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Fractional Cointegration between Energy Exports to the Euro Area and Inflation Rate Persistence

Abstract. *This study aims to analyse the degree of persistence in the energy exports in in energy exporting countries to the European region along with the inflation rates persistence. We have also focused attention on the relationship between the two variables in the most important countries exporting energy to the EU area (Algeria, Norway, Russia, Libya, Saudi Arabia, Nigeria, and the United Kingdom). The methodology used deals with long-memory processes and is based on the concepts of fractional integration and fractional cointegration. Our results showed that inflation persistence of energy-exporting does not appear to increase due to energy exports shocks for the case of the UK, Nigeria, Saudi Arabia and Algeria, suggesting that the monetary policies of these countries accommodates energy exports shocks, and may not necessarily be changed due to energy exports shocks. As for the case of Norway case, that the effect of the energy exports shock on the inflation rate persistence this country will last for a short period. As for the case of (Libya and Russia) , the shock duration has a lasting effect, as energy exports shocks cause permanent inflation rate persistence in these countries. Our results also show that countries operating floating regime with inflation targeting (IT&FR) have higher inflation persistence than countries operating pegged exchange rate regime with non-inflation targeting monetary policy (NIT&PR). Meanwhile, we also found that energy-exports countries in the EU area operating non-inflation targeting monetary policy (NIT&PR) like Norway tend to have short memory inflation persistence ($d < 0.5$), unlike their energy-exporting counterparts (such as UK, Saudi Arabia, Nigeria, and Algeria) which tend to have long memory temporary inflation persistence ($0.5 \leq d < 1$); and (Libya and Russia) which tend to long memory permanent inflation persistence ($d > 1$).*

Keywords: *inflation rate persistence, energy exports, fractional cointegration, FCVAR model, euro area.*

JEL Classification: C32, E31, E52, Q43.

1. Introduction

The link between energy exports and inflation is a topic of great interest for economists and politicians. As the Eurozone continues to rely heavily on energy imports, especially from fossil fuel exporting countries, understanding the dynamic interaction between these variables is crucial for effective monetary and fiscal

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policies. These debates and studies on measuring macroeconomic variables (e.g., the role of energy in inflation, measuring the presence of macroeconomic imbalances) have become increasingly important in recent years. In contrast, the lower the stability, the greater the "policy space," which is defined as the ability of monetary policy to absorb temporary price shocks; this is why stability is important because it affects production costs to bring inflation down to the target, often described as a "sacrifice ratio." In other words, inflation rate persistence is sometimes defined as the tendency for price shocks to push the inflation rate away from its steady state, including the inflation target, over a long period of time (Roache, 2014).

The importance of studying inflation persistence is that it plays an important role in monetary policy design because it determines the extent to which the monetary policy authorities can simultaneously maintain output and inflation levels constant, thereby determining the performance of monetary policy. (Antonakakis et al., 2016). Therefore, a country's increase in its persistent inflation rate due to energy exports indicates that the effectiveness of its monetary policy is weak. This requires a review of monetary policy to deal with energy export shocks. On the other hand, if the inflation rate continues to decline or remains unchanged due to energy exports, it means that the country's current monetary policy is dealing with energy export shocks, and there is no need to review monetary policy in this case.

This study examines whether there is a fractional cointegration relationship between Eurozone energy exports and inflation rates in major energy-exporting countries. Although energy resources have always been recorded using methods from economic life, energy still plays an important role in contemporary life, measured in terms of import costs and supply security. Fractional cointegration analysis allows for a more nuanced examination of long-run equilibrium relationships and has the potential to reveal complex dependencies that may not be captured by traditional cointegration methods. By studying this relationship, the study aims to gain insight into the underlying mechanisms of inflation dynamics and the role of energy trading, ultimately providing information for policymakers to address the challenges of price stability and energy security in the Eurozone.

We use the fractional cointegrating vector autoregression (FCVAR) model introduced by (Johansen, 2008) and further developed by (S. Johansen & Nielsen, 2012) instead of the traditional cointegrating vector autoregression (CVAR) model proposed (S. Johansen, 1995). Both models capture the long-run relationship between the variables, but the CVAR model assumes only two cases of long-run relationships characterised by either a zero integration order I(0) or a first integration order I(1), while the FCVAR model allows for different integration orders (I(d)), where d represents any real-valued integration order and implements long-memory persistence ($1 < d < 0$) (Gil-Alana & Carcel, 2020).

This study will contribute to the empirical literature analysing the determinants of inflation persistence in the most important energy-exporting countries by examining the impact of an external factor represented by the energy exports using the recently developed Fractional Cointegration Vector

Autoregressive (FCVAR) model. It will also shed light on the role of energy-exporting countries' monetary policies in modelling this impact. The findings of this research will contribute to a better understanding of the interplay between inflation and energy exports and provide valuable insights for policymakers in designing and implementing appropriate monetary policies to promote economic stability and growth.

The organisation of this study after this introductory section is as follows: Section 2 reviews the existing literature, evaluates its findings, and highlights the added value of our study; Section 3 presents the data and its temporal evolution; Section 4 outlines the methodological framework of the study; Section 5 presents the results and discussion; and finally, Section 6 concludes the paper.

2. Literature review

This paper belongs to the massive literature that researches the macroeconomic impacts of electricity region factors. For example (Tiwari, 2013) plays a wavelet analysis to break down the outcomes of oil expenses in the German macro-economy; (Fagnart & Germain, 2016) use an input-output version to observe the macroeconomic implications of the first-class of strength production. (Magazzino, 2017) also investigates the power intake-economic growth link in Italy and reveals an unmarried lengthy-run relationship. Regarding international trade, the empirical paintings of (Sato & Dechezleprêtre, 2015) estimates, through a panel dataset, the relation among the asymmetry of energy expenses and worldwide transactions. (Islam et al., 2020) explain that the increasing use of electricity is important for modern economic and financial improvement and discover a solid dating between energy coverage and worldwide exchange.

However, our work is even more related to the area that documents the link between Energy Exports to the euro area and inflation rate persistence, that is, considering structural factors as additional determinants of the continuation of inflation. For instance, the study by Benkhelouf & Sahed (2023) dealt with the effect of oil price shocks on the continuity of the inflation rate in Algeria. The results of the study show that inflation rate persistence in Algeria continues for a longer period due to the oil price shock before it eventually fades away. (Oloko et al., 2021) The study used a fractional cointegration VAR model to examine the impact of oil price shocks on inflation rate persistence in ten oil exporting and importing countries using a fractional cointegration VAR model. The results showed that the price movements in the oil exporting and importing countries were not significantly affected by the oil price shocks.

Regarding the fractional cointegration approach, there are few studies that use such analysis to study the relationship between the energy sector and the macroeconomy (Kıran, 2012) uses fractional cointegration framework to investigate the relationship between energy consumption and GDP for Turkey and provides evidence of the cointegration relationship between them. (de Menezes & Houllier, 2016) assessed the spot price series and the month-ahead price series in the electricity market. They found that spot prices are fractionally integrated and exhibit mean-reversion, whereas the one-month-ahead prices are increasingly resistant to shocks and demonstrate more stable trends. (Gil-Alana & Yaya, 2014), through recall length integration and the cointegration method for oil prices and the stock market in Nigeria, find that both series exhibit recall length but do not support the cointegration hypothesis.

Other papers that use fractional cointegration to analyse inflation rate persistence are (Granville & Zeng, 2019), whose study examined the nature and dynamics of inflation rate persistence in the United States (USA) and found that changes in inflation persistence formed expectations are significantly influenced by memories of past price increases. Using Turkey as a case study, (Bilici & Çekin, 2020) applied the TVP estimation method and revealed that inflation increases slowly and does not persist during periods of inflation. Furthermore, (Antonakakis et al., 2016) used internet and government price signals for constant prices in selected countries (Argentina, Brazil, China, Japan, Germany, South Africa, UK, and USA). Their study confirmed that the degree of price persistence from long-term memory measures is relatively low when online price indexes are considered as measures of inflation indicating that economy the effectiveness of policies in controlling inflation was underestimated by official price indexes.

Our study falls within the class of studies that consider structural factors as additional determinants of inflation persistence. However, it focuses on an external factor, energy export, as opposed to the domestic factors considered in the previous studies. It also focuses on energy-exporting countries to the euro area, particularly with recognition of their economic structural peculiarities as energy-dependent countries. This innovation was motivated by the established empirical relationship between the energy sector and the inflation rate in many countries. Thus, the current study identifies the fractional integration properties of these two variables and employs a fractional cointegrated VAR (FCVAR) approach, thereby making the assessment of the effect of energy exports on inflation persistence possible.

3. Methodology

Here is a brief description of the methodology used in this study, which is a Fractional Cointegration Vector Auto-regression (FCVAR) model developed recently by (Johansen & Nielsen, 2012). This model has gained wide popularity, as reflected in its recent use in various studies.

3.1 Fractional model integration approaches

Fractional integration, or fractional differentiation, is a time series technique that allows for a unique number of differences in the data. Given a time series xt, t = 1, 2, ..., it is said to be an integrated order d and is denoted I(d) if its d-variance is a covariance constant and is an integrated order 0, which means, I(0) is the value. The second stationary function is I(0), and it is called a small residual if the sum of all its Eigen variances has a finite value. This interpretation is based on the time domain representation of the data.

This model allows fractional integration with non-zero order when the series is not integrated to zero order (Gil-Alana & Carcel, 2020). The latter provides researchers with evidence of when temporary ones are appropriate, rather than assuming explicit permanent shocks that take longer to disappear, so we will use the fractional integration framework in the euro area for energy exports and price stability for important energy exporting countries to Europe.

To define fractional integration, we define a particular process I(d) in equation (1) below.

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

where d can be any real value, L is a delay operator (Lxt = xt-1) and ut is I(0), defined as a covariance stationary process with a positive and finite spectral density function at zero frequency. The polynomial (1) Ld 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:

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

Implying that Eq. (1) can be expressed as

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

Thus, the parameter d plays an important role in its dependence (standardisation), because the higher the value of d, the higher the consistency in the data, so that if d is allowed to take fractional values, it allows for more extensive possibilities in the model specification. If d is a negative value, then xt is considered an "anti-constant." If d is equal to 0, then xt has a short memory, and positive d values indicate a long memory; In this category, if 0 < d < 0.5 holds the covariance constant when d is equal to or greater than 0.5, it indicates instability, and the higher the value of d, the greater the volatility in terms of a, that is, the variance of the partial in xt increases with d. Furthermore, this approach can check whether the chain of shocks will have a transient effect (d < 1) or a permanent effect (d ≥ 1). (Gil-Alana & Carcel, 2020)

3.2 The fractionally cointegration VAR model

The parameters of the fractional adjustment model are illustrated in the previous section. As an example variable, it uses the fractional integration parameter, d, which describes the pattern of energy exports or inflation rate integration in the euro area as energy exports and inflation are fractionally integrated, so The next step 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 inflation rate and Energy Exports to the Euro Area. (Robinson, 2008) introduced the fractional cointegration technique, which allows for simultaneous estimation of the differencing parameter d and other parameters in the relationship. In a broad sense, given two real numbers d, b, the components of the vector zt are said to be cointegrated of order d, b, denoted zt ∼ CI(b, d) if:

(i) All the components of zt are I(d)

(ii) There exists a vector α ≠ 0 such that st = α ′ zt ∼ I(γ) = I(d − b), b > 0

Where α is the cointegrating vector and st is the error term. (see also Aye, Carcel, Gil-Alana et al., 2017)

In multivariate model specification, we start our model specification with the CVAR model, followed by the FCVAR model since the latter is a fractional modification of the former.

The CVAR model is:

$$\Delta Y_t = \alpha\beta' Y_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta Y_{t-i} + \varepsilon_t = \alpha\beta' L Y_t + \sum_{i=1}^{k} \Gamma_i \Delta L^i Y_t + \varepsilon_t \tag{5}$$

The simplest way to obtain the FCVAR models is to replace the difference and lag operator L in (2) with their fractional equivalents, b and Lb = 1 b, respectively. Now we obtain

$$\Delta^b Y_t = \alpha\beta' L_b Y_t + \sum_{i=1}^{k} \Gamma_i \Delta^b L_b^i Y_t + \varepsilon_t \tag{6}$$

Which is applied to Y X t = d b t such that

$$\Delta^d X_t = \alpha\beta' L_b \Delta^{d-b} X_t + \sum_{i=1}^{k} \Gamma_i \Delta^b L_b^i Y_t + \varepsilon_t \tag{7}$$

Where Ɛt is p-dimensionally independent and uniformly distributed, with zero mean and covariance matrix Ω. The parameters have general implications for the CVAR model. Thus, α and β are p × r matrices, with 0 ≤ r ≤ p. The β column is covalently bonded in the system, that is, long-term equilibrium. The Γi parameters control the short-term behaviour of the variables and the in coefficients represent the rate of change to equilibrium for each variable. FCVAR models allow long-term equilibrium to be modelled simultaneously, with the response of variables to deviations from equilibrium and short-term dynamics of the system. (L. Gil-Alana & Carcel, 2020)

Assuming that the individual sequences are non-stationary I(1), valid values for b are (0, 0,5). Then, the parity errors are integrated in order above 0.5, and thus, a medium-reversible and unstable model is constructed. On the other hand, if b is in (0.5, 1), the errors exhibit an order smaller than 0.5 and are therefore stable. Finally, when d = b = 1, the FCVAR model reduces to the classical CVAR. (Malmierca-Ordoqui et al., 2024)

To derive implications for inflation persistence from the fractional cointegration between inflation and energy exports, which would be of interest to monetary authorities, the vector of endogenous variables in this study was normalised at consumer prices, so, as in our case:

$$\text{inflation rate}_{\mathrm{t}} = \alpha + \beta \text{ energy export}_{\mathrm{t-k}} + x_t, (1 - \mathrm{L})^{\mathrm{d}} x_t = \mathrm{u_t}, \mathrm{t} = 1,2, \dots, \quad (8)$$

Although parameter d indicates sustainability, currently β is an indicator of the effect of energy exports in the euro area on the inflation rate of the countries concerned the discriminating parameter d in the cointegration equation, Eq. (8), is based on the equation between the aggregate fraction of energy exports and the rate of inflation ($d_{\text{energy export}} = d_{\text{inflation rate}}$). Thus, in equation d. (8), there is fractional cointegration stability, which can explain the effect of inflation persistence on energy exports in the euro area.

According to the value of the cointegration difference coefficient d, energy exports to the euro area can influence the persistence of inflation in the participating countries in four different scenarios, as described by the fractional cointegration between energy exports to the euro area and the inflation rate:

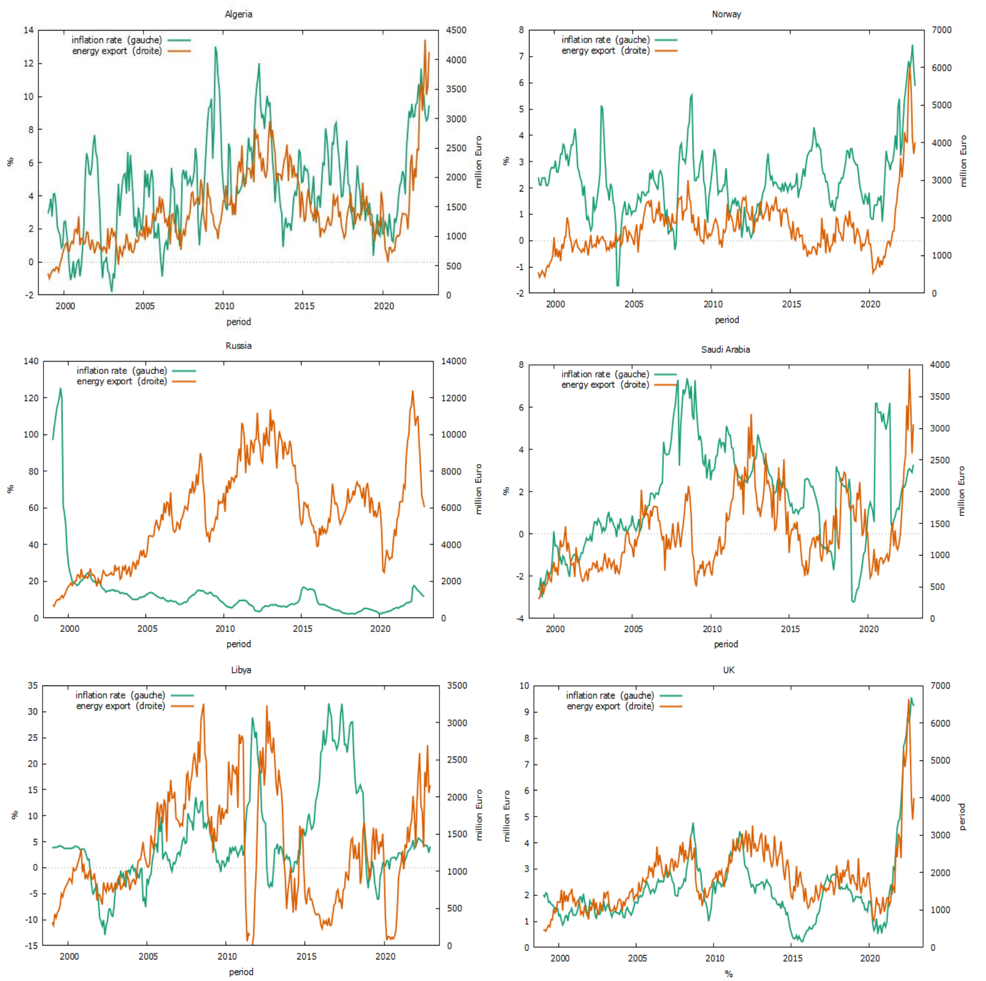
The first case is where (d = 0) the cointegration process is constant and has a short memory with no cointegration continuity. This means that the change in the inflation rate persistence due to the energy exports to the euro area will vanish almost immediately; in other words, the effect of the energy exports to the euro area 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 energy exports to the euro area on the persistence of the inflation rate will last for a short period. In other words, the change in the persistence of inflation rate due to an energy export to the euro area will fade away within a short period of time. The third case is ($0.5 < d < 1$) The cointegration process is also highly stable, but it shows a long memory with high continuity in the cointegration, meaning that the change in the inflation rate persistence due to the energy exports to the euro area 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 energy exports to the euro area cause permanent inflation to continue. (see also, Tule et al., 2020; Aye et al., 2017; Gil-Alana et al., 2017).

have employed this model and a R code for its computation is provided in Morin et al., (2021).

When ensuring that each series is fractionally 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 of the unconstrained model using specified optimal delay and cointegration order; Fourth testing the model residuals for serial correlation and Partial cointegration test of the constrained model; And Finally A comparison between the FCVAR model and the CVAR model using the probability ratio [LR] test.

4. Data

In this study, we use monthly data for the energy exports to the Euro area from the seven major suppliers (Algeria, Libya, Norway, Russia, Saudi Arabia, Nigeria, and the United Kingdom). The data source is Eurostat, reporting the series in terms of trade value in millions of euros and the inflation rate for the same countries measured as a percentage. The data source for inflation rates is the World Bank, from January 1999 to December 2022. This dataset includes 288 observations, covering periods of high and low inflation rates in the major energy-exporting countries to Europe, as well as high and low energy exports.



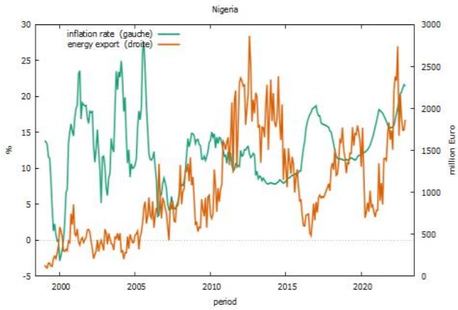


Figure 1. Trends in energy export and inflation rate for Countries exporting energy to euro area
Source: Computed by the authors.

Table 1. Descriptive Statistics

Countries	Mean	Max	Min	S.Dev	Skew	Kurt	J-B	Obs
energy export								
Algeria	1427.56	4338.60	284.00	657.00	1.32	5.54	161.06	288
Libya	1298.35	3258.10	0.00	742.48	0.47	2.45	14.22	288
Norway	1733.81	6050.60	425.90	743.97	2.14	11.31	1049.64	288
Nigeria	1049.82	2867.20	98.40	610.92	0.60	2.50	20.32	288
Russia	5667.78	12415.50	651.30	2690.08	0.19	2.26	8.44	288
Saudi	1349.75	3943.40	315.20	600.07	1.06	4.40	77.56	288
Arabia	1861.51	6650.60	437.60	864.14	1.95	9.71	721.6	288
UK								
inflation rate								
Algeria	4.43	13.02	-1.83	2.95	0.40	2.85	7.99	288
Libya	5.34	31.60	-12.96	8.97	1.10	3.96	68.96	288
Norway	2.29	7.45	-1.71	1.33	0.82	5.12	86.48	288
Nigeria	12.41	27.60	-2.86	4.95	-0.05	3.63	4.87	288
Russia	13.55	125.52	2.22	18.42	4.63	25.43	7068.42	288
Saudi	1.77	7.36	-3.21	2.38	0.19	2.51	4.52	288
Arabia	2.22	9.56	0.22	1.51	2.63	11.95	1294.21	288
UK								

Source: Computed by the authors.

5. Results and discussion

5.1 Stationarity of Data

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

Countries	test	Dickey-Fuller		Phillips-Perron	
		inflation rate	Energy export	inflation rate	Energy export
Algeria	With Constant	-2.59 (0.096)*	-1.25 (0.65) no	-3.66 (0.01) ***	-1,40 (0.58) no
	With Const & Trend	3.07 (0.12) no	-1.91 (0.65) no	-4.04 (0.01) ***	-2,24 (0.47) no
	Without Const & Tren	-0.30 (0.58) no	0.55 (0.83) no	-1.44 (0.14) no	0,64 (0.85) no
Norway	With Constant	-2.03 (0.27) no	-2.42 (0.14) no	-3,31 (0.02) **	-2,60 (0.09) *
	With Const & Trend	-2.36 (0.40) no	-2.71 (0.24) no	-3,44 (0.05) **	-2,92 (0.16) no
	Without Const & Tren	0.11 (0.72) no	-0.14 (0.63) no	-0,71 (0.41) no	0,00 (0.68) no
Russia	With Constant	-5.56 (0.00) ***	-2.44 (0.13) no	-4,68 (0.00) ***	-2.47 (0.12) no
	With Const & Trend	-5.20 (0.00) ***	-2.50 (0.32) no	-4,28 (0.00) ***	-2.62 (0.27) no
	Without Const & Tren	-5.14 (0.00) ***	-0.60 (0.46) no	-4,41 (0.00) ***	-0.58 (0.46) no

Countries	test	Dickey-Fuller		Phillips-Perron	
		inflation rate	**Energy export**	**inflation rate**	**Energy export**
Saudi Arabia	With Constant With Const & Trend Without Const & Tren	-2.01 (0.28) no -1.95 (0.62) no -1.15 (0.23) no	-2.58 (0.10) * -3.02 (0.13) no -0.29 (0.58) no	-3,01 (0.03) ** -3,04 (0.12) no -2,13 (0.03) **	-3,35 (0.01) ** -4,00 (0.01) *** -0,46 (0.51) no
Libya	With Constant With Const & Trend Without Const & Tren	-1.90(0.33) no -2.04 (0.58) no -1.54 (0.11) no	-3.47(0.01) *** -3.46 (0.05) ** -1.33 (0.17) no	-2,56 (0.10) no -2,72 (0.23) no -2,19 (0.03) **	-3,57 (0.01) *** -3,57 (0.03) ** -1,32 (0.17) no
Nigeria	With Constant With Const & Trend Without Const & Tren	-3.32 (0.15) ** -3.47 (0.04) ** -0.74 (0.39) no	-2.03 (0.27) no -2.59 (0.28) no -0.33 (0.57 no	-3,60 (0.01) *** -3,75 (0.02) ** -1,06 (0.26) no	-3,14 (0.03) ** -4,40 (0.00) *** -0,80 (0.37) no
UK	With Constant With Const & Trend Without Const & Tren	-1.07 (0.73) no -1.26 (0.89) no 0.50 (0.82) no	-3.20 (0.02) ** -3.64 (0.03) ** -0.14 (0.63) no	0,15 (0.97) no -0,29 (0.99) no 0,88 (0.90) no	-3,08 (0.03) ** -3,62 (0.03) ** -0,30 (0.58) no

Notes: (*) (**) (***) Significant at the 10%, 05%, 01% respectively; and (no) Not Significant, *MacKinnon (1996) one-sided p-values.

Source: Computed by the authors.

The first step in our analysis is to check whether our various sequences have unit roots or not. To this end, we propose the Dickey-Fuller (1979, 1981) and Phillips-Perron (1988) tests. The results appear in Table 2.

By conducting Dickey-Fuller (ADF) and Philips-Perron (PP) tests, the results came as shown in Table (02), 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 energy export for all countries (Algeria, Norway, Russia, Libya, Saudi Arabia, Nigeria, and the United Kingdom), since the “t” statistics have greater than critical values at all levels of conventional significance. The probabilities also show that the unit root hypothesis is not rejected for the inflation rate and the energy export; the non-stationarity of the time series allows further tests for the cointegration.

5.2 Fractional integrated model estimation

Tables 3 and 4 present the results of the fractional integration on the time series using both the 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 show that dues are computed as either less than 1 or greater than 1 in all cases across the three period-gram points for the two time series (inflation rate and energy export).

As a summary of the univariate framework, the inflation rate series are, in general, highly persistent, and the effect of shocks will be permanent. This implies that the trend followed by almost all the inflation rate series is highly determined by exogenous factors that affect the variable. Therefore, the change in the behaviour of the European energy import time series might influence the direction of the inflation rates for all countries, providing a rationale for the bivariate analysis of both variables.

By contrast, regarding the energy imports time series, the analysis suggests that the effects of shocks will be transitory in all countries. Thus, the path followed by energy imports does not seem too dependent on the economic fluctuations or other exogenous factors.

Moving now to the multivariate framework, a necessary condition for cointegration is that the individual series must display the same degree of integration. Table 3 and Table 4 summarise the results for the individual series using a local Whittle estimator and the GPH test. We see in these tables that the orders of integration of the two variables are similar in all cases (We say they are similar in the sense that the confidence intervals for the differencing parameters overlap.

So, the fact that the integration factor for the inflation rate and the energy exports in all the countries concerned with the study differ from zero and from the one, which indicates that the inflation rate and the energy export in all the countries are fractional integrated, and this is what drives us to more tests to estimate the FCVAR model.

Table 3. Fractional integration estimates based on local Whittle estimator

Countries/variable	m	Algeria	Norway	Russia	Saudi Arabia	Libya	Nigeria	UK
Inflation rate	$T^{0.6}$	0.90 (0.91)	0.68 (0.91)	0.72 (0.09)	0.99 (0.09)	1.27 (0.09)	1.04 (0.09)	0.99 (0.09)
	$T^{0.7}$	0.86 (0.69)	074 (0.69)	1.09 (0.07)	0.95 (0.07)	1.12 (0.07)	1.09 (0.07)	1.01 (0.07)
	$T^{0.8}$	0.83 (0.52)	0.90 (0.52)	1.00 (0.05)	0.83 (0.05)	1.07 (0.05)	1.03 (0.05)	1.02 (0.05)
	p-val	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***
Energy export	$T^{0.6}$	0.64 (0.12)	0.73 (0.09)	1.06 (0.09)	0.53 (0.09)	0.73 (0.09)	1.02 (0.09)	0.77 (0.09)
	$T^{0.7}$	0.77 (0.07)	1.02 (0.07)	1.09 (0.07)	0.88 (0.07)	0.81 (0.07)	0.80 (0.07)	1.19 (0.07)
	$T^{0.8}$	0.75 (0.05)	0.83 (0.05)	1.00 (0.05)	0.89 (0.05)	0.97 (0.05)	0.74 (0.05)	0.86 (0.05)
	p-val	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***

Note: total sample T is 288 and the three period-gram points, $T^{0.6}$, $T^{0.7}$ and $T^{0.8}$ are 30, 53 and 93, respectively, Asterisks *** indicate 1% level of significance. figures in square brackets represent the standard errors.

Source: Computed by the authors.

Table 4. Fractional integration estimates based on GPH test

Countries/variable	m	Algeria	Norway	Russia	Saudi Arabia	Libya	Nigeria	UK
Inflation rate	$T^{0.6}$	0.96 (0.91)	0.70 (0.12)	0.73 (0.08)	1.12 (0.12)	1.33 (0.17)	0.90 (0.18)	0.59 (0.14)
	$T^{0.7}$	0.95 (0.13)	0.77 (0.09)	1.04 (0.08)	1.03 (0.12)	1.40 (0.16)	0.93 (0.11)	0.78 (0.10)
	$T^{0.8}$	0.95 (0.13)	0.92 (0.07)	1.08 (0.07)	0.90 (0.09)	1.25 (0.12)	0.99 (0.09)	0.91 (0.06)
	p-val	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***
Energy export	$T^{0.6}$	0.72 (0.12)	0.57 (0.12)	1.15 (0.18)	0.65 (0.15)	0.74 (0.11)	1.07 (0.12)	0.73 (0.10)
	$T^{0.7}$	0.83 (0.08)	0.89 (0.11)	1.08 (0.11)	0.84 (0.10)	0.84 (0.09)	0.92 (0.11)	1.11 (0.11)
	$T^{0.8}$	0.84 (0.07)	0.86 (0.08)	1.03 (0.07)	0.88 (0.08)	1.01 (0.07)	0.83 (0.08	0.91 (0.08)
	p-val	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***

Note: total sample T is 288 and the three period-gram points, $T^{0.6}$, $T^{0.7}$ and $T^{0.8}$ are 30, 53 and 93, respectively, Asterisks *** indicate 1% level of significance. figures in square brackets represent the standard errors.

Source: Computed by the authors.

5.3 Fractional cointegration model estimation

In the Table 5 we report the results assuming that d = b, i.e., imposing that the equilibrium relationship is I(0). Cointegration is found in all cases with the lowest degrees of integration observed in the cases of Nigeria (0.680) and the particularly Libya and UK (0.510) (0.529), respectively. If the coefficients for d and b are supposed to be different, some support for a low order of cointegration is found in Algeria (d = 0.842 and b = 1.562), Norway (d = 0.853 and b = 0.827), Saudi Arabia (d = 0.908 and b = 1.529) and Nigeria (d = 0.909 and b = 1.460). For Norway and the UK, the reduction in persistence in the long run relationship is very small (b = 0.011 in Norway and 0.355 in the UK) implying a high degree of persistence in the cointegrating relationships, and for the rest of cases d = b supporting the standard cointegration, i.e., I(0) behaviour in the equilibrium errors.

In the Table 6 we report the results assuming that $d \neq b$, for the case of the UK, Nigeria, Saudi Arabia and Algeria we cannot reject the hypothesis where the shock duration is mean-reverting in the long-run. 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 these countries will persist for a longer period due to the shock of energy exports before eventually is fading away.

In Norway case, the shock duration has a short-lived effect due to its short-run stationary behaviour, this means 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 energy exports shock on the inflation rate persistence these countries will last for a short period. In other words, the change in the persistence of inflation rate due to an energy exports shock will fade away within a short period.

In other cases (Libya and Russia), the shock duration has a lasting effect, which means that the variance is not fixed, as energy exports shocks cause permanent inflation rate persistence in these countries.

The economic reading of these results is that, in general, there is a strong relationship between the inflation rate series and the energy imports series. Therefore, the strategic changes in the European energy imports bill might affect the inflation rate persistence for the most important energy exporting countries to Europe. Finally, the important effects that the energy exports might have on the inflation rate persistence imply that the energy sector is crucial for the different economies.

Table 5. Fractional cointegration test results (FCVAR) For the unrestricted model

Series	k	r	$d = b$	β	B	μ
Algeria	1	1	**0.935** (0.057)	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.118 Var 2 = 1540.014	var 1 = 0.022 Var 2 = 367.000
Norway	2	1	**0.849** 0.000	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.099 Var 2 = 235.202	var 1 = 0.019 Var 2 = 558.700
Russia	1	1	1.101 0.000	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.003 Var 2 = -296.537	var 1 = 0.956 Var 2 = 721.000
Saudi Arabia	1	1	1.013 0.000	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.040 Var 2 = 1270.381	var 1 = -0.025 Var 2 = 315.200
Libya	1	1	0.510 0.042	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.075 Var 2 = 266.171	var 1 = 0.038 Var 2 = 314.800

Series	k	r	$d = b$	β	B	μ
Nigeria	3	1	0.680 (0.084)	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.143 Var 2 = 347.199	var 1 = -0.132 Var 2 = 133.300
UK	1	1	0.529 (0.000)	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.092 Var 2 = -3074.847	var 1 = 0.019 Var 2 = 465.400

Note: Figures in square brackets represent the standard errors.
Source: Computed by the authors.

Table 6. Fractional cointegration test results (FCVAR) For the restricted model

Series	k	r	$d \neq b$	β	B	μ
Algeria	1	1	d = 0.842 (0.000) b = 1.562 (0.000)	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.031 Var 2 = 523.234	var 1 = 0.011 Var 2 = 367.000
Norway	2	1	d = 0.853 (0.000) b = 0.827 (0.000)	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.087 Var 2 = -154.548	var 1 = 0.022 Var 2 = 558.700
Russia	2	1	d = 0.010 (0.000) b = 1.155 (0.000)	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.000 Var 2 = -8.360	var 1 = 0.953 Var 2 = 721.000
Saudi Arabia	1	1	d = 0.908 (0.000) b = 1.529 (0.000)	Var 1 = 1.000 Var 2 = 0.000	var 1 = -0.008 Var 2 = 229.341	var 1 = -0.025 Var 2 = 315.200
Libya	2	1	d = 0.010 (0.107) b = 1.132 (0.083)	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.001 Var 2 = -7.771	var 1 = 0.043 Var 2 = 314.800
Nigeria	2	1	d = 0.909 (0.000) b = 1.460 (0.000)	var 1 = 1.000 Var 2 = 0.000	var 1 = -0.022 Var 2 = 76.875	var 1 = 0.121 Var 2 = 133.300
UK	1	1	d = 0.581 (0.000) b = 0.010 (0.000)	var 1 = 1.000 Var 2 = 0.000	var 1 = -1055.720 Var2 = -40857376.784	var 1 = 0.020 Var 2 = 465.400

Note: Figures in square brackets represent the standard errors.
Source: Computed by the authors.

5.4 Comparison of the FCVAR and VAR model using the LR likelihood ratio

Table 7. LR likelihood ratio test results between the CVAR and FCVAR models

Countries	Unrestricted log-likelihood	Restricted log-likelihood	LR statistic	P-value	the decision
Algeria	-1119.650	-1120.288	1.276	0.259	CVAR
Norway	**-929.822**	**-932.187**	**4.731**	**0.030 ****	**FCVAR**
Russia	-1713.862	-1714.892	2.062	0.151	CVAR
Saudi Arabia	-1017.456	-1017.475	0.037	0.848	CVAR
Libya	**-1329.674**	**-1336.560**	**13.772**	**0.00 *****	**FCVAR**
Negiria	**-1200.236**	**-1203.535**	**6.598**	**0.01 *****	**FCVAR**
UK	**-744.729**	**-760.157**	**30.855**	**0.000*****	**FCVAR**

Note: Asterisks *** indicate level of significance.
Source: Computed by the authors.

Here, we test the CVAR model (null hypothesis: d = b = 1) against the FCVAR model (alternative hypothesis: d = b ≠ 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, we prefer the CVAR model. By examining the test results shown in Table 7, which presents the log-likelihood values for both models, degrees of freedom, the LR test statistic, and the p-values indicate the level of significance in the cases (Norway, Libya, Nigeria, and the UK), which is significant at all traditional confidence levels. Therefore, the test clearly rejects the null hypothesis that the preferred model is CVAR. Consequently, we accept the alternative hypothesis, indicating that the FCVAR model is the better choice in the following cases (Norway, Libya, Nigeria, and the UK). Unlike the three countries (Algeria, Russia, and Saudi Arabia), they are not significant at any of the traditional confidence levels. Therefore, the test clearly accepts the null hypothesis that the preferred model is CVAR, indicating that the CVAR model is the better choice in these cases.

6. Conclusions

In this paper, we have examined the degree of persistence of energy exports to the EU area along with the persistence of the inflation rate. We have also focused attention on the relationship between the two variables in the most important countries exporting energy to the EU area: Algeria, Norway, Russia, Libya, Saudi Arabia, Nigeria, and the United Kingdom. The methodology used deals with long-memory processes and is based on the concepts of fractional integration and fractional cointegration, which allow us to determine, among other things, if shocks in the individual series (or in long-run equilibrium relationships) have permanent or transitory effects over time.

It contributes to the literature on the analysis of the degrees and determinants of inflation persistence of selected countries; it examines the effect of an external factor, energy exports to the EU area, on the inflation persistence of energy-exporting countries in the EU area using the fractional cointegration vector autoregressive (FCVAR) model.

The likelihood ratio (LR) test comparing the CVAR and FCVAR for the inflation persistence models that have been augmented with energy exports overly favours the FCVAR model in four countries (Norway, Libya, Nigeria and the UK), in contrast to the three countries (Algeria, Russia, and Saudi Arabia). This confirms the appropriateness of the choice of FCVAR in modelling the relationship between energy exports and inflation persistence in this study.

Evidently, the main results of this study show that the persistence of inflation in energy exports does not appear to increase due to energy export shocks in the cases of the UK, Nigeria, Saudi Arabia, and Algeria, suggesting that the monetary policies of these countries accommodate energy export shocks and may not necessarily be changed due to energy export shocks. As for the case of Norway, the effect of the energy export shock on the persistence of the persistence of the inflation rate in these countries will last for a short period. In other words, the change in the persistence of the inflation rate due to an energy export shock will fade away within a short period of time. As for the cases of Libya and Russia, the shock duration has a lasting effect, which means that the variance is not fixed, as energy export shocks cause permanent inflation rate persistence in these countries.

Our results also show that countries operating a floating regime with inflation targeting (IT&FR) have higher inflation persistence than countries operating a pegged exchange rate regime with non-inflation targeting monetary policy (NIT&PR). Meanwhile, we also found that energy exporting countries to the EU area operating non-inflation targeting monetary policy (NIT&PR) like Norway tend to have short-memory inflation persistence (d < 0.5), unlike their energy-exporting counterparts (such as the UK, Saudi Arabia, Nigeria, and Algeria), which tend to have long-memory temporary inflation persistence (0.5 ≤ d < 1); and Libya and Russia, which tend to have long memory permanent inflation persistence (d > 1)**.**

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