Eco. Env. & Cons. 28 (2) : 2022; pp. (727-735)

ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i02.022

CO_2 emission, economic growth and energy consumption in India: A VAR analysis

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(Received 25 July, 2021; Accepted 28 August, 2021)

ABSTRACT

The present paper tries to see the causal relationship among emission of carbon dioxide (Co2), GDP (Economic Growth) and energy consumption (Oil) in India. The secondary data has been collected from various issues of Economic survey of India, GoI, various issues of Energy statistics, GoI, and data published by the World Bank on India. The VAR (Vector Auto Regression Model) has been applied due to absence of long-run relationship among variables. The study also found that there is no causality among the variables. The Government of India should take necessary steps to attain efficiency in energy use while preserving it and steps to be taken for lesser use of fossil fuels.

Key words: *Causal relationship, Economic Growth, Vector Auto Regression Model.*

Introduction

Attaining Economic growth is a goal for many countries. This goal puts pressure on countries to increase industrial production which requires consumption of energy in higher amount and its supply is uncertain. Hence, energy is vital for every economy. But, due to massive use of fossil fuels for energy which is non-renewable natural resources is responsible for greenhouse gases emissions mainly Co_2 emissions. It has a vital role for global warming and depletion in ozone layer. So it is an important area of research to see the relationship among energy, economic growth and CO_2 emissions (Al-Iriani (2006); Ang (2007); Arouri *et al.* (2012); Apergis and Payne (2011); Bartleet and Gounder (2010); Chang *et al.* (2009); Halicioglu (Halicioglu, 2009; 2007); Jumbe (2004); Lean and Smith (2009); Menyah and Rufael (2010); Niu *et al.* (2011); Ozturk and Acaravci, (2010); Soytas *et al.* (2007).

The EKC (Environmental Kuznets Curve) is also known as CKC (Carbon Kuznets Curve). It is a hypothesis which is used by the researchers to study the relationship between environmental pollution and economic growth in recent years. This hypothesis having an inverted U-shape relationship among environmental pollution and economic growth tells that degradation of environment increases due to increase in per capita income at initially, but it tends to fall down soon after achievement of the critical economic growth level.

Many countries signed the Montreal Protocol (1987) and Kyoto Protocol (1997) with a view to solve the environmental issues. The countries agreed to reduce greenhouse gasses including CO_2 under the Kyoto Protocol agreement and under the Montreal Protocol agreement, countries aimed to reduce energy consumption and environmental Pollution. Despite the above protocols and numerous efforts taken by the countries to conserve the environment, still there are environmental issues which emerge in the countries such as increase in the CO_2

emissions.

Studies on energy consumption and economic growth

Many researchers have focused to study the association between energy consumption and economic growth (GDP) and found the causality running from growth to energy consumption was unidirectional such as Ghosh (2002), Ghosh (2009) and Pradhan (2010), Gelo (2009), Mucuk and Yilmaz (2010), Binh (2011), Eddrief-Cherfi and Kourbali (2012), Onuonga (20124), Shahbaz and Feridun (2012), Kwakwa (2012) and Ishida [28] and Hwang and Yoo [27] showed the causality running from growth to energy use was unidirectional . Some studies on India are Ghosh (2002), Ghosh (2009) and Pradhan (2010). The other studies who found unidirectional causality running from energy consumption to growth are Lee (2005), Mehrara (2007), Narayan and Smyth (2008), Sarkar *et al.* (2010), Odhiambo (2011), Li and Li (2011), Tiwari (2011) and Vidyarthi (2013); Talebi *et al.* (2012) and Acaravci and Ozturk (2012) concluded that the real economic activity was Granger caused by energy consumption. Some studies on India are Tiwari (2011) and Vidyarthi (2013). A bidirectional causality relationship found by Mizra and Kanwal (2017) and Omri (2013).

Studies on CO_2 emission and economic growth

A few studies found the existence of unidirectional causality running from CO_2 emission to Economic growth are Hwang and Yoo (2014), Omri (2013), Menyah and Wolde-Rufael (2010). While unidirectional causality running from Economic growth to CO_2 emission found by Govindaraju and Tan, (2013), Chang *et al.* (2009). The researchers who found a bidirectional causality relationship between CO_2 emission and economic growth are Mizra and Kanwal (2017); Pakistan, Shahbaz *et al.* (2015), Ozcan (2013); Shahbaz *et al.* (2013) Chandran and Tang (2013); Pao *et al.* (2011). Some studies on India are having bidirectional causality relationship are Tiwari (2011) and Vidyarthi (2013), Govindaraju and Tang (2013) and Tiwari *et al.* (2013).

Studies on energy consumption, CO_2 emission and economic growth

Another number of studies investigated the relationship between energy consumption, GDP, CO_2 emissions are Abdallah and Abugamos (2017), Nairn *et al.* (2017), Rehman and Rashid (2017), Dogan and Aslan (2017), Kasman and Dunman (2015), Dritsaki and Dritsaki (2014), Menyah and Wolde-Rufael (2010).

Out of many research on this subject matter, it is not clear to know the direction of causality among energy consumption, CO_2 emission and economic growth i.e. whether energy consumption causes CO_2 emission or economic growth causes CO_2 emission or economic growth causes energy consumption or vice versa or bi-directional causality exists. The results of the present study on the above fact can help to have suitable and effective policy implication to conserve the environment, to resolve environmental issues and to reduce CO_2 emissions while attaining economic growth.

The contribution of the current study is to see the relationship between energy consumption, CO_2 emission and economic growth (GDP) in India to know the direction of causality among these three variables and to suggest suitable and effective policy. The present study is organised as follows: section 2 is the data and methodology. The results and discussions are presented in section 3. The section 4 deals with the Robustness test results. The conclusion and policy implication are presented in Section 5.

Methodology and Data Source

Data Source

The Indian time series (annual) data has been used in the present study for empirical analysis over the period 1971-2016. The present study uses consumption of crude oil as the proxy of energy consumption ('000 tonnes of crude oil equivalent) collected from the various issues of Energy statistics, GoI, Gross domestic product at constant prices (2011-12 prices) is the proxy of Economic growth collected from Economic survey of India, GoI, and emission of carbon dioxide (Co2 in kilotons) collected from data published by the World Bank on India.

Unit Root Analysis

The present paper used the ADF test to see the order of integration of variables at level I (0) or first difference I (1).

$$\Delta B_t = \alpha + \beta t + \delta B_{t-1} + \Sigma_{i=1}^{m} Y_i \, \Delta B_{t-1} + U_t \quad .. (1)$$

Where α stands for constant, stands for white noise error term, stands for first difference, stands for time series variable, stands for coefficient of time trend.

The Cointegration (Johansen) Test

The Cointegration (Johansen) test has been used in the present study to test cointegration among variables which is based on vector error correction model.

$$\Delta C_t=\Gamma_1\Delta C_{t-1} + \Gamma_2\Delta C_{t-2} +....+ \Gamma_{\kappa-1}\Delta C_{t-k-1}+ \Pi C_{t-1}+U_t \quad ..(2)$$

Where Γ_i = (1- S_1- S_2- ....- S_k) (i= 1,2...... k-1), Γ= – (I- S_1- S_2- ....- S_k),

C_t = [$Co2_t$ EG_t OC_t], $\alpha\beta'$= where α = adjustment speed to coefficient of equilibrium while β' is the long run coefficient matrix. The Co2 is emission of carbon dioxide, EG is the Economic Growth and OC is the oil consumption.

The VAR model

$$\ln Co2_t = \alpha_1+\Sigma_{t=1}^{n}b_i \ln EG_{t-1}+\Sigma_{i=1}^{n} c_i \ln OIL_{t-1} + \Sigma_{i=1}^{n}di \ln Co2_{t-1} + \varepsilon_{1t} \quad ..(3)$$

$$\ln EG_t = \alpha_2 + \Sigma_{i=1}^{n} g_i \ln OIL_{t-1}+ \Sigma_{i=1}^{n} h_i \ln Co2_{t-1}+\Sigma_{t=1}^{n} j_i \ln EG_{t-i} + \varepsilon_{2t} \quad ..(4)$$

$$\ln OIL_t = \alpha_3 + \Sigma_{t=1}^{n} k_i \ln Co2_{t-1}+ \Sigma_{i=1}^{n} l_i \ln EG_{t-1}+\Sigma_{i=1}^{n} m_i \ln OIL_{t-1} + \varepsilon_{3t} \quad ..(5)$$

Where lnCo2, lnEG and lnOC are the logarithms of the emission of carbon dioxide, Economic Growth and oil consumption. The ε_t stands for error term.

The VAR model can also be written in matrix form as follows

Empirical Result

Results of Unit Root Test

The ADF (Augmented Dickey Fuller) test was applied for examining the stationarity of the variables at level I(0) or after first difference I(1). The results of the unit root are given in the Table 1. The table shows that stationarity is not found at level for all the variables. They become stationary after first difference.

Lag Order Selection Criteria

It is essential to select optimal lag structure for the VAR mechanism before estimation of Johansen Cointegration test. For VAR mechanism, the AIC statistics was used for selecting the appropriate lag structure. The minimum value of AIC was used to select the number of lag. The results of lag order selection are given in the Table 2. The table shows that the AIC has lowest value at lag 2.

Johansen Cointegration Test Results

The Table 3 shows the results of the Johansen

Table 1. The results ADF unit root test

			LCO_2	LGDP	LOIL
At Level	Tau (τ) statistics		-1.913506	-1.770963	-2.233239
	Critical (τ) values	1%	-4.175640	-4.180911	-4.175640
		5%	-3.513075	-3.515523	-3.513075
		10%	-3.186854	-3.188259	-3.186854
At First	Tau (τ) statistics		-6.501712	-9.717748	-6.609460
Difference	Critical (τ) values	1%	-4.180911	-4.180911	-4.180911
		5%	-3.515523	-3.515523	-3.515523
		10%	-3.188259	-3.188259	-3.188259

Source: Calculated by author, based on E-views 9.

Table 2. Lag Order Selection Criteria Results

Lag	LogL	LR	FPE	AIC	SC	HQ
0	38.38063	NA	3.72e-05	-1.684792	-1.560673	-1.639297
1	238.2785	361.7199*	4.20e-09	-10.77516	-10.27869*	-10.59319*
2	247.7875	15.84844	4.14e-09*	-10.79941*	-9.930571	-10.48094
3	252.1958	6.717305	5.24e-09	-10.58075	-9.339558	-10.12580
4	256.8475	6.423875	6.68e-09	-10.37369	-8.760141	-9.782262

Source: Calculated by author, based on E-views 9.

* Optimum lag order of the respective criterion

Table 3. Johansen Cointegration Test Results

Null Hypothesis	Trace statistics	Critical Values	Max-Eigen Statistics	Critical Values
r = 0	23.17051	29.79707	13.06819	21.13162
r ≤ 1	10.10232	15.49471	9.981993	14.26460
r ≤ 2	0.120325	3.841466	0.120325	3.841466

Source: Calculated by author, based on E-views 9.

cointegration test. It is seen from the table that the 5% critical value is higher than the Trace Statistics value. So, the variables don't have long-run cointegration. The Max-eigen value statistics also confirms the absence of cointegration among the variables in long-run as it is lower than the 5% critical value. The cointegration results indicate that the use of VAR is valid as variables don't have long-run cointegration.

VAR Results

The Table 4 shows the VAR estimation result.

Table 4. VAR Results

Independent variables	Dependent variables		
	D(LCO_2)	D(LGDP)	D(LOIL)
D(LCO2(-1))	-0.053344	0.289140	0.578880
	(0.18713)	(0.25364)	(0.36430)
	[-0.28506]	[1.13997]	[1.58904]*
D(LCO2(-2))	-0.078631	0.116041	-0.330823
	(0.18590)	(0.25197)	(0.36190)
	[-0.42297]	[0.46053]	[-0.91412]
D(LGDP(-1))	0.120765	-0.274692	0.234053
	(0.12241)	(0.16592)	(0.23831)
	[0.98652]	[-1.65556]	[0.98214]
D(LGDP(-2))	0.075620	0.072787	-0.036807
	(0.12731)	(0.17255)	(0.24783)
	[0.59401]	[0.42183]	[-0.14852]
D(LOIL(-1))	-0.003550	0.027688	0.118569
	(0.09377)	(0.12709)	(0.18254)
	[-0.03786]	[0.21787]	[0.64957]
D(LOIL(-2))	-0.060526	0.005875	-0.092225
	(0.08703)	(0.11796)	(0.16942)
	[-0.69548]	[0.04981]	[-0.54436]
C	0.055622	0.043086	0.032201
	(0.01757)	(0.02381)	(0.03420)
	[3.16626]	[1.80955]	[0.94161]

Source: Calculated by author, based on E-views 9.
Notes: Standard errors in ( ) and t- statistics in [ ].

On the basis of parameter estimation results shown in Table 4, it is possible to have the regression equation as below:

DLCO2= 0.055622-0.053344* DLCO2 (-1) - 0.078631* DLCO2 (-2) + 0.120765* DLGDP (-1) +0.075620* DLGDP (-2) -0.003550* DLOIL (-1) - 0.060526* DLOIL (-2)

DLGDP= 0.043086+ 0.289140* DLCO2 (-1) + 0.116041* DLCO2 (-2) -0.274692* DLGDP (-1) +0.072787* DLGDP (-2) + 0.027688* DLOIL (-1) +0.005875* DLOIL (-2)

DLOIL= 0.032201+ 0.578880* DLCO2 (-1) - 0.330823* DLCO2 (-2) + 0.234053* DLGDP (-1) - 0.036807* DLGDP (-2) + 0.118569* DLOIL (-1) - 0.092225* DLOIL (-2)

Granger causality test

The Table 5 shows the Granger causality test results. The results show that there is no Granger causality among the variables.

Impulse Response Function

With regard to the response of Co2 emission to the impact from economic growth, the response was 0 in the current period, and then increased to 0.004818 in the second period. Then, the value declined in third period and was negative in the fourth period. There was increase in the value during the sixth and seventh period and turned negative in eighth period. Further, the value increased in ninth period and again the value turned negative in tenth period.

With regard to the response of Co2 emission to the impact from energy consumption, the response was 0 in the current period, then declined and was negative in second, third and fourth period. Further, the response turned positive in fifth and sixth period. Again the value turned negative in seventh and eighth period. Further, the value turned positive in ninth and tenth period.

The response of economic growth due to the impact of Co2 emission on it, the response in the current period was 0.001668, and then increased in sec-

Table 5. Granger causality test

Dependent variable:	Excluded variable	Chi-sq	df	Prob.
D(LCO2)	D(LGDP)	1.054407	2	0.5903
D(LCO2)	D(LOIL)	0.485599	2	0.7844
D(LGDP)	D(LCO2)	1.534143	2	0.4644
D(LGDP)	D(LOIL)	0.050128	2	0.9752
D(LOIL)	D(LCO2)	3.301584	2	0.1919
D(LOIL)	D(LGDP)	1.214565	2	0.5448

Source: Calculated by author, based on E-views 9.
Notes: Chi-sq: Chi-squared statistics. df: degree of freedom. Prob.: Probability

ond period, then declined in third period. Thereafter, the response turned positive till the seventh period and it turned negative in eighth and ninth period. Further, the value turned positive in tenth period.

The response of economic growth due to the impact of energy consumption on it, the response was 0 in the current period, and then increased in second and third period. Thereafter, the response turned negative in fourth and fifth period. Further, the value turned positive in sixth and seventh period. The value again turned negative in eighth and ninth period and increased in tenth period.

The response of energy consumption due to the impact of Co2 emission on it, the response in the current period was negative (-0.027915) in the current period, then increased in second period, and declined in third and fourth period. Thereafter, the response turned positive in fifth and sixth period. Further, the value turned negative in seventh, eighth and ninth period and increased in tenth period.

The response of energy consumption due to the impact of economic growth on it, the response in the current period was 0.008785, then declined in second period, and turned negative in third period. Thereafter, the response turned positive in fourth period and it is negative in fifth period. Further, the value turned positive in sixth and turned negative in seventh period. The value again turned positive in eighth period and it is negative in ninth period and increased in tenth period.

Variance Decomposition Analysis

The contribution of each structural impact to the endogenous variables are analysed by the variance decomposition. We can further judge the importance of different factors using it. The Table shows the results of variance decomposition analysis of the VAR model established from D(LCO2) or Co2 emission, D(LGDP) or economic growth and D(LOIL) or energy consumption. It is found from the Table that among the influencing factor of Co2 emission fluctuates, Co2 emission itself accounted for 100% in the period one and thereafter, there was a slow decline in it. at the period one, the proportion of economic growth kept in a very low level but it reached to 2.7425% at the end. All these periods show a small proportion of economic growth.

Among the influencing factors of economic growth fluctuations, Co2 is emission accounted for 0.172278% in the first period. And economic growth itself accounted for 99.82772%. In later periods, there was a little change in the proportion of these two factors. The proportion of energy consumption increased from 0 to 0.106179% during the second period. Thereafter, it increased to 0.141343% during the fifth period. And it was almost stable and changed little thereafter.

Among the influencing factors of energy consumption fluctuations, the proportion of Co2 emission accounted for 23.38948% in the first period, the economic growth accounted for 2.316495% and energy consumption accounted for 74.29403%. In later periods, the Co2 emission is almost constant after third period. The economic growth is almost constant after first period. And the energy consumption is almost constant after second period.

Robustness Test

The VAR stability check and the Granger causality test was conducted to see more accurate relationship among emission of carbon dioxide (Co2), economic growth and energy consumption in India. Then, the impulse response and variance decomposition was constructed.

AR Roots Test

The stability condition check results are presented in

Table 6. Impulse Response Function Results

	Response of D(LCO_2):			Response of D(LGDP):			Response of D(LOIL):		
Period	D(LCO_2)	D(LGDP)	D(LOIL)	D(LCO_2)	D(LGDP)	D(LOIL)	D(LCO_2)	D(LGDP)	D(LOIL)
1	0.029650	0.000000	0.000000	0.001668	0.040153	0.000000	-0.027915	0.008785	0.049752
2	-0.001281	0.004818	-0.000177	0.007342	-0.010786	0.001378	0.014244	0.010440	0.005899
3	0.000389	0.000908	-0.002856	0.001405	0.007619	2.62E-05	-0.004630	-0.000786	-0.003669
4	-4.08E-05	-0.000952	-7.04E-05	6.76E-05	-0.002017	-0.000820	-0.001155	5.61E-05	-0.002619
5	0.000370	0.000359	0.000363	5.78E-05	0.000936	-0.000219	0.000102	-0.001525	0.000739
6	6.51E-05	1.82E-05	5.36E-05	8.74E-05	-0.000452	0.000102	0.000358	0.000630	0.000541
7	-2.51E-05	7.70E-05	-8.22E-05	5.25E-05	0.000248	3.30E-05	-3.35E-05	-3.33E-05	-6.09E-05
8	-1.24E-05	-4.78E-05	-2.07E-05	-6.59E-06	-7.38E-05	-1.77E-05	-6.40E-05	5.11E-05	-0.000119
9	8.06E-06	8.16E-06	1.20E-05	-2.82E-06	3.46E-05	-1.19E-05	-6.81E-06	-7.04E-05	1.45E-06
10	3.60E-06	-9.18E-07	5.38E-06	6.29E-07	-1.97E-05	2.41E-06	1.34E-05	1.83E-05	2.28E-05

Source: Calculated by author, based on E-views 9.

Table-7. Variance Decomposition Results

	D(LCO2):			D(LGDP):			D(LOIL):		
Period	D(LCO2)	D(LGDP)	D(LOIL)	D(LCO2)	D(LGDP)	D(LOIL)	D(LCO2)	D(LGDP)	D(LOIL)
1	100.0000	0.000000	0.000000	0.172278	99.82772	0.000000	23.38948	2.316495	74.29403
2	97.42890	2.567647	0.003451	3.171780	96.72204	0.106179	26.70113	5.061022	68.23784
3	96.47081	2.632243	0.896950	3.175613	96.72162	0.102766	27.02303	5.029257	67.94771
4	96.37466	2.728742	0.896597	3.167723	96.69345	0.138832	26.99938	5.018268	67.98235
5	96.34774	2.741677	0.910588	3.166319	96.69234	0.141343	26.97878	5.076801	67.94442
6	96.34741	2.741691	0.910895	3.166351	96.69176	0.141889	26.97628	5.086346	67.93737
7	96.34608	2.742298	0.911621	3.166388	96.69167	0.141943	26.97627	5.086368	67.93736
8	96.34579	2.742540	0.911665	3.166381	96.69166	0.141959	26.97623	5.086410	67.93736
9	96.34577	2.742547	0.911681	3.166379	96.69165	0.141967	26.97620	5.086536	67.93727
10	96.34577	2.742546	0.911684	3.166378	96.69165	0.141967	26.97619	5.086544	67.93726

Source: Calculated by author, based on E-views 9.

Table 8 and Figure 1. It is observed that no root lied outside the unit circle. So, the VAR model satisfies the stability condition.

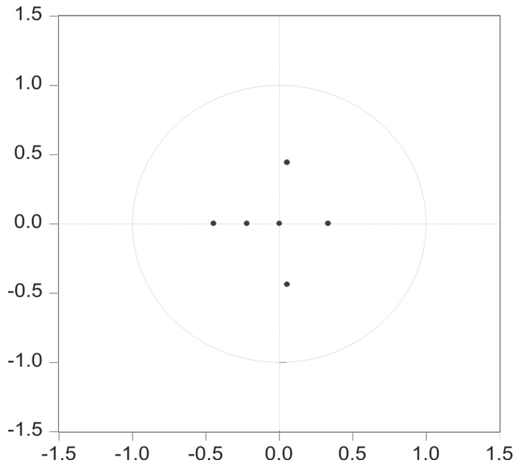

Figure 1. AR root graph of the VAR model.
Source: Generated from E-views 9.

Table 8. VAR stability condition check

Root	Modulus
0.056172 - 0.440385i	0.443953
0.056172 + 0.440385i	0.443953
-0.443787	0.443787
0.335150	0.335150
-0.217222	0.217222
0.004050	0.004050

Source: Calculated by author, based on E-views 9.

Serial Correlation LM Tests

The Table 9 shows the residual serial correlation LM tests which shows that there is no serial correlation in the errors.

Table 9. VAR Residual Serial Correlation LM Tests

Lags	LM-Stat	Prob
1	5.833921	0.7564
2	3.398726	0.9464
3	4.993309	0.8349

Probs from chi-square with 9 df.
Source: Calculated by author, based on E-views 9.

Heteroskedasticity Test

The Table 10 shows the Heteroskedasticity test result. It is observed from the table that there is no Heteroskedasticity.

Table 10. VAR Residual Heteroskedasticity Tests: Joint test

Chi-sq	df	Prob.
77.89042	72	0.2969

Source: Calculated by author, based on E-views 9.

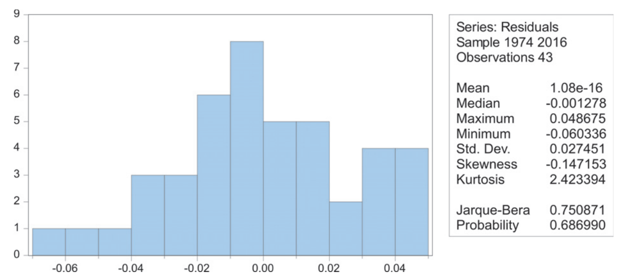

Fig. 2. Normality test
Source: Generated from E-views 9.

Normality test

The Normality test result is presented in the Figure 2 which shows that the probability value is not significant. So, the distribution is normal.

The estimated VAR model in the present study does not suffer from existence of serial correlation, heteroscedasticity and normality of residuals. So, the estimated model is robust.

Conclusion

The current study made an attempt to see the causal relationship between energy consumption (OIL), CO2 emissions (CO_2) and economic growth (GDP) in India using the ADF unit root test, Johansen cointegration test and Vector Auto Regression Model during the period 1971-2016. The study exhibit the absence of long-run association among energy consumption (OIL), CO2 emissions (CO_2) and economic growth (GDP) in India. The results of the present study also confirm that there is no Granger Causality among the variables in India. The Government of India should take necessary steps for preserving and conserving energy and to attain efficiency in energy use, steps to be taken for lesser use of fossil fuels so as to keep the environment free from any kind of pollutants by giving more emphasis on carbon-free energy which will not hamper the energy consumption.

The current study may be extended by taking other variables such as consumption of coal and electricity to know the better insights so that suitable policy measures can be taken for Indian economy. Secondly, for methodological improvements, possible structural breaks may be carried out to have reliable results. And lastly, for examining the robustness of the causality results, the non linear Granger causality analysis may be done in future research.

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