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OIL PRICES SHOCKS AND INFLATION RATE PERSISTENCE FOR ALGERIA: A FRACTIONAL COINTEGRATION RELATIONSHIP

This study aims to analyse the relationship between oil prices and inflation rates in Algeria to determine the extent of inflation persistence in face to oil price shocks from January 1998 to March 2023 using the recently developed Fractional Cointegration Model. This topic was chosen due to its significance for monetary policymakers, investors, financial analysts and academics in understanding the dynamics of inflation persistence in Algeria. Our results indicate that the inflation rate in Algeria will persist for a longer period due to the shock of oil prices before eventually fading away.

Keywords: *inflation rate persistence; oil prices shocks; fractional cointegration; Algeria.*

Inflation is considered a macroeconomic problem for all countries around the world, without exception, due to its negative effects on economic expansion and income redistribution. Therefore, achieving an acceptable inflation rate is one of the economic goals of any central bank in any country. This task requires

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a deep understanding of inflation dynamics such as the persistence of the inflation rate [1]. Understanding the dynamics of inflation persistence will help central bank officials to make appropriate monetary policy decisions [2; 3; 4].

Inflation persistence is the time it takes for inflation rate shocks to dissipate [5], or it is the speed at which the inflation rate returns to its equilibrium in the medium and long term after a shock. The effectiveness of monetary policy strategy lies in its ability to achieve low inflation persistence which means that inflation rate shocks can be quickly eliminated [6—9]. On the contrary, the wrong appreciation of the inflation rate persistence can be charged with monetary policy makers. The shock of oil prices is one of the most obvious external shocks that affect the rate of inflation in countries [9—13].

Price shocks, including oil price shocks, are considered external shocks that impact inflation rates in any country. Numerous studies have been conducted on the determinants of inflation persistence, but little attention has been given to the role of oil prices as a key indicator of inflation,[9]confirmed that the potential impact of oil price shocks on inflation rates in countries suggests that inflation persistence in these countries may be affected by oil price shocks. They found that the impact of oil prices on inflation is greater than the impact of food prices. Therefore maintaining low inflation persistence aligns with the effectiveness of monetary policy [6; 7; 8].

Therefore, an increase in the country's persistent inflation rate as a result of an oil price shock indicates a weakness in the effectiveness of its monetary policy. This calls for a review of the monetary policy in response to the oil price shock. On the other hand, if the inflation rate continues to declines or remains unchanged due to an oil price shock, it means that the current monetary policy of the country is responsive to the oil price shock, and there is no need to review the monetary policy in the face of such shock. The importance of studying inflation persistence lies in its significant role in shaping monetary policy. It determines the extent to which monetary authorities can maintain a stable level of output and inflation simultaneously, thus influencing the performance of monetary policies [14].

The main objective of our study is to investigate the impact of oil price shocks on the persistence of inflation in Algeria, as it is one of the major oil-exporting countries. Therefore, this study is highly important for the monetary authorities in Algeria to determine whether they should review their monetary policy in the face of global oil price shocks. We will use the Fractional Cointegration Vector Autoregressive (FCVAR) model, introduced by S. Johansen [15] and further developed by S. Johansen & Nielsen [16], instead of the traditional Cointegrated Vector Autoregressive (CVAR) model proposed by S. Johansen [17]. Both models capture the long-term relationship between variables, but the CVAR model assumes only two cases of long-term relationship indicated by zero-order of integration $I(0)$ or first-order of integration $I(1)$, while the FCVAR model allows for different orders of integration ($I(d)$), where d represents any real-valued order of integration, enabling long memory persistence ($0 < d < 1$) [18; 19; 20].

For more details, we chose the FCVAR model instead of the CVAR model because several studies have found that the inflation rate is fractional integrated (see for example [1; 20; 21]). The same applies to oil prices, as [22] found that oil prices are fractional integrated. This makes the FCVAR approach more suitable for analyzing the long-term relationship between oil prices and inflation. Additionally, recent studies have shown a decreased impact of oil price shocks on inflation (see [13; 23; 24; 25]). Therefore, the FCVAR model provides more accurate and realistic results compared to the CVAR model.

This study will contribute to the empirical literature on analysing the determinants of inflation persistence in Algeria by examining the impact of an external factor represented by oil prices using the recently developed Fractional Cointegration Vector Autoregressive (FCVAR) model. It will also shed light on the role of Algeria's monetary policy in modeling this impact.

The organization of this study after this introductory section is as follows: Section 2 provides the theoretical background on the relationship between oil prices and inflation, Section 3 reviews the existing literature and evaluates its findings and highlights the added value of our study, Section 4 presents the data and its temporal evolution, Section 5 outlines the methodological framework of the study, Section 6 presents the results and discussion and Finally, Section 7 concludes the paper.

Economic literature has not been gathered around a unified definition of continuity of inflation, among the most important definitions are:

Inflation persistence is defined as the time it takes for the shocks to inflation to dissipate [5], and it can also be defined as the speed at which inflation returns to its equilibrium level (medium and long term) after a shock [21]. The effectiveness of monetary policy strategy is determined by its ability to achieve a low level of inflation persistence, indicating that shocks to inflation are eliminated within a short period [6; 7; 8].

Inflation persistence [26] is sometimes defined as the tendency for price shocks to push inflation away from its stable state, including the inflation target, for an extended period. Persistence is important because it affects the costs of production in reducing inflation to the target. It is often described as a "sacrifice ratio", where a lower level of persistence implies a larger policy space. Policy space refers to the ability of monetary policy to absorb temporary price shocks. Countries with high persistence and low policy space may need to adjust macroeconomic policies materially to accommodate price shocks, as they impact overall inflation and inflation expectations over a sustained period [27].

Distinguished between three types of persistence [26]:

• positive serial correlation in inflation: This refers to the positive relationship between current and lagged inflation rates, indicating a persistent pattern in inflationary movements;

• time lags in the effects of systematic monetary policy measures on inflation (peak effects): This refers to the delays between the implementation of systematic monetary policy actions and their impact on inflation. It highlights the lagged response of inflation to policy measures;

• delayed responses of inflation to non-systematic policy measures (such as policy shocks): This type of persistence refers to the delayed effects of non-systematic policy actions on inflation. It captures the delayed response of inflation to unexpected policy shocks.

In addition, there is another type of persistence mentioned by Fuhrer & Moore [28], which is the inflation response to its own shocks. This type of persistence emphasises how inflation responds to its own disturbances.

The significant economic implications of oil price fluctuations have sparked extensive academic and governmental deliberation. An increase in oil prices is welcomed as positive news for oil-exporting nations but is regarded as unfavorable for oil-importing countries, with the opposite effect anticipated when oil prices decline. The correlation between oil price shocks and the macro-economy is thoroughly investigated [10].

Oil price shocks can have a significant impact on inflation persistence, and this impact varies depending on several factors, including the size of the shock, monetary policy response, and underlying economic conditions. However, generally, oil price shocks tend to have a more pronounced effect on inflation in countries with weaker monetary policy frameworks and/or higher inflation levels. For example, a study conducted by IMF [29] found that a 10% increase in oil prices could lead to an increase in inflation ranging from 0.2 to 0.4 percentage points in the short term. The study also found that the impact of oil price shocks on inflation can be more persistent in countries with weaker monetary policy frameworks.

And large research finds that oil price shocks have affected inflation, Nevertheless, the impact of oil price fluctuations can vary across countries, influenced by factors like their sectoral composition, their role as oil importers or exporters, and variations in their tax structure. Consequently, comprehending the empirical correlation between oil prices and inflation rates becomes crucial, particularly for monetary authorities striving to maintain control over inflation. A thorough understanding of the inflationary effects resulting from oil price increases enables monetary authorities to devise policies that can better accommodate such shocks [10].

Here are some of the political effects of oil price shocks:

Monetary Policy: Central banks can use monetary policy to help mitigate the impact of oil price shocks on inflation. For example, they can raise interest rates to slow economic growth and reduce demand for goods and services.

Fiscal Policy: Governments can also use fiscal policy to help mitigate the impact of oil price shocks. For example, they can provide tax cuts or increased spending to offset the negative impact of higher oil prices on household and business incomes.

Regulation: Governments can also regulate the energy sector to help reduce oil price volatility. For example, they can invest in renewable energy sources or develop strategic oil reserves [30].

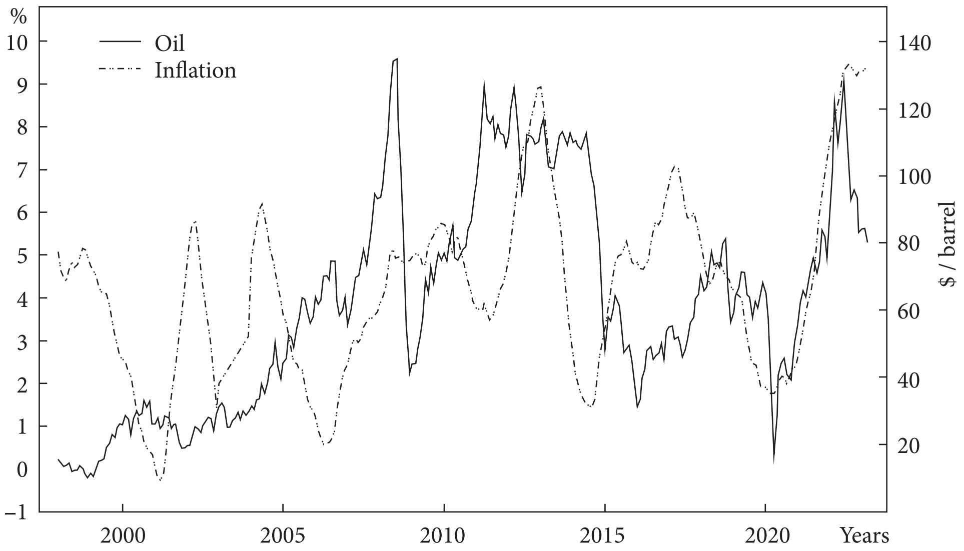
The persistence of inflation is the time it takes for inflation rate shocks to dissipate [5], and it can also be defined as the speed at which inflation rate returns to its long-term equilibrium level after a shock [21]. Understanding the nature of inflation persistence will assist authorities and policymakers in implementing effective monetary policies towards maintaining price stability and economic stability [31]. Numerous studies have been conducted in this field, which can be categorized into two types: studies that believe inflation persistence dynamics are determined by the characteristics of inflation rate, and studies that argue that inflation persistence can be influenced by structural economic factors.

THE DYNAMICS OF THE INFLATION RATE PERSISTENCE ARE DETERMINED BY THE CHARACTERISTICS OF THE INFLATION RATE

These studies believe that the dynamics of inflation persistence are determined by the characteristics of inflation rate in the economy. These studies employ techniques such as single-variable autoregressive modeling, including tests for stationarity, partial integration, fractional unit roots, or time-varying parameter estimation. There are consistent findings for these studies, for example: The study by Bilici & Зekin [21] used a time-varying parameter (TVP) estimation model to examine inflation persistence in Turkey. They found that inflation persistence increases and exhibits high volatility during periods of high inflation, The study by Granville & Zeng [20] investigated the dynamics of inflation persistence in the United States and concluded that the persistence dynamics are related to the expectations formed by past inflation memories, The study by Antonakakis et al. [14] utilized online price indices to analyze inflation persistence in selected countries (Argentina, Brazil, China, Japan, Germany, South Africa, the United Kingdom, and the United States). Their study showed that the estimated degree of inflation persistence using the long-memory parameter was relatively small when considering online price indices as a measure of inflation. This implies that the effectiveness of monetary policies in managing price stability may have been diminished through official price indices; The study by Bratsiotis et al. [6] explored the role of inflation targets in inflation persistence across seven countries. The results revealed that inflation targets significantly reduce the persistence of inflation, The study by Gerlach & Tillmann [7] analyzed inflation persistence in Asian and Pacific countries before and after the adoption of inflation targeting policies. They found that the speed at which persistence declines varies across countries, and persistence tends to decrease after the adoption of inflation targeting.

THE INFLATION RATE PERSISTENCE IS AFFECTED BY STRUCTURAL ECONOMIC FACTORS

Other studies suggest that inflation persistence can be influenced by structural economic factors such as progressive taxation, human capital, and the monetary policy framework, particularly inflation targeting or exchange rate regimes. These studies have yielded different results, for example: The study by Oloko et al. [32] titled "Fractional Cointegration between Gold Price and Inflation Rate: Application to Inflation Persistence" aimed to analyse the relationship between gold price and inflation rate using the fractional cointegration model to determine the extent of inflation persistence in the face of gold price shocks in some advanced and developing countries. The results indicated that the impact of gold price shocks remains significant for a long period in relation to inflation persistence in developing countries and for a short period in relation to inflation persistence in advanced countries. The study by Oloko et al. [33] titled "Oil Price Shocks and Inflation Persistence: A Fractional Cointegration VAR Model" investigated the effect of oil price shocks on inflation persistence among the top ten oil-exporting and oil-importing countries using the fractional cointegration VAR model. The results showed that the inflation persistence in both oil-exporting and oil-importing countries is not significantly increased due to oil price shocks, indicating that the monetary policies of these countries accommodate oil price shocks. The study Geronikolaou et al. [34] that investigated the effect of progressive taxes and human capital on the persistence of inflation in 28 OECD countries, where they found that increasing progressive taxes reduces the spread of shocks and thus increases the persistence of inflation. The dispersion of human capital across sectors acts as a barrier to labor mobility and thus further rigidifies inflation through the same channel. The study of Wu & Wu [35] examined the role of the flexible exchange rate system in continuing inflation using 23 industrialized countries, and its results concluded that there is ambiguity in the effect of the exchange rate system on the continuity of relative inflation; Floating compared to bound rates, Study Canarella & Miller [36] who analyzed the relationship between inflation targeting and inflation persistence in selected developed countries (Canada, Sweden, United Kingdom) and industrialized and newly emerging economies (Chile, Israel, and Mexico) that adopted inflation targeting (information technology) before 2000. They concluded Overall results were mixed and varied according to the level of development in countries. Specifically, the inflationary processes in the three advanced economies were partially integrated, steady, medium-yielding, and share a common inflationary persistence. Whereas, the inflationary processes in the three emerging market economies were partially integrated, medium return, and unstable, The study conducted by Salisu et al. [12] found mixed short-term and similar long-term relationships between oil prices and inflation rates in both oil-importing and oil-exporting countries. This indicates that the empirical result of the impact of oil price shocks on inflation rate persistence in oil-importing and oil-exporting countries may be similar or divergent, Study by Kilian & Park [37]. This study investigated the role of oil price shocks in inflation persistence for a group of industrialized countries. It found that oil price shocks have a substantial impact on inflation persistence, with the effect varying across countries, The study by Mishkin & Schmidt-Hebbel [38] examined the impact of the monetary policy framework on inflation persistence and showed that medium-term inflation targeting reduces inflation persistence more than fixed-money targeting, the study by Papava & Charaia [39], which addressed the problems caused by inflation in the developing Asia-Pacific region during the global pandemic,



Trends in oil price (right) and inflation rate for Algeria
Source: computed by the authors via gretl software.

found that inflation targeting mechanisms have failed, especially in developing countries, due to uncontrollable external factors (imported inflation, fluctuating oil prices, supply chain disruptions, the war between Russia and Ukraine, etc.) that have overshadowed internal factors. The study suggested to use a combination of already well-known indexes and policies, with the new statistical indicators, which reflects price fluctuations on the medication, utilities, and nutrition.

This study falls within the category of studies that consider structural factors as additional determinants of inflation rate persistence. It focuses on an external factor, which is oil prices, in contrast to the local factors addressed in previous studies. Moreover, it specifically focuses on Algeria, where the investigation of inflation rate persistence has not been conducted yet, especially considering its unique economic characteristics as a resource-rich country and one of the largest oil exporters. Additionally, the study utilises the Fractional Cointegration model as a new and developed standard approach, which is used for the first time in Algeria economic studies. Lastly, to the best of our knowledge, this article is one of the initial attempts to study the relationship between oil prices and inflation rate persistence in Algeria, which serves as a motivation for undertaking this study.

DATA

In this study, we use monthly data for both Algerian Saharan Blend oil prices and inflation rates in Algeria from January 1998 to March 2023. This dataset comprises 303 observations, covering periods of both high and low inflation rates in Algeria, as well as positive and negative oil price shocks worldwide. The inflation rate data was obtained from the Bank of Algeria

Table 1. **Descriptive Statistics**

Variable	Inflation rate, %	Oil price (US$ / barrel)
Observations	303	303
Mean	4.21	62.21
Median	4.29	59.77
Maximum	9.48	134.49
Minimum	–0.24	10.23
Std. Dev	2.10	31.98
Jarque-Bera	7.17	15.37
Bropability	0.027799	0.027799

Source: computed by the authors via EViews 12 software.

website [1], the Saharan Blend oil prices were sourced from the Organization of Arab Petroleum Exporting Countries (OAPEC) Information Bank website [2]. The inflation rate is expressed as a percentage, while the oil price is expressed in US dollars per barrel.

Based on the monthly data provided in Figure and Table 1, the study shows that oil prices experienced significant fluctuations. The lowest recorded price was in December 1998 at $10.23 per barrel. Subsequently, there was a gradual increase in oil prices, reaching their peak during the global oil crisis in 1999-2000. In the new decade, oil prices witnessed a sharp increase due to the growing demand from emerging economies like China and India. Oil prices reached record levels during the strong global economic growth in the mid-2000s. The highest recorded price was 134.9 in July 2008. However, after 2014, oil prices experienced a sharp decline due to increased shale oil production in the United States and a slowdown in global oil demand. Prices reached very low levels in 2016 before recovering modestly in the following years. Oil prices have been influenced by various factors such as supply and demand tensions, geopolitical developments, and major global events like the COVID-19 pandemic. Overall, the average price of Saharan Blend crude oil, the Algerian benchmark, during this period was $62.21 per barrel with a standard deviation of $31.98.

Regarding the inflation rate in Algeria, the highest rate was recorded in April 2022 at 9.48%, Due to the economic conditions that Algeria has experienced and the aftermath of the COVID-19 pandemic during that period. And the lowest value was recorded in March 2001 at –0.24%, resulting from improved political and economic conditions, increased petroleum revenues due to higher oil prices in this period, and the implementation of developmental and reform programs launched by Algeria during that period. Ove-

[1] The Bank of Algeria. URL: https://www.bank-of-algeria.dz/IPC-et-inflation/ (accessed on: 20.06.2023).

[2] The Organization of Arab Petroleum Exporting Countries (OAPEC) Information Bank. URL: https://oapecorg.org/ar/Home/DataBank/ (accessed on: 20.06.2023).

rall, the average inflation rate in Algeria and its standard deviation are 4.21 and 2.10% respectively. This indicates that the inflation rate in Algeria is relatively high and more volatile.

METHODOLOGY

Fractional integration approaches. Here is a brief description of the method that will be adopted in this study, which is the recently developed Fractional Cointegration Vector Auto-regression (FCVAR) model by S. Johansen & Nielsen [16]. This model has gained significant popularity, as evident from its recent application in various fields of study, including [1; 18; 19; 40-43]. This model allows for fractional integration with non-zero orders when the series are not integrated at the zero order [19]. The latter provides researchers with evidence of when transience is found to be reasonable, rather than assuming the explicit nature of permanent shocks that require a long time to fade away. Therefore, we will apply the framework of fractional integration to inflation rates in Algeria and global oil prices.

To explain fractional integration, we define the typical process $I(d)$ in Equation (1) below.

$$(1-L)^d x_t = u_t,\ t = 0, \pm 1,\ ..., \tag{1}$$

where d can be any real value, L is the lag-operator ($Lx_t = x_t - 1$) and u_t is $I(0)$, defined as a covariance stationary process with a spectral density function that is positive and finite at the zero frequency. The idea of fractional integration was introduced by [44-47], although Adenstedt [48] had already given evidence of its meaning. The polynomial $(1 - L)^d$ in (1) can be formulated in terms of its binomial expansion in such a way that for all real d,

$$(1-L)^d = \sum_{j=0}^{\infty} \psi_j L^j = \sum_{j=0}^{\infty} \binom{d}{j} (-1)^j L^j = 1 - dL + \frac{d(d-1)}{2} L^2 - ... \tag{2}$$

and thus

$$(1-L)^d x_t = x_t - dx_{t-1} + \frac{d(d-1)}{2} x_{t-2} - ... \tag{3}$$

Implying that *Eq*. (1) can be expressed as

$$x_t = dx_{t-1} - \frac{d(d-1)}{2} x_{t-2} + ... + u_t. \tag{4}$$

Given the parameterization in (1) we can distinguish different cases depending on the value of d. If $d = 0$, $x_t = u_t$, x_t is said to be "short memory" or $I(0)$; if $d > 0$, x_t is said to be "long memory", because of the strong association between observations which are far in time. Here, if d belongs to the interval (0, 0.5) then x_t is still covariance stationary, while $d \geq 0.5$ implies non-stationarity. Finally, if $d < 1$, the series is mean reverting, meaning that the effect of shocks will eventually disappear in the long run, contrary to what happens if $d \geq 1$, with shocks persisting forever [49].

The fractionally cointegration VAR model. The theoretical derivation of fractional integration model has been shown in the previous section. As a univariate model, this includes one fractional integration parameter, *d*, which describes the order of integration of either inflation or oil prices. As gold prices and inflation rate are fractionally integrated, the next is to determine evidence of fractional cointegration between the two variables. In other words, this is to determine the existence of common fractional integration between oil prices and inflation in the Algeria As the differencing parameter, *d*, an integer value, was not restricted by [50], [51] introduced the fractional cointegration technique which allows for simultaneous estimation of the differencing parameter *d* as well as other parameters in the relationship. In a broad sense, given two real numbers *d*, *b*, the components of the vector z_t are said to be cointegrated of order *d*, *b*, denoted $z_t \sim CI(b,\ d)$ if:

(i) all the components of z_t are $I(d)$;

(ii) there exists a vector $\alpha \neq 0$ such that $s_t = \alpha' z_t \sim I(\gamma) = I(d-b),\ b > 0$, where α is the cointegrating vector and s_t is the error term (see also [41]).

In the multivariate model specification we start our model specification with the CVAR model and after that the FCVAR model since the latter is a fractional modification of the first, the CVAR model is:

$$\Delta Y_t = \alpha\beta' Y_{t-1} + \sum\nolimits_{i=1}^{k} \Gamma_i \Delta Y_{t-i} + \varepsilon_t = \alpha\beta' L Y_t + \sum\nolimits_{i=1}^{k} \Gamma_i \Delta L^i Y_t + \varepsilon_t. \quad (5)$$

The simplest way to derive the FCVAR model is to replace the difference and lag operators and *L* in (2) by their fractional counterparts, *b* and L_b = 1*b*, respectively. We then obtain

$$\Delta^b Y_t = \alpha\beta' L_b Y_t + \sum\nolimits_{i=1}^{k} \Gamma_i \Delta^b L_b^i Y_t + \varepsilon_t. \quad (6)$$

Which is applied to YX_t = *dbt* such that

$$\Delta^d X_t = \alpha\beta' L_b \Delta^{d-b} X_t + \sum\nolimits_{i=1}^{k} \Gamma_i \Delta^b L_b^i Y_t + \varepsilon_t, \quad (7)$$

where ε_t is *p*-dimensional independent and identically distributed, with mean zero and covariance matrix Ω. The parameters have the usual interpretations from the CVAR model. Thus, α and β are $p \times r$ matrices, where $0 \leq r \leq p$. The columns of β are the cointegrating relationships in the system, that is to say the long-run equilibria. The parameters Γ_i govern the short-run behavior of the variables and the coefficients in represent the speed of adjustment towards equilibrium for each of the variables. The FCVAR model permits simultaneous modeling of the long-run equilibria, the adjustment responses to deviations from the equilibria and the short run dynamics of the system [18; 49].

The CVAR model is a special case of the FCVAR model that has this relationship, *d* = *b* = 1. To derive implication for inflation persistence from the fractional cointegration between inflation and oil prices, which will be interesting to monetary authorities, the vector of endogenous variables was normalized on inflation rate in this study, such that we have:

$$\text{Inflation}_t = \alpha + \beta\ \text{oil}_{t-k} + x_t, (1-L)^d\, x_t = u_t,\ t = 1,\ 2,\ \ldots, \quad (8)$$

where the parameter *d* indicates the degree of persistence, β is now an indicator of the effect of the present (and past) oil prices on domestic inflation rate of the respective countries (see also, [18]). The differencing parameter, d, in the cointegrating equation, *Eq*. (8), relies on equality between fractional integration of inflation and oil prices ($d_{\text{inflation}} = d_{\text{oil}}$). Hence, d in *Eq*. (8) is the fractional cointegrating persistence, which can explain the effect of shocks to oil prices of inflation persistence.

The fractional cointegration between oil prices and the rate of inflation describes how oil price shocks can affect the persistence of inflation in four cases depending on the values of the cointegration difference coefficient d:

The first case is where ($d = 0$) the cointegration process is constant and has short memory with no cointegration continuity. This means that the change in the inflation rate persistence due to the oil price shock will vanish almost immediately, in other words the effect of the oil prices shocks on the inflation rate persistence does not persist. The second case is ($0 < d < 0.5$) the cointegration process is also stationary but it shows a long memory with low persistence in the cointegration this indicates that the effect of the oil price shock on the inflation rate persistence in a country will last for a short period. In other words, the change in the persistence of inflation rate in a country due to an oil price shock will fade away within a short period. The third case is ($0.5 < d < 1$) the cointegration process is also highly stable, but it shows a long memory with a high continuity in the cointegration, meaning that the change in the inflation rate persistence due to the shock of oil prices will continue for a longer period before it finally fades. The fourth case is ($d \geq 1$), which means that the variance is not fixed, as oil price shocks cause permanent inflation to continue (see also, [1; 18; 41]).

When ensuring that each series is fractional integrated, the FCVAR model estimation is performed in four steps.

First: determine the optimal delay length model.

Second: determine the degree of integration.

Third: partial cointegration test using specified optimal delay and cointegration order.

Fourth: testing the model residuals for serial correlation.

Fifth: a comparison between the FCVAR model and the CVAR model using the probability ratio [LR] test.

RESULTS AND DISCUSSION

Stationarity of Data. By conducting Dickey-Fuller (ADF) and philips-perron (PP) tests, the results came as shown in Table 2, where we do not reject the hypothesis that there is a unit root in each of the time series of the inflation rate and the price of oil, since the "*t*" statistics Greater than critical values at all levels of conventional significance. The probabilities also show that the unit root hypothesis is not rejected for both the rate of inflation and the price of oil, the non-stationarity of the time series allows further tests for the cointegration.

Fractional integrated model estimation. Table 3 presents the results of the fractional integration on the time series, using both local Whittle estimator and log-period-gram (GPH) approaches.

The results are computed for three period-gram points $m = T^{0.6}$, $m = T^{0.7}$ and $m = T^{0.8}$, Fractional integration estimates, d_s are computed confined either less than 1 or greater than it in all cases across the three period-gram points for the two time series (inflation rate and oil prices).

So the fact that the integration factor for the price of oil and the rate of inflation in Algeria differ from zero and from the one, which indicates that the

Table 2. **Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) test results**

Test	At Level	Inflation rate	Oil price
Phillips–Perron test (PP)			
With Constant	*t*-Statistic	–2.4615	–2.2315
	Prob	0.1261	0.1956
		no	no
With Constant & Trend	*t*-Statistic	–2.9903	–2.4364
	Prob	0.1367	0.3600
		no	no
Without Constant & Trend	*t*-Statistic	–0.7749	–0.5625
	Prob	0.3799	0.4730
		no	no
Augmented Dickey–Fuller test (ADF)			
With Constant	*t*-Statistic	–3.4793	–2.5794
	Prob	0.0092 ***	0.0984 *
With Constant & Trend	*t*-Statistic	–4.0614	–2.8070
	Prob	0.0080 ***	0.1959
			no
Without Constant & Trend	*t*-Statistic	–0.9523	–0.7758
	Prob	0.3038	0.3795
		no	no

Notes: * — Significant at the 10%; *** — Significant at the 1% and no — Not Significant.
Source: computed by ehe authors via EViews 12 software.

Table 3. **Fractional integration estimates based on local Whittle estimator and GPH test**

Variable	*m*	Local Whittle Estimator	GPH test
Inflation rate	$T^{0.6}$	1,37423 *** (0,0912871)	1,13851 *** (0,172232)
	$T^{0.7}$	1,3936 *** (0,0680414)	1,19718 *** (0,0980175)
	$T^{0.8}$	1,37522 *** (0,051031)	1,28237 *** (0,063866)
	p-value	*p*-value 0.0000	*p*-value 0.0000
Oil price	$T^{0.6}$	0,903696 *** (0,0912871)	0,908769 *** (0,148676)
	$T^{0.7}$	1,00257 *** (0,0680414)	1,02091 *** (0,111381)
	$T^{0.8}$	1,06176 *** (0,051031)	1,13126 *** (0,0843498)
	p-value	*p*-value 0.0000	*p*-value 0.0000

Note: total sample T is 303 and the three period-gram points, $T^{0.6}$, $T^{0.7}$ and $T^{0.8}$ are 30, 54 and 86, respectively, *** — indicate 1 level of significance. Figures in square brackets represent the standard errors.
Source: computed by the authors via gretl software.

price of oil and the rate of inflation in Algeria are fractional integrated and this is what drives us to more tests to estimate the FCVAR model.

Fractional cointegration model estimation. ***Lag-order selection.*** According to Table 4, the lowest value of the AIC information criteria suggests that a lag length of 1 may be a suitable choice. Considering the LR statistic and its *p*-value, which indicate the significance of Γ1 by rejecting the null hypothesis of Γ1 = 0 at a 1% significance level, and the fractional cointegration order *b* greater than 1/2, all these criteria indicate that Lag 1 is the appropriate choice for the model.

Table 4. **Lag Selection Results**

Lag Selection Results			
Dimension of system	2	Number of observations in sample	436
Order for WN tests	12	Number of observations for estimation	436
Restricted constant	No	Initial values	0
Unrestricted constant	No	Level parameter	Yes

Parameter Estimates and Information Criteria

k	r	d	b	LogL	LR	pv	AIC	BIC
3	2	0.940	0.940	364.48	3.40	0.493	–690.95	–620.39
2	2	0.891	0.891	362.77	1.04	0.903	–695.55	–639.84
1	2	0.883	0.883	362.25	116.44	0.000	**–702.51*****	–661.66***
0	2	1.457	1.457	304.03	0.00	0.000	–594.07	–568.07

Tests for Serial Correlation of Residuals

k	pmvQ	pQ1	pLM1	pQ2	pLM2
3	1.00	0.62	0.27	0.93	0.52
2	0.99	0.65	0.38	0.94	0.39
1	0.99	0.64	0.34	0.93	0.36
0	0.00	0.00	0.04	0.00	0.22

Note: *** — indicate 1% level of significance, suppose: *d* = *b*.
Source: computed by the authors via *R*-studio software.

Table 5. **Cointegration Rank Results**

Likelihood		Ratio	Tests for Cointegrating		Rank
Dimension of system		2	Number of observations in sample		436
Number of lags		1	Number of observations for estimation		436
Restricted constant		No	Initial values		0
Unestricted constant		No	Level parameter		Yes
Rank	*d*	*b*	Log-likelihood	*LR* statistic	*P*-value
0	0.932	0.932	496.584	12.520	0.345
1	0.883	0.883	502.558	**0.572**	**0.957**
2	0.887	0.887	502.844	—	—

Note: — the *LR p*-values in the last column are missing.
Source: computed by the authors via *R*-studio software.

Cointegration rank selection. Table 5 presents the relevant test results for selecting the appropriate order of fractional cointegration. It includes the probability ratio test statistics for a specific joint integration order against an unrestricted model with full integration order when available. The p-values are calculated using the "fracdist" package, which obtains simulation-based p-values from [52]. By reading the table from the lowest order to the highest order, we reject the null hypothesis of order 0 against order 2 because the LR statistic is

Table 6. **Fractional cointegration test results (FCVAR)**

Fractional parameters	Fractional parameters	Fractional parameters	
Coefficient	Estimate	Standard error	
d	**0.883**	**0.041**	
Cointegrating equations (beta)			
Variable	CI equation 1		
Inflation rate	1.000		
Oil price	0.000		
Adjustment matrix (alpha)			
Variable	CI equation 1		
Inflation rate	–0.020		
SE 1	(0.006)		
Oil price	–7.132		
SE 2	(15.147)		
Long-run matrix (Pi)			
Variable	Inflation rate	Oil price	
Inflation rate	–0.020	–0.000	
Oil price	–7.132	–0.000	
Level parameter (mu)			
Inflation rate	0.052		
SE 1	(0.002)		
Oil price	15.555		
SE 2	(5.435)		
Lag matrix 1 (Gamma_1)			
Variable	Inflation rate	Oil price	
Inflation rate	0.904	–0.000	
SE 1	(0.057)	(0.000)	
Oil price	35.511	0.476	
SE 2	(102.327)	(0.078)	
Roots of the characteristic polynomial			
Number	Real part	Imaginary part	Modulus
1	2.100	0.000	2.100
2	1.043	–0.141	1.052
3	1.043	0.141	1.052
4	1.000	0.000	1.000

Note: standard errors in parentheses.
Source: computed by the authors via *R*-studio software.

higher than the critical value at all traditional significance levels. We then test the null hypothesis of order 1 against order 2, and since the LR statistic for order 1 is smaller than the critical value at all traditional significance levels, we accept the null hypothesis with a *p*-value of 0.957. Therefore, the order of fractional cointegration is equal to 1, which means there is one cointegrated long-run equilibrium relationship between the oil prices and inflation rate.

Model estimation FCVAR. Through the results of Table 6, we observe that the fractional cointegration coefficient, d, is estimated at 0.883 and is bounded between 0.50 and 1 ($0.5 < d < 1$). This means that the Cointegration process is highly stable but exhibits long memory with a high level of persistence in the cointegration. Hence, the variation in the inflation rate in Algeria will persistence for a longer period due to the shock of oil prices before eventually fading away.

Testing the model residuals for serial correlation. The results of the white noise tests are shown below. For each residual both the *Q*- and *LM*-test statistics and their *P*-values are reported, in addition to the multivariate *Q*-test and associated *P*-value in the first line of the Table 7. From the output of this table we can conclude that there does not appear to be any problems with serial correlation in the residuals.

Comparison of the FCVAR and VAR model using the LR likelihood ratio. Here we test the CVAR model (null hypothesis: $d = b = 1$) against the FCVAR model (alternative hypothesis: $d = b \neq 1$), which restricts $b = d = 1$, where we reject the null hypothesis if the probability ratio (*LR*) is statistically significant, where we prefer the FCVAR model, otherwise the opposite, we prefer the CVAR model. By examining the test results shown in Table 8, which presents

Table 7. **White Noise Test Results**

Variable	*Q*	*P*-value	*LM*	*P*-value
Multivar	38.213	0.843	—	—
Inflation rate	9.616	0.650	13.259	0.350
Oil price	14.058	0.297	14.592	0.265

Note: — the *LM p*-values in the last column are missing.
Source: computed by the authors via *R*-studio software.

Table 8. **LR likelihood ratio test results between the CVAR and FCVAR models**

Unrestricted log-likelihood	Restricted log-likelihood	*LR*-statistic	*P*-value
502.558	499.380	**6.356**	0.012 **

Note: ** — indicate 5% level of significance.
Source: computed by the authors via *R*-studio software.

the log-likelihood values for both models, degrees of freedom, the *LR*-test statistic, and the *p*-value estimated to be 0.012, which is significant at all traditional confidence levels. Therefore, the test clearly no accepts the null hypothesis that the preferred model is CVAR. Consequently, we accept the alternative hypothesis, indicating that the FCVAR model is the better choice.

CONCLUSION

This study investigated the integration relationship between the inflation rate and oil prices, analysing the persistence of the impact of oil price shocks on the inflation rate in Algeria. The study contributes to the literature on analyzing the degrees and determinants of inflation persistence in Algeria by examining the effect of the external factor represented by oil prices on inflation persistence. Given the nature of the multivariate analysis, we employed the Fractionally Cointegrated Vector Auto-regression (FCVAR) model. The results of the study are as follow:

- the preliminary analysis of inflation rate data in Algeria confirmed that it is characterized by high inflation rates, especially during periods of economic crises that the country has experienced, as well as during periods of oil price collapses. Oil prices constitute a significant economic resource in Algeria;
- the results of the applied fractional integration test on oil price data on one hand and inflation rates in Algeria on the other hand showed that they are fractional integrated;
- our results also showed that Algeria has a co-integration relationship between oil prices and the inflation rate, with an estimated persistence of 0.883, which is greater than 0.5 and less than 1. This indicates that the impact of oil price shocks is still present for a long time on the inflation rate persistence in Algeria, in other words the inflation rate in Algeria will persistence for a longer period due to the shock of oil prices before eventually fading away, and with the adoption of a monetary policy targeting inflation in Algeria, it will contribute to reducing the inflation rates persistence;
- these results come to confirm the hypotheses that we presented and are also compatible with various economic theories;
- the results of this study will open horizons for researchers to study the impact of other (external) structural factors on the inflation rate persistence in Algeria in order to understand more broadly the dynamics of the inflation rate persistence in Algeria.

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НАФТОВІ ЦІНОВІ ШОКИ І СТІЙКІСТЬ РІВНЯ ІНФЛЯЦІЇ ДЛЯ АЛЖИРУ: ДРОБОВО-КОІНТЕГРАЦІЙНИЙ ЗВ'ЯЗОК

Проаналізовано зв'язок між цінами на нафту і рівнем інфляції в Алжирі з метою визначення ступеня стійкості інфляції в умовах нафтових цінових шоків з січня 1998 р. по березень 2023 р. за допомогою нещодавно розробленої моделі дробової коінтеграції, яка дає змогу інтегрувати різниці дробово, а не стаціонарно, з класичним коінтеграційним підходом, заснованим на $I(0)$ стаціонарності або $I(1)$ коінтеграційних зв'язках. Цю тему було обрано через її важливість для розробників монетарної політики, інвесторів, фінансових аналітиків і науковців у плані розуміння динаміки стійкості інфляції в Алжирі й вивчення впливу на неї деяких цінових шоків, таких як нафтові цінові шоки. Отримані результати також показали, що в Алжирі спостерігається коінтеграційний зв'язок між цінами на нафту і рівнем інфляції з розрахунковою стійкістю 0,883, що більше за 0,5 і менше від 1. Це свідчить про те, що вплив нафтових цінових шоків на стійкість рівня інфляції в Алжирі все ще наявний протягом тривалого часу, іншими словами, рівень інфляції в Алжирі зберігатиметься довше через нафтовий ціновий шок, перш ніж нарешті спаде, і разом із запровадженням в Алжирі монетарної політики, спрямованої на регулювання інфляції, це сприятиме зниженню стійкості рівня інфляції.

Ключові слова: *стійкість рівня інфляції; нафтові цінові шоки; дробова коінтеграція; Алжир.*

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