t-Statistic	Prob.*	At Level
LNINVACO	-2.614	0.277	Yes UR
LNICAP	-4.491	0.006	No UR
LNMDE	-2.062	0.548	Yes UR
	At First Difference		
LNINVACO	-4.185	0.012	No UR
LNICAP			Not Required
LNMDE	-4.264	0.010	No UR
With Constant and Linear Trend, both are significant			

Source: *Author's computation based on secondary data*

The ARDL model is given as follows on the basis of the test results found and the selected model is (2,0,1). This test is made on the basis of Akaike Info Criterion (AIC) with lag years up to four. The F-statistics value is 7817.78 and significant at p<1%. The R^2 value is very high and satisfactory. The DW test (1.925) is showing very marginal existence of positive auto-correlation. All the coefficients are significant including positive constant and trend.

Table-4: ARDL Model Co-integration Test

ARDL Model: LNINVACO=f(LNMDE, LNICAP)	
F-Statistic	7817.78**
R-squared	0.999
Adjusted R-squared	0.999
S.E. of regression	0.017
Durbin-Watson stat	1.925
LNINVACO(-1)	0.834**
LNINVACO(-2)	-0.336*
LNMDE	0.132**
LNICAP	0.085#
LNICAP(-1)	-0.152**
C	13.585**
TREND	0.038**
** Significant level 1%	
* Significant level 5%; # Significant level 10%	

Source: *Author's computation based on secondary data*

The same model has been tested for short-run equilibrium adjustment with the help of ECM in Table-5, where the main condition is that the co-integration coefficient must be negative and highly significant. The study result on the selected model is able to fulfill that condition. This is showing that almost fifty percent of shock is to be adjusted within a year lag to come to the equilibrium point of the selected variables. Here the first difference is indicated by 'δ' sign. The R^2 value is showing that the model is valid with 60% efficiency. Here, the δMDE has not been considered as it has been selected at level on the basis of ARDL model 2,0,1. The ECM model is showing that there is short term significant relationship between independent and dependent variables and the speed of adjustment from previous year's disequilibrium to current year's equilibrium is 50 percent.

Table-5: Error Correction Model (ECM)

ARDL Error Correction Model (ECM)	
Dependent	δLNINVACO
R-squared	0.604
Adjusted R-squared	0.551
δLNINVACO(-1)	0.336**
δ LNICAP	0.085#
CointEq(-1)	-0.502**

Source: *Author's computation based on secondary data*

The long-run cointegration test has been made on the basis of ARDL Bound Test. This is shown in the Table-6. The Table-6 is also showing validity of the model and its coefficients as long-term integration, on the basis of Wald test, BPG test, JB test and LM test. The F-Bound statistic and t-Bound statistic values are showing higher values at 1% lower and upper bound values. This means that there exists long-run co-integration within the given lag period among the dependent and independent variables. Other than the negative lag value of dependent variable (LNINVACO), the LNMDE has long-term positive and significant impact of 0.132 percent and lag value of LNICAP has 0.067 percent significantly negative long-term impact on the dependent variable.

The Wald test of coefficients is showing that the Bound test model coefficients are significantly differing from zero value. The BPG test value is

showing no existence of heteroscedasticity in the residuals, which are normally distributed (as per JB test). The LM test is accepting that there is no serial correlation in the variables under study.

Table-6: ARDL Bounds Test & Other Test Statistics

F-Bound Statistic	9.466**
t-Bound Statistic	-5.516**
LNINVACO(-1)	-0.502**
LNMDE	0.132**
LNICAP(-1)	-0.067**
Wald Test: F-statistic: Prob. F(2, 28): c(1)=c(2)=0	18.929**
F-statistic: Prob. F(3 28): c(3)=c(4)=c(5)=0	7.592**
Heteroscedasticity BPG Test: F-statistic & Prob. F(6,28)	1.347 & 0.270
Normality Test: JB statistic & Prob.	0.390 & 0.822
Breusch-Godfrey Serial Correlation LM Test:	
F-statistic & Prob. F(2,26): Lag 2	0.137 & 0.872
F-statistic & Prob. F(4,24): Lag 4	1.066 & 0.395

Source : *Author's computation based on secondary data*

The stability of the selected ARDL ECM has been tested by cumulative sumo of recursive residuals (CUSUM) and cumulative sumo of squares of recursive residuals (CUSUMSQ) stability testing process in Figure 1 and Figure 2 respectively. Both the figures show that the plots remains within 5 percent level of significance bound values, to indicate stability of the model.

Figure 1

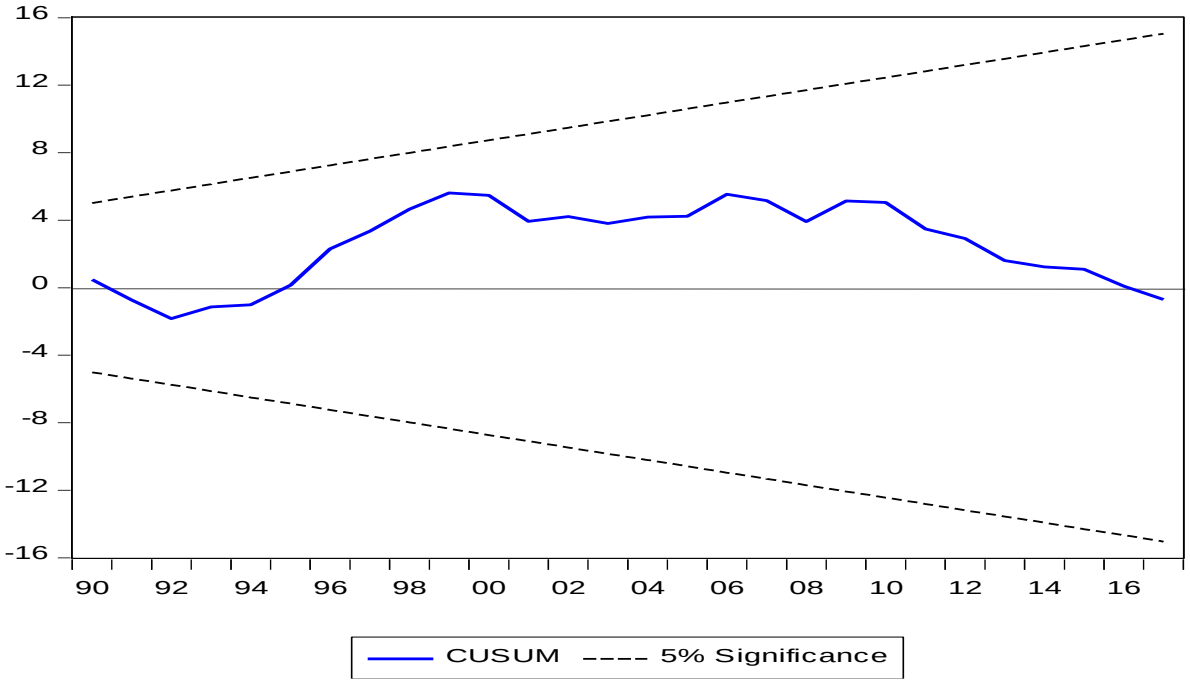
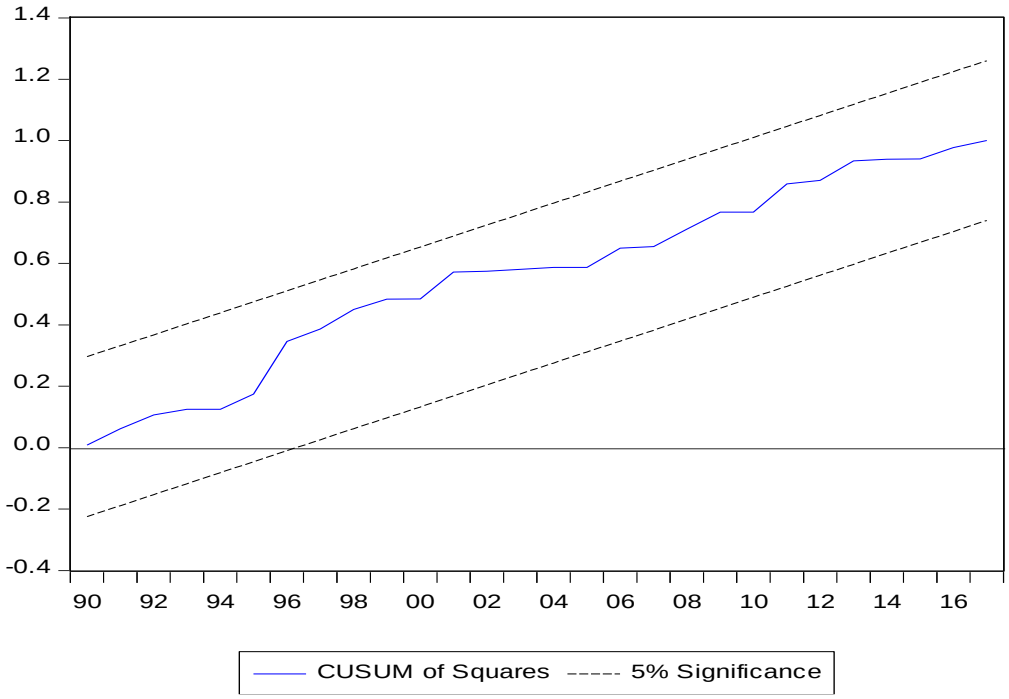


Figure 2



Discussion & Conclusions: The study has shown very basic relationship of capital, labour and value addition of the industries as a whole. Basic CD model has shown that the factor productivity does not hold the idea of 'constant return to scale'. In case of long-run impact of input factors towards value addition, results are showing long-term positive impact of labour factor and negative impact of capital. The negative long-run effect can be understood from the significantly negative trend from the value addition per unit of capital invested (-15766.24 at $p<1\%$ with level value and -0.059 at $p<1\%$ with log value). Another interesting finding is that the basic CDF regression shows that labourfactor has insignificant impact on the industrial value addition, but in long term model it is differing. These two issues can be discussed further with reasonable understanding. Other researchers can also try other production functions with the same study objectives.

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