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Economic Growth and Greenhouse Gases in Algeria: Revisiting the Environmental Kuznets Curve Hypothesis

BENATEK Adel *, University of Djillali Liabes - Sidi bel-Abbes, Algeria, Laboratory: "Management des enterprises", adel.benatek@univ-sba.dz

AKRICHE Kamel, University of Djillali Liabes - Sidi bel Abbes Algeria, kml.akriche@gmail.com

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Abstract: The current research paper aims to study the link between gross domestic product (GDP) and CO2 by testing the "Environmental Kuznets Curve" (EKC) hypothesis, Considering electricity consumption (EC) and its potential impact on emissions in Algeria during the period 1990–2019. Employing Engle-Granger co-integration test, results revealed that the EKC hypothesis is invalid in this country.GDP had a negative and significant effect on CO2, nevertheless, electricity had a significant and positive impact on carbon dioxide emissions. Additionally, the causality test suggested the presence of unidirectional causality from GDP to CO2, and from EC to CO2. These findings call for further economic development efforts directed toward sustainable development.

Keywords: Sustainable Development; CO_2; EKC; Co-integration; Energy.

JEL codes: Q01; Q53; Q4.

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Introduction:

The average global temperature has increased dramatically over the previous few decades. In 2022, it was 1.06 °C higher than in the pre-industrial age (Lindsey, Dahlman, 2024). Simultaneously, we are witnessing an increase in greenhouse gas emissions in particular CO2, which accounts for approximately 75% of total (Ritchie et al. 2020), and has increased in concentration by 47% since the start of the Industrial Age (Buis, 2019). This rapid change destabilizes the climate, which commenced with the discovery of fossil fuels and further aggravates as more people use more energy to fulfill their demands. in this situation, investigating economic development and environmental performance linkage is vital.

Essentially, there are two primary approaches for styding that topic. The first one examines how environment can affect economic growth. The second approach on which our study is based focuses on the influence of economic growth on the environment. Within this context, a contentious debate persists about the effect of economic development on environmental quality. Such conflicting views have been explained via the "Environmental Kuznets Curve" hypothesis (hereafter EKC) which was initially examined by Grossman, Krueger, (1991) and defined later by Panayotou, (1993) under the name of the "EKC" (Dinda, 2004).

* . **Corresponding Author**

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According to the "EKC" hypothesis, the relationship between economic development and the environment is illustrated in an inverted U-shaped curve. Several factors are responsible for shaping this curve namely: scale, composition, and technique effects (Dinda, 2004). First, the scale effects dominate at early stages of economic development which leads to higher pollution levels related to the increased industrial activities. In this phase, environmental regulations are weak and countries are trying to get wealthier. Afterward, the composition effects become substantial as long as the economy structurally changes from energy-intensive industry to a services-based economy (Dinda, 2004), which explains the turning point where the pollution levels stabilize and then decline. Lastly, in later stages of economic development, the technique effects play a vital role in declining pollution levels as investment in better technologies, and environmental regulations enforcement begin to take place (Özcan, Ozturk, 2019).

As previously stated, since the work of Grossman, Krueger (1991), several studies have been conducted to test the "EKC" across the world using various econometric approaches. These studies can be classified into multiple country studies using panel data analysis (Damette, Seghir, 2013; Shahbaz et al. 2016; Ouédraogo et al. 2021; Appiah et al. 2023; Onifade, 2023; Idowu et al. 2023) and single country studies using time series analysis (Touitou, Langarita, 2021; Adouka, Bayer, 2021; Shehzad et al. 2022; Ayad et al. 2023). As one of the major oil producers in Africa, Algeria presents an interesting case study in this regard. However, the "EKC" studies for Algeria have received less attention. Among those studies, Narayan, Narayan, (2010); Arouri et al. (2012) tested the existence of the "EKC" hypothesis in a panel data analysis including Algeria from 1980-2004 and 1981–2005 respectively, their results indicate that the "EKC" does not exist in Algeria. However, these studies do not consider the characteristics of the Algerian economy. Also, Lacheheb and others, (2015) tested the "EKC" hypothesis in Algeria from 1971-2009, their findings revealed the non-existence of the "EKC" hypothesis, with a significant impact of income and population on CO2 from electricity production. On the other hand, the findings of Bouznit and others, (2016) show that the "EKC" hypothesis exists in Algeria from 1970-2010, but the turning point is very high.

By reviewing these studies, we observe several key findings, first and foremost, there are only a few studies directed to Algeria on this topic. Second, there is no accord regarding the validity of the "EKC" in Algeria. Third, the sample size of those studies does not cover recent years. Therefore, this work enriches the literature by extending the sample size to cover the period from 1990 to 2019, thereby addressing the gap in the literature for the years from 2010 to 2019. This period includes significant events in Algeria that may affect the validity of the "EKC" hypothesis.

Those observations above motivated the writing of the current research paper which investigates whether the "EKC" hypothesis is valid ? particularly when including electricity consumption as an additional factor that can affect CO2.

To addresse our research question, we have formulated the following hypotheses:

H_1: The "EKC" hypothesis is valid in Algeria.

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H_2: Electricity consumption drives CO2 in Algeria.

Since the purpose of this research is to examine the long-run equilibrium relationship between CO2 and GDP, we employed a two-step Engel-Granger cointegration methodology. In this section, we will explain our econometric approach utilized to test the "EKC" hypothesis in Algeria. Since the "EKC" is a long-run relationship (Dinda, 2004), then the appropriate methodology for its testing is cointegration. We relied on the two-stage Engel-Granger methodology.

Methodology:

1- Data:

In this study, the log-linear form of the "EKC" equation has been employed following the original Grossman, Krueger's (1991) study, and Stern (2004) who argued that except in the case of deforestation, the regression that allows the level of indicators to take null or negative values is unsuitable, therefore the logarithmic usage will impose this restriction (Stern, 2004, p. 1422). Consequently, to test our "EKC" hypothesis in Algeria we define our equation as follows:

$$LCO_{2_t} = \beta_0 + \beta_1 LGDP_t + \beta_2 [LGDP_t]^2 + \beta_3 LE_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where LCO_2 is the logarithm of per capita CO2 as measured in metric tons, This variable was chosen as an environmental degradation indicator because CO2 is regarded as one of the primary contributors to drive global warming and climate change (Maâlej, Cabagnols, 2021, p. 2), Also, CO2 is the largest contributor to greenhouse gases accounting for roughly 75% of total emissions (Ritchie et al. 2020). *LGDP* is the logarithm of per capita gross domestic product as measured in constant 2015 U.S. dollars, We also considered its squared value to test the "EKC" hypothesis, Moreover, *LE* is the logarithm of electricity consumption as measured in (kwh) per capita, LE is as a determinant of CO_2 emissions because: if we consider greenhouse gas emissions by sector in Algeria, Then electricity and heat dominate, followed by transport, manufacturing, and construction (Ritchie et al. 2020). Secondly, electricity growth rate was 198% from 1990-2021 in Algeria, according to the World Bank database (2023). Additionally, demand of electricity is predicted to increase by more than 100% by 2030 (Bouznit, et al. 2016). Finally, In Algeria, only 2% of the electricity is generated using renewables (Bouznit et al. 2016, p. 96). The data in our study were retrieved from the World Bank indicators website.

Table (1): Variables and its unit of measurement

Variables	Abr.	Position	Units	Source
Per capita carbon dioxide	CO2	Dependent variable	Metric tons per capita	(WDI)
Per capita gross domestic product	GDP	Main independent variable	constant 2015 U.S. dollars	(WDI)
Per capita electricity consumption	E	Additional independent variable	KWH per capita	(WDI)

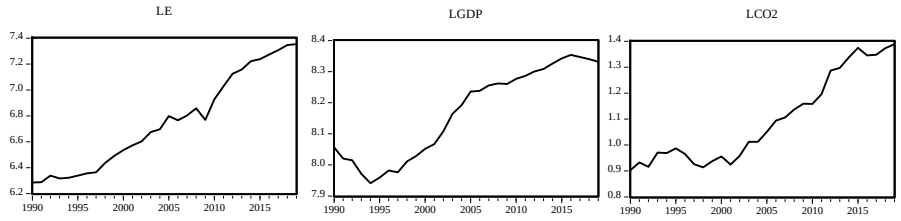
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Using our equation above (1) we can verify the "EKC" hypothesis based on the signs of coefficients. Where the results stand for an inverted U-shaped curve if: "$\beta_1 > 0; And\ \beta_2 < 0$" (Özcan & Ozturk, 2019, p. 12). The positive coefficient of β_1 represents the first stage of industrialization, in which pollution indicators such as carbon dioxide in our case grow rapidly. Following that, when income grows over a certain threshold, people value the environment more, and pollution will decrease with the help of some regulating authority (Dinda, 2004, p. 432), and this is what explains the negative value of the coefficient β_2.

Our time series are plotted in Fig.1. From these histograms, it is evident that all of our variables are non-stationary at their levels due to the existence of a trend. Additionally, We notice some fluctuations in LCO_2 at the start of the sample period and a decline in LGDP at that time from 1990 to 1993, which is linked to oil price fluctuations that could affect economic growth both positively and negatively (Kori Yahia, 2023).

Fig (1): Evolution of our time series in the sample period from 1990 to 2019



Source: "EViews 10" outputs

Table (2): Descriptive statistics

	LCO_2	LGDP	LE
Mean	1.097883	8.166933	6.752550
Maximum	1.388798	8.353790	7.352441
Minimum	0.902754	7.941199	6.285253
Std. Dev.	0.171078	0.145157	0.367245

Source: "EViews 10" outputs

2- Econometric Approach:

In the context of stationary and non-stationary time series, there is a phenomenon known as spurious regression, First discovered by Yule who proved that regressing non-stationary time series could give us misleading and meaningless results (Gujarati, Porter, 2009, p. 748). But if two series share the same trend and are both integrated I(1), the regression of one on the other may not always be spurious as long as a co-integration relationship exists between them, as Granger notes: "A co-integration test can be thought of as a pre-test to avoid spurious regression situations" (Gujarati, Porter, 2009, p. 762)**.**

In our study, we tested for co-integration using the Engle-Granger two-step method, And as a prerequisite for this approach, we must confirm that the series are integrated I(1), this explains why we performed the various unit root tests below.

2.1. Engle-Granger approach for co-integration:

Our econometric method aims to explore the existence of co-integration relationship. We used one of the most popular approaches that focuses on testing the residuals proposed by Engle, Granger (1987), which is also known as Engle-Granger's two-step method:

2.1.1. The first step:

Involves the estimation of the long-run elasticity in the following co-integration equation:

$$LCO_{2_t} = \beta_0 + \beta_1 LGDP_t + \beta_2 [LGDP_t]^2 + \beta_3 LE_t + \varepsilon_t$$

Where, $\beta_1, \beta_2,$ And β_3 are the elasticity. The variables included in our analysis: LCO_2, LGDP, And LE should be integrated I(1), which justifies the need for the different unit root tests. Let us write the equation above as the following:

$$e_t = LCO_{2_t} - \beta_0 - \beta_1 LGDP_t - \beta_2 [LGDP_t]^2 - \beta_3 LE_t$$

We will subject the residual series "e_t" to unit root analysis, and if results indicate that residuals are stationary I(0), then we conclude that the variables are co-integrated. But in this process, there is a common mistake in the literature that has to be mentioned, which is represented in testing these residuals using the ADF unit root test and its critical values. As noted by Engle and Granger (1987) using OLS to estimate our equation will minimize the residual variance, therefore these residual series are more likely to be stationary. Thus using standard ADF tests may reject the null hypothesis of non-stationary too often (Verbeek, 2017, p. 354), i.e. this method will be more inclined to justify the existence of co-integration that may not exist, to address this issue, we should take into account the critical values that Engle and Yoo (1987) and Phillips and Ouliaris (1990) have tabulated (Maddala, Kim, 1998, p. 199).

2.1.2. The Second Step: Estimation of the Error Correction Model (ECM):

The ECM introduced into the econometric literature by Sargan in 1964 (Maddala, Kim, 1998, p. 34), And it gained recognition by Engle and Granger who suggest that if variables are co-integrated, then the relationship can be expressed as ECM (Gujarati, Porter, 2009, p. 764), like the following:

$$\Delta LCO_{2_t} = \alpha_0 + \alpha_1 \Delta LGDP_t + \alpha_2 [\Delta LGDP_t]^2 + \alpha_3 \Delta LE + ECT\varepsilon_{t-1} + \mu_t$$

Where μ_t is an error term, And ε_{t-1} is its lagged value in equation (1).

ECM equation states that $\Delta LnCO_{2_t}$ depends on $\Delta LnGDP_t$, $[\Delta LnGDP_t]^2$, ΔLE, And also on the equilibrium error term which is expected to be negative and significant. Therefore, this will push $\Delta LnCO_{2_t}$ to restore its equilibrium and adjust.

Results:

As noted above, our methodology requires proving first that our series are integrated I(1), this explains why we performed the various unit root tests shown in Table (3).

Table (3): Unit root tests

	ADF		PP		KPSS	Decision
LCO_2	-1.545677	0.7894	-1.544221	0.7900	0.160441	
$DLCO_2$	-4.941643	0.0004*	-4.96177	0.0004*	0.219289*	I(1)
LGDP	-2.418748	0,3630	-2.626027	0.2724	0.096688*	
DLGDP	-1.661813	0,0905*	-2.799690	0.0069*	/	I(1)
LE	-2.733461	0.2315	-2.733461	0.2315	0.157494	
DLE	-6.259627	0.0000*	-6.246509	0.0000*	0.203508*	I(1)

Notes: The model selected in all unit root tests at level is model 3: with trend and intercept, and at first differences we select model 1: without trend and intercept for ADF, PP and model 2: with intercept in KPSS, the values in parenthesis indicate p-value, (*) indicates a significant value and stationarity series, And "D" indicates the first difference of the series.

Source: "EViews 10" outputs.

Based on the results of the ADF and PP unit root tests, all our series of the variables are stationary at their first difference. We considered model 3 with trend and intercept in these tests at the level because the results prove both the significance and presence of a trend much like in the plotting. Furthermore, as noted in (Maddala, Kim, 1998, p. 100) the argument of Schwert (1989) that many economic time series contain a large parameter of MA, and in this case, the PP test will suffer from size distortions, Also the DF tests will differ from "Dickey-Fuller" distribution. Therefore, it would be better for us to consider testing for an MA-based tests such as KPSS, which also has been suggested that this type of test can be used for confirmatory analysis (Maddala, Kim, 1998, p. 126).

Table (4): Co-integration tests

Engle-Granger		
H_0: Series are not co-integrated		
	Value	**Prob.***
tau-statistic	-4.757004	0.0317
Phillips-Ouliaris		
H_0: Series are not co-integrated		
	Value	**Prob.***
tau-statistic	-4.749653	0.0311

Note: (*) indicates MacKinnon (1996) p-values.

Source: "EViews 10" outputs

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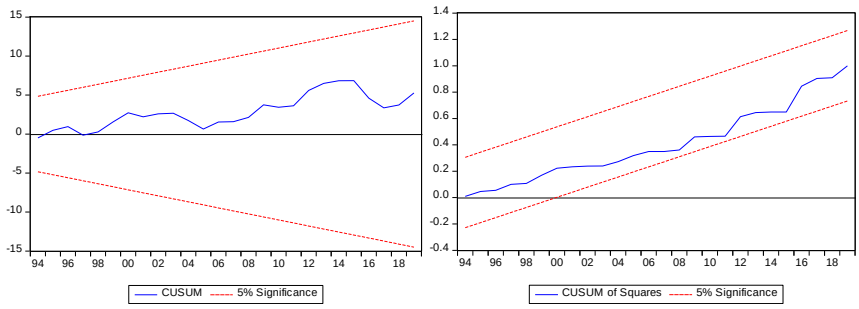
Engle-Granger and Phillips-Ouliaris co-integration tests are only unit root tests for the residuals, according to the results shown in Table (4), the presence of a long-run relationship between the variables is confirmed because the MacKinnon p-value for finite samples is significant at 5%, therefore we reject H_0. As a result, the estimation of the long-run equation displayed in Table (5) is not a spurious regression.

Table (5): Long-run Elasticity estimation

LCO_2: as a dependent variable.			
Variable	**Coefficient**	**t-Statistic**	**Prob.**
LGDP	-68.01006	-8.484733	0.0000
$(LGDP)^2$	4.209136	8.460480	0.0000
LE	0.178966	3.128708	0.0043
C	274.4930	8.434192	0.0000
R-squared	0.982177	J-B Normality test	0,55019
P-value of F-statistic	0.000000	LM-test for serial correlation	0,1941
Durbin-Watson stat	1.785636	Heteroscedasticity ARCH test	0,4552

Source: "EViews 10" outputs

Fig (2): Residuals stability test



Source: "EViews 10" outputs

Results of estimating the long-run equation using OLS method are revealed in Table (5), where the p-value of (LM-test) indicates that residuals are serially uncorrelated, similarly, the p-value of heteroscedasticity ARCH test indicates that we can not reject H_0. moreover, based on the Jarque-Bera p-values, We can not reject H_0 and we say the residuals distribution is normal. Furthermore, both plots of "CUSUM" and "CUSUMSQ" tests indicate the stability of error correction coefficients.

According to the results shown in Table. 4, and based on the coefficients that represent elasticity of both LGDP and its Squared values, We conclude that the "EKC" hypothesis in Algeria is invalid, with a U-shaped curve representing the relationship between LGDP and LCO_2 is a. This explains that in the early phases when income levels were extremely low, Algeria did not place any pressure on the environment and its resources until a particular point and threshold, when the country attempted to get wealthier., We can calculate this turning point as noted by (Dinda, 2004) in a logarithmic model if a turning point exists, we can

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calculate it with our coefficients by: $(-\beta_1/2\,\beta_2)$. From the estimated results, the value of the turning point is $(68.01006)/(2\times 4.209136)=8.08$, As a result, we may conclude that when Algeria attempted to boost its logarithmic income over (8.08), it put pressure on the environment, causing LCO_2 levels to rise. This can be explained by Algeria's dependence on the oil sector and non-renewable energy. Also, the results show a statistically significant and positive effect of EC on LCO_2 in the long-run model, which confirms the dependence on fossil fuel energies to generate this electricity.

Table (6): Short-run relationship estimation

$DLCO_2$: as a dependent			
Variable	**Coefficient**	**t-Statistic**	**Prob.**
DLGDP	-67.58977	-4.155181	0.0003
$D(LGDP)^2$	4.184483	4.153754	0.0003
DLE	0.055247	0.547934	0.5886
e_{t-1}	-0.906623	-4.238095	0.0003
Prob of heteroscedasticity Breush-Pagan-Godfrey test			0.9659
J-B prob Normality test			0.6762

Source: "EViews 10" outputs

Table 5 shows the estimates of ECM using the ordinary least squares method, from these results it is evident that the model is of any econometric problems such as autocorrelation and heteroscedasticity. Furthermore, "e_{t-1}" coefficient is negative and statistically significant at one percent, its value (-0.9066) indicates that 90.6% is the adjustment speed toward long-run equilibrium within a year. We should also highlight that EC is insignificant in the short-run.

The presence of co-integration between variables indicates that there is a causality at least in one direction. The results of the Granger-causality test are summarized in Table 7.

Table (7): Granger Causality Test

H_0: The 1st Variable does not Granger cause the 2nd Variable	**F-Statistic**	**P-value**
LGDP $\longrightarrow$ LCO_2	4.06224	0.0308**
LCO_2 $\longrightarrow$ LGDP	0.10866	0.8975
LE $\longrightarrow$ LCO_2	5.60319	0.0104**
LCO_2 $\longrightarrow$ LE	0.52829	0.5966
LE $\longrightarrow$ LGDP	1.38246	0.2710
LGDP $\longrightarrow$ LE	0.60641	0.5538

Note: (**): indicates the significance of F-statistic at 5%, Therefore the null hypothesis of no causality will be rejected.

Source: "EViews 10" outputs

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From the results shown in Table (7), there is unidirectional causality running from LGDP to LCO2 emissions, and from LE to LCO2 emissions.

Discussion:

Economic development and expansion are goals for developing countries, but this usually leads to more environmental degradation and more pressure on the planet, particularly in the case of oil-exporting countries such as Algeria, due to their reliance on that sector.

Our findings show the existence of a U-shaped relationship between economic growth and CO2 emissions as a measure of environmental deterioration, which makes the "EKC" hypothesis invalid in Algeria. The low GDP level, along with the slow growth, can both explain Algeria's findings of a negative relationship between per capita income and CO2 emissions at the first stage, particularly at the beginning of the sample period, when the country was still recovering from the 1986 oil crisis. additionally, there are more reasons behind this slow growth, as noted by Bouznit et al. (2016): First of all, Algeria made no major investments in the manufacturing sector and had rapid deindustrialization which caused a significant decline in the manufacturing sector's percentage of GDP from 48.95% in 2008 to 26.5% in 2021 (The World Bank database, 2023), Second, economic growth in Algeria has not been linked with energy-intensive industrial processes because none of the attempts at industrial reforms have been substantial until 2013 (Bouznit et al. 2016). However, after a certain level, represented by the estimated turning point of LGDP, which equals (8,08), income begins to positively affect carbon dioxide emissions, when the country attempts to expand its economy. Therefore, the reliance on the oil industry justifies this positive effect in Algeria when the structure of its economy is still resource-intensive rather than service-based economy, in which fossil fuels income have accounted for 50% of the national budget (Hochberg, 2020). In addition, we should note that our results concerning the "EKC" hypothesis which is invalid in Algeria are similar to Lacheheb et al. (2015) findings, In contrast, the study of Bouznit et al. (2016) confirm the "EKC" hypothesis for Algeria, nevertheless, their estimated turning point is at a high level of GDP which has not yet been reached, therefore GDP is increasing emissions.

Furthermore, the statistical significance and the positive effect of per capita electricity consumption on CO2, in the long-run, explains that this electricity is generated from fossil fuels, implying that Algeria is still dependent on non-renewable energies. It is expected that the country to increase its production and exports of electricity this will cause more CO2 emissions and more environmental degradation unless policymakers consider this point and develop ways to generate this electricity using renewables. In this context, we highlight that just 2,3% of electricity was generated from renewables in 2022 (Statista Research Department, 2023). As a result, Algeria still has to work toward decoupling CO_2 emissions from growth, and according to our findings, we must highlight that increasing the amount of electricity generated from renewable energies can help Algeria decrease its emissions. Those findings concerning electricity are in line with previous studies of Bouznit et al. (2016), Also Bélaïd, Youssef (2017) in which they found that in the long-run GDP and non-renewable EC increase pollution levels as measured by CO_2 emissions.

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Conclusion:

The Algerian government has started to be worried about environmental concerns, especially in light of the fluctuating oil and gas prices and the rising domestic electricity consumption, which have encouraged Algeria to prioritize investments in clean energy to combat climate change. The government has set a goal of generating around a third of its electricity from renewables by 2030.

This paper analyzes the relationship between GDP and environmental degradation as measured by CO2 in Algeria, taking into account EC. In this context, we tested the "EKC" hypothesis throughout 1990-2019 using the Engle-Granger co-integration test. The estimated results show a U-shaped curve representing the GDP and CO2 nexus, therefore, the invalidation of the "EKC" hypothesis in Algeria. Along with significant positive impact of EC in the long-run. Indicating that any future electricity generation from nonrenewable energies to meet domestic demand will cause more emissions. In this regard, we recommend developing effective ways to generate this electricity from renewable sources, which will help address the climate change problem in Algeria without harming growth.

In this sense, Future research would benefit from investigating the challenges and barriers faced by this country in its transition towards clean energy. Additionally, it is crucial to examine the requirements necessary to achieve the intended goal of generating around one-third of its electricity from renewables by 2030.

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