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STUDYING THE RELATIONSHIP BETWEEN THE PRICE OF GOLD AND THE INFLATION RATE PERSISTENCE IN ALGERIA USING THE FRACTIONAL INTEGRATION MODEL

The effectiveness of a monetary policy strategy lies in its ability to achieve sustained low inflation, which means that inflation rate shocks can be eliminated quickly. Gold price shocks are considered external shocks that can affect inflation rates in Algeria, especially in the context of the Ukrainian war, which affected gold prices.

***Keywords**: inflation rate persistence; gold price 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 (Tule, Salisu, Ebuh, 2020). Understanding the dynamics of inflation persistence will help central bank officials to make appropriate monetary policy decisions (Amano, 2007; Coenen, 2007; Tetlow, 2019).

Inflation persistence is the time it takes for inflation rate shocks to dissipate (Sbordone, 2007), 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 (Bratsiotis, Madsen, Martin, 2015; Gerlach, Tillmann, 2012; Meller, Nautz, 2012; Misati, Nyamongo, Mwangi, 2013). On the contrary, the wrong appreciation of the inflation rate persistence can be charged with monetary policy makers.

Gold price shocks are among the external shocks that can affect inflation rates in any country. Many studies have been conducted on the determinants of inflation rates persistence, but little attention has been paid to the role of gold price as a leading indicator of inflation. This is because gold is typically analyzed as a commodity. However, unlike other commodities, gold is characterized by being a store of value and a hedge against inflation. Therefore, considering it as a financial asset will allow us to monitor its prices as leading indicators of inflation rates persistence. However, we find some recent studies (Aye, Carcel, Gil-Alana et al., 2017; Lucey, Sharma, Vigne, 2017; Salisu, Ndako, Oloko, 2019) that point to the importance of the relationship between gold price and inflation rates that can be explored by monetary authorities.

Therefore, an increase in the country's persistent inflation rate as a result of an gold 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 gold price shock. On the other hand, if the inflation rate continues to declines or remains unchanged due to an gold price shock, it means that the current monetary policy of the country is responsive to the gold 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 (Antonakakis, Cunado, Gil-Alana et al., 2016).

The main objective of our study is to investigate the impact of gold price shocks on the persistence of inflation in Algeria. 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 gold price shocks. We will use the Fractional Cointegration Vector Autoregressive (FCVAR) model, introduced by S. Johansen (2008) and further developed by S. Johansen & M. Nielsen (2012), instead of the traditional Cointegrated Vector Autoregressive (CVAR) model proposed by S. Johansen (1995). 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 ($1 < d < 0$) (Gil-Alana, Yaya, Awe, 2017; Gil-Alana, Carcel, 2020; Granville, Zeng, 2019).

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 (Tule, Salisu, Ebuh, 2020; Granville, Zeng, 2019; Bilici, Çekin, 2020)). The same applies to gold prices, as (Aye, Carcel, Gil-Alana et al., 2017) found that gold prices are fractional integrated. This makes the FCVAR approach more suitable for analyzing the long-term relationship between gold price and inflation. 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 gold price 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 gold price 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.

THEORETICAL BACKGROUND

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 (Sbordone, 2007), and it can also be defined as the speed at which inflation returns to its equilibrium level (medium and long term) after a shock (Bilici, Çekin, 2020). 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 (Bratsiotis, Madsen, Martin, 2015; Gerlach, Tillmann, 2012; Meller, Nautz, 2012).

Inflation persistence (Batini, Nelson, 2001) 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 (Roache, 2014).

Distinguished between three types of persistence (Batini, Nelson, 2001):

• 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 (1995), which is the inflation response to its own shocks. This type of persistence emphasises how inflation responds to its own disturbances.

From a macroeconomic perspective, the interest in gold prices lies specifically in the embedded inflation expectations, as it is to be determined to what extent gold prices movements can lead to future movements in inflation. In theory, an increase in inflation expectations reduces the perceived purchasing power of money. Therefore, agents strip themselves of money and increase their holdings of gold. This increase in demand for gold will lead to an increase in its prices. Therefore, high gold prices should indicate higher inflation rates in the future (Stock, Watson, 2003).

Some theoretical frameworks confirm the relationship between asset prices (including gold) and inflation, so that the relationship between gold price and inflation can be examined through a variety of channels and economic theories:

Karl Marx's economic theory has played a decisive role in the intellectual history of monetary theory. Marx believed that money has five functions, including a store of value. Marx argued that to make the actual circulating amount of money compatible with the saturation of the sphere of circulation, the amount of gold and silver available in a country must be greater than the amount of gold and silver that can perform the function of currency. This condition is met through the hoarding of money. Therefore, in history, money in terms of gold and silver has been a means of accumulating social wealth and expanding the social rights of the individual. In other words, the function of money as a store of value is considered a hedge against inflation, which reduces the value of money over time (Wang, 2019);

Tobin's q theory suggests that an increase in asset prices makes the purchase of new capital more profitable, which gives momentum to investment growth, which then translates into demand-pull inflation (Mishkin, 1990), The wealth effect of this increase in asset prices not only leads to an increase in private consumption, but also to an increase in borrowing capacity and thus inflation (Kent, Lowe, 1997);

Classical Interest Theory: Fisher (1930) posits that expected nominal stock returns should move one-for-one with expected inflation. In other words, rational investors will require a nominal return that compensates for the decline in the purchasing power of money. This supposed Fisher hypothesis is generalized to other investment assets. This implies that the expected nominal return on any investment asset should be equal to its real return plus the expected rate of inflation (Fama, Schwert, 1977);

post-Keynesian theory of inflation: asset prices suggest that an increase in the stock market or property values can contribute to overall inflationary pressures in and of itself (through the wealth effect on consumer spending), which requires a higher central bank base rate and implies greater economic hardship for those who lose their jobs later (Dalziel, 1999);

Hypothesis of Dollar Destruction: the idea of gold and inflation is linked to the gold's response to the "Dollar Destruction" theory. Inflation can be defined as an increase in the money supply, while productivity and production remain the same, prices rise. This has happened on many occasions, where bad governments print large amounts of money and eventually send their countries into hyperinflation. The story is somewhat similar, as proponents of this theory claim, that when the Federal Reserve or the government reduces the value of the dollar by lowering interest rates or managing a budget deficit, they believe that the best defense against the loss of purchasing power that comes from these government actions is to buy gold. This differs from the inflation hedge theory because it does not only include a loss of purchasing power due to the general rise in prices, but also a loss of purchasing power in a global environment due to unfavorable exchange rate changes for dollar holders. We look at the subject from two angles: first, we investigate the relationship between gold and real interest rates, and second, we investigate the relationship between gold and exchange rates (Fei, 2009).

Some analysts view the prices of gold as a leading indicator of inflation because gold is widely held as a store of value. Gold is considered a store of value partly because of its physical properties, such as durability and attractiveness, and partly because of its historical role as a cornerstone of the global monetary system (Laurent, 1994). Many countries issued gold coins and held a stockpile of gold bullion to back their paper currencies fully or partially. Thus, although gold has industrial uses, much of the demand for gold has always been as a store of value. Moreover, the supply of gold is relatively fixed because new gold production is small compared to the current stockpile of the metal. Even though gold no longer plays a major role in the global monetary system, the prices of gold may be a good leading indicator of inflation. The rationale is that if enough people view gold as a good store of value, then the expectation of rising inflation may cause some investors to shift their money from financial assets with fixed nominal interest rates to gold coins or jewelry. Because the supply of gold is relatively fixed, the prices of gold may rise sharply with a slight increase in demand. In contrast, the general inflation rate tends to rise more slowly because the prices of many goods and services adjust slowly. As a result, an increase in the prices of gold may precede a rise in the general inflation rate, provided that the expectation of rising inflation is correct in the first place (Garner, 1995).

The persistence of inflation is the time it takes for inflation rate shocks to dissipate (Sbordone, 2007), and it can also be defined as the speed at which inflation rate returns to its long-term equilibrium level after a shock (Bilici, Çekin, 2020). Understanding the nature of inflation persistence will assist authorities and policymakers in implementing effective monetary policies towards maintaining price stability and economic stability (Bernanke, Gertler, Watson et al., 1997). 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 (2020) 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 (2019) 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. (2016) 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. (2015) 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 (2012) 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. (2021) titled "Fractional Cointegration between Gold Prices and Inflation Rate: Application to Inflation Persistence" aimed to analyse the relationship between gold prices 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 Aye et al. (2017) titled Is Gold an Inflation Hedge in the UK? Evidence from the fractional cointegration approach. This study aimed to study the inflation hedging ability of gold in the United Kingdom using fractional cointegration. The study concluded that gold provides protection against inflation and that its value will be maintained in the presence of inflation, The study by Oloko et al. (2021) 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, A study Geronikolaou et al. (2020) 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 (2018) 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 (2016) 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 Batten et al. (2014) entitled The Economic Determinants of Gold's Relationship with Inflation, which studied the long-term dynamic relationship between inflation and the prices of gold using the cointegration model, and the results concluded that gold's sensitivity to inflation is linked to interest rate changes, The study by Mishkin & Schmidt-Hebbel (2007) 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.

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 gold price, 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 deeply, especially considering its unique economic characteristics as a resource-rich country. Additionally, the study utilises the Fractional Co-integration 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 gold price and inflation rate persistence in Algeria, which serves as a motivation for undertaking this study.

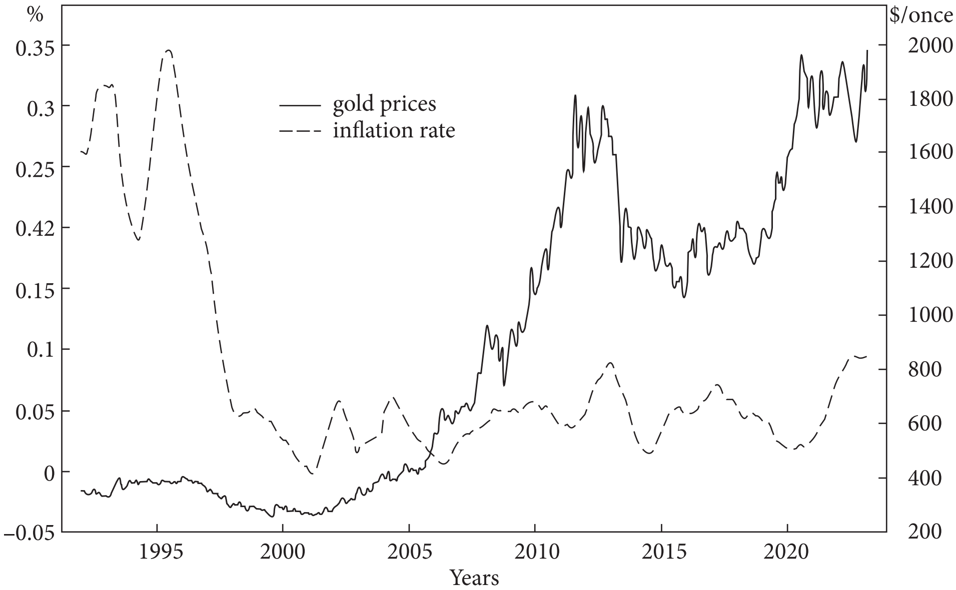
DATA

In this study, we use monthly data for both gold prices and inflation rates in Algeria from January 1998 to March 2023. This dataset comprises 375 observations, covering periods of both high and low inflation rates in Algeria, as well as positive and negative gold price shocks worldwide. The inflation rate data was obtained from the Bank of Algeria website [1], Gold prices data was taken from the World Gold Council website [2]. The inflation rate is expressed as a percentage, while the gold price is expressed in US dollars per ounce.

Based on the monthly data provided in Figure and Table 1, the study shows that gold prices experienced significant fluctuations over time. However, the overall trend has been one of significant increase. The lowest recorded price was $254.80 per ounce in August 1999, when central banks began reducing their gold reserves and mining companies sold gold in the futures markets to protect themselves from a decline. The highest value was recorded in March 2023 at $1979.70 per ounce. This increase is due to several reasons, the most important of which is the war in Ukraine. The war has led to increased global geopolitical tensions, which has led to increased demand for gold as a safe haven. Gold is considered a safe haven in times of political and economic uncertainty. In general, the average price of gold throughout the study period was $677 per ounce, with a standard deviation estimated at $549.80 per ounce. This

[1] The Bank of Algeria. URL: https://www.bank-of-algeria.dz/IPC-et-inflation/ (accessed on: 20.10.2023).

[2] World Gold Council. URL: https://www.gold.org / (accessed on: 20.10.2023).



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

Table 1. **Descriptive Statistics**

Variable	Inflation rate, %	Gold price, $ / ounce	Variable	Inflation rate, %	Gold price, $ / ounce
Observations	375	375	Minimum	–0.24	254.80
Mean	7.97	874.87	Std. Dev	8.77	549.80
Median	4.81	677	Jarque-Bera	257.43	37.44
Maximum	34.54	1979.70	Bropability	0.00000	0.00000

Source: computed by the authors via EViews12 software.

large standard deviation is evidence of the volatility of gold prices over time. However, the overall trend has been one of continuous increase.

Regarding the inflation rate in Algeria, the highest rate was recorded in June 1996 at 34.54%, due to the economic, political and security conditions that Algeria went through during that period. And the lowest value was recorded in March 2001 at –0.24%, resulting from improved political, security 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. Overall, the average inflation rate in Algeria and its standard deviation are 4.81% and 8.77% 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 (2012). This model has gained significant popularity, as evident from its recent application in various fields of study, including. (Tule, Salisu, Ebuh, 2020; Aye, Carcel, Gil-Alana et al., 2017; Gil-Alana, Yaya, Awe, 2017; Gil-Alana, Carcel, 2020; Solarin Sakiru Adebola, Gil-Alana L., Madigu, 2019; Yaya, O., Ogbonna, A., Atoi, 2019). This model allows for fractional integration with non-zero orders when the series are not integrated at the zero order (Gil-Alana, Carcel, 2020). 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 gold prices.

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

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

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 (Granger, 1981; Granger, 1980; Granger, Joyeux, 1980; Hosking, 1981), although Adenstedt (1974) 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,

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

And thus

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

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

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

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 (Gil-Alana, Carcel-Villanova, 2018).

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 rate or gold price. As gold price 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 gold price and inflation rate in the Algeria As the differencing parameter, d, an integer value, was not restricted by (Engle, R., Granger, 1987; Robinson, 2008) 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, Aye, Carcel, Gil-Alana et al., 2017).

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:

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

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 $L_b = 1b$, respectively. We then obtain

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

Which is applied to $YX_t = dbt$ such that

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

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 (Gil-Alana, Yaya, Awe, 2017; Gil-Alana, Carcel-Villanova, 2018).

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 rate and gold price, which will be interesting to monetary authorities, the vector of endogenous variables was normalized on inflation rate in this study, such that we have:

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

where the parameter *d* indicates the degree of persistence, β is now an indicator of the effect of the present (and past) gold price on domestic inflation rate of the respective countries (see also, Gil-Alana, Yaya, Awe, 2017). The differencing parameter, *d*, in the cointegrating equation, Eq. (8), relies on equality between fractional integration of inflation rate and gold price ($d_{inflation} = d_{gold}$). Hence, *d* in Eq. (8) is the fractional cointegrating persistence, which can explain the effect of shocks to gold price of inflation persistence.

The fractional cointegration between gold price and the rate of inflation rate describes how gold 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 gold price shock will vanish almost immediately, in other words the effect of the gold price 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 gold 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 gold 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 gold 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 gold price shocks cause permanent inflation to continue (see also, Tule, Salisu, Ebuh, 2020; Aye, Carcel, Gil-Alana et al., 2017; Gil-Alana, Yaya, Awe, 2017).

When ensuring that each series is fractional integrated, the FCVAR model estimation is performed in five 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 gold price, 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 gold, 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

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

Test	At Level	Inflation rate	Gold price
Phillips-Perron test (PP)			
With Constant	*t*-Statistic	−2.3527	0.2188
	Prob	0.1562	0.9735
		No	No
With Constant & Trend	*t*-Statistic	−2.0950	−2.0642
	Prob	0.5464	0.5636
		No	No
Without Constant & Trend	*t*-Statistic	−2.1060	1.7137
	Prob	0.0340	0.9793
		**	No
Augmented Dickey-Fuller test (ADF)			
With Constant	*t*-Statistic	−2.1475	0.1980
	Prob	0.2263	0.9722
		No	No
With Constant & Trend	*t*-Statistic	−1.5471	−2.1858
	Prob	0.8116	0.4956
		No	No
Without Constant & Trend	*t*-Statistic	−2.0958	1.6955
	Prob	0.0348	0.9784
		**	No

Notes: ** — significant at the 5%; No — not Significant.
Source: computed by the authors via EViews 13 software.

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

m	Variable	GPH test	Local Whittle estimator
$T^{0.6}$	Inflation rate	1.27993 *** (0.108518)	1.3882 *** (0.0845154)
$T^{0.7}$		1.22488 *** (0.0633632)	1.31264 *** (0.0629941)
$T^{0.8}$		1.15838 *** (0.0367127)	1.20728 *** (0.0468293)
p-value		*p*-value 0.0000	*p*-value 0.0000
$T^{0.6}$	Gold price	1.00878 *** (0.0798827)	1.05001 *** (0.0845154)
$T^{0.7}$		0.91913 *** (0.0525782)	0.948013 *** (0.0629941)
$T^{0.8}$		0.996384 *** (0.0458552)	0.959084 *** (0.0468293)
p-value		*p*-value 0.0000	*p*-value 0.0000

Note: total sample T is 375 and the three period-gram points, $T^{0.6}$, $T^{0.7}$ and $T^{0.8}$ are 35, 63 and 114, respectively; *** indicate 1 level of significance. Figures in square brackets represent the standard errors.
Source: computed by the authors via gretl software.

less than 1 or greater than it in all cases across the three period-gram points for the two time series (inflation rate and gold price).

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

Table 4. **Lag Selection Results**

Lag Selection Results			
Dimension of system	2	Number of observations in sample	375
Order for WN tests	12	Number of observations for estimation	375
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	0.699	0.699	–275.73	7.77	0.101	589.46	664.08
2	2	0.598	0.598	–279.61	11.03	0.026	589.23 **	648.13
1	2	1.005	1.005	–285.13	226.54	0.000	592.25	635.45 ***
0	2	1.619	1.619	–398.40	0.00	0.000	810.79	838.28

Tests for Serial Correlation of Residuals

k	*pmvQ*	*pQ1*	*pLM1*	*pQ2*	*pLM2*
3	0.00	0.00	0.02	0.00	0.22
2	0.00	0.00	0.06	0.00	0.18
1	0.00	0.00	0.04	0.00	0.19
0	0.00	0.00	0.00	0.00	0.00

Note: ** significant at the 5%; *** significant at the 1%, 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	375
Number of lags	1	Number of observations for estimation	375
Restricted constant	No	Initial values	0
Unestricted constant	No	Level parameter	Yes

Tests for Serial Correlation of Residuals

Rank	*d*	*b*	Log-likelihood	*LR* statistic	*P*-value
0	0.628	0.628	–287.647	16.065	0.031
1	0.593	0.593	–280.144	**1.059**	**0.635**
2	0.598	0.598	–279.614	----	----

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

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

Fractional parameters		
Coefficient	Estimate	Standard error
d	**0.593**	**0.000**
Cointegrating equations (beta)		
Variable	CI equation 1	
Inflation rate	1.000	
gold price	0.000	
Adjustment matrix (alpha)		
Variable	CI equation 1	
Inflation rate	0.006	
SE 1	(0.000)	
Gold price	–67.305	
SE 2	(0.000)	
Long-run matrix (P_i)		
Variable	Inflation rate	Gold price
Inflation rate	0.006	0.000
Gold price	–67.305	–0.005
Level parameter (mu)		
Inflation rate	0.260	
SE 1	(0.000)	
gold price	354.100	
SE 2	(0.000)	
Lag matrix 1 (Gamma_1)		
Variable	Inflation rate	Gold price
Inflation rate	2.100	0.000
SE 1	(0.000)	(0.000)
gold price	–266.777	0.451
SE 2	(0.000)	(0.000)
Lag matrix 2 (Gamma_2)		
Variable	Inflation rate	Gold price
Inflation rate	–1.222	0.000
SE 1	(0.000)	(0.000)
gold price	737.538	0.408
SE 2	(0.000)	(0.000)

Roots of the characteristic polynomial			
Number	Real part	Imaginary part	Modulus
1	–2.207	0.000	2.207
2	1.039	0.000	1.039
3	1.000	0.000	1.000
4	0.999	0.000	0.999
5	0.889	–0.285	0.933
6	0.889	0.285	0.933

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

length of **2** 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 **2** is the appropriate choice for the model.

Co-integration 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 (MacKinnon, Nielsen, 2014). 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 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 **0.635**. Therefore, the order of fractional cointegration is equal to 1, which means there is one cointegrated long-run equilibrium relationship between the gold price and inflation rate in Algeria.

Model estimation FCVAR. Through the results of Table 6, we observe that the fractional cointegration coefficient, *d*, is estimated

Table 7. **White Noise Test Results**

Variable	Q	P-value	LM	P-value
Multivar	97.938	0.000	----	----
Inflation rate	52.562	0.000	20.060	0.066
Gold price	33.528	0.001	16.646	0.163

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**

P-value	LR statistic	Restricted log-likelihood	Unrestricted log-likelihood
0.006***	7.535	–283.912	–280.144

Note: *** indicate 1% level of significance.
Source: computed by the authors via *R*-studio software.

at **0.593** 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 gold 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 the log-likelihood values for both models, degrees of freedom, the LR-test statistic, and the p-value estimated to be 0.006, 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 gold price, analyzing the persistence of the impact of gold 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 gold price 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, political and security crises that the country has experienced, as well as during periods of oil price collapses, As Oil prices constitute a significant economic resource in Algeria;

• gold prices have been on a steady rise, increasing by more than 10% in 2023 to reach their highest level in over two years. There are several reasons for this increase, including:

Inflation: Rising inflation around the world has led to increased demand for gold as a safe haven investment. Gold is a limited-supply asset that does not easily lose value in tough economic conditions.

The war in Ukraine: The war in Ukraine has led to increased global geopolitical tensions, which has led to increased demand for gold as a safe haven. Gold is considered a safe haven in times of political and economic uncertainty.

Interest rate hikes: The Federal Reserve raised interest rates several times in 2023 in an effort to curb inflation. This led to higher bond yields, making gold less attractive to investors looking for yield. However, rising inflation was a more important factor in driving gold prices higher;

• the results of the applied fractional integration test on gold 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 gold price and the inflation rate, with an estimated persistence of 0.593, which is greater than 0.5 and less than 1. This indicates that the impact of gold 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 gold price 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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ВИВЧЕННЯ ЗВ'ЯЗКУ МІЖ ЦІНОЮ НА ЗОЛОТО І СТІЙКІСТЮ РІВНЯ ІНФЛЯЦІЇ У АЛЖИРІ ЗА ДОПОМОГОЮ МОДЕЛІ ДРОБОВОЇ ІНТЕГРАЦІЇ

Проаналізовано взаємозв'язок між ціною на золото і рівнем інфляції у Алжирі, визначено ступінь стійкості інфляції в умовах шоків цін на золото з січня 1992 р. по березень 2023 р. за допомогою нещодавно розробленої моделі дробової коінтеграції, яка уможливлює дробову інтеграцію залишків замість їх стаціонарності, з класичним коінтеграційним підходом, заснованим на $I(0)$-стаціонарності або коінтеграційних зв'язках $I(1)$. Цю тему було обрано з огляду на її важливість для розробників грошової політики, інвесторів, фінансових аналітиків і науковців у плані розуміння динаміки стійкості інфляції у Алжирі й вивчення впливу на неї деяких цінових шоків, зокрема на золото. На ці шоки вплинуло кілька чинників, найважливішим з яких є війна в Україні, яка спричинила рекордне зростання цін на золото. Отримані результати також показали, що в Алжирі існує коінтеграційний зв'язок між ціною на золото і рівнем інфляції з розрахунковою стійкістю 0,593, тобто більше від 0,5 і менше за 1. Це вказує на те, що вплив шоків цін на золото на стійкість рівня інфляції у Алжирі все ще спостерігається протягом тривалого часу, іншими словами, через шок цін на золото рівень інфляції у Алжирі зберігатиметься довший період, перш ніж остаточно спаде, і, в разі запровадження грошової політики, спрямованої на подолання інфляції у Алжирі, це спричинить зниження стійкості рівня інфляції.

Ключові слова*: стійкість рівня інфляції; шоки цін на золото; дробова коінтеграція; Алжир.*