FRACTIONAL COINTEGRATION BETWEEN ENERGY IMPORTS TO THE EURO AREA AND EXCHANGE RATES TO THE US DOLLAR

ABSTRACT

The global dominance of the dollar is unquestionable, but the European Commission is committed to strengthening the role of the euro in international relations. Most of the transactions between countries are paid in US dollars even though the United States does not participate in them. Some argue that the euro could become more powerful if it were given more presence in international trade, in particular, in the energy bill of the Eurozone. With the aim of validating that statement, this paper analyses the cointegrating structure between energy imports to the Euro Area from its main partners and those partners' currency exchange rates to the US dollar. We find that there is a bivariate fractional cointegration relationship between the series in most of the countries considered.

Keywords: Energy trade; exchange rates; long memory; fractional cointegration; Euro Area policy

JEL classification: C22; C32; F14; F31; Q43

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

1. Introduction

More than two decades after the birth of the euro and as a result of the successive crises and challenges that the European currency has had to face to date, it seems appropriate to consider its relevance for international transactions. This is strongly related to the dependence of European trade on the other major currency at international level, the US dollar. From the Bretton Woods agreement in 1944 to the present day, the leadership of the US dollar in international trade relations has been undeniable (see Eichengreen and Flandreau, 2008; Carter, 2020; Tooze, 2021; among others). During the last decade, this supremacy has been strengthened especially since the euro was weakened in the wake of the sovereign debt crisis of 2010.

The IMF Global Financial Stability Report (October 2019) reveals that in 2019 almost 40% of the international debt held all around the world was issued in US dollars. During that year, around 60% of all the well-known central banks' foreign exchange reserves were claims in US dollars, according to the Currency Composition of Official Foreign Exchange Reserve (COFER) of the IMF. Bertaut et al. (2021) confirm that this trend continues during the years 2020 and 2021, against a 21% share of globally disclosed foreign exchange reserves comprised in euros. Furthermore, although the US dollar share of foreign exchange reserves has declined since 2000, the latter has been replaced by a group of currencies. This is only a small sample of the international economic data confirming the US dollar's global dominance.

Regarding trade, in 2019, the US dollar was present in 88% of all the transactions carried out on the market of foreign exchange, according to the 2019 Triennial Survey of Forex Exchange, even though the United States did not participate in this volume of international operations. By contrast, the euro, in the second position among the most traded currencies, was only present in 32% of all trades. However, some of the latest developments may threaten the US dollar's international status. First, the unilateral position that the American nation acquired under Donald Trump's political mandate led some countries to consider the use of other currencies in their international trade relations. Second, the increasing European integration bolsters the attractiveness of the euro as a medium of exchange in the international markets. And, finally, the new digital currencies pose a challenge to the US dollar position as investors and consumers might shift their payment preferences (see Bertaut et al., 2021).

This research is motivated by the State of the Union speech in Parliament on September 12th, 2019 delivered by the European Commission's president at that time, Jean-Claude Juncker, who underlined the need for Europe to boost its sovereignty in international relations. More specifically, he declared "absurd that Europe pays for 80% of its energy import bill – worth 300 billion euros a year – in US dollars when only about 2% of the energy imports in Europe come from the US", with Russia being the main energy supplier for Europe. Since then, the European Commission has been particularly interested in strengthening the international energy role of the euro.

Our contribution is threefold. The first objective of this work is to confirm Juncker's statement that paying the energy invoice in euros will provide the European countries with a more solid position in international transactions. Therefore, the present paper tries to shed new light on the importance of the Euro Area energy imports for the US dollar's current global supremacy. To that end, we perform a novel analysis in this framework that assesses the long run cointegrating relationship between the Euro Area's energy imports and the exchange rates to the US dollar of its main trading partners. Secondly, this paper intends to evaluate the consequences of carrying out transactions in one or another currency not only for the Euro area but also for its main trade partners and the US. The appeal of this study lies in the possibility of gaining a better understanding of the effects that the replacement of the US dollar by the euro on the international trade transactions of the Eurozone might have on the global economy. Finally, this work highlights the increasing importance of the energy sector for international relations, foreign exchange rates and the dependence of all countries on foreign economies. The European Commission's concern about the currency of its energy bill evidences the crucial role of energy for the world's economy. Moreover, policymakers and international institutions that are at the forefront of the transition to more sustainable sources of energy should then consider that their decisions could have a global impact and affect each country's national economy.

Our analysis is the first, to our knowledge, that uses methods based on fractional integration and cointegration to analyze the relation between energy imports and foreign exchange rates to the US dollar. Thus, the main novelties of the work are the use of fractional differentiation in the univariate part and of fractional cointegration in the bivariate analysis implemented to analyze the long run relationship between foreign trade and foreign exchange rates. We show that, for almost all countries, the series exhibit fractionally cointegrating relationships, which leads us to the conclusion that the energy bill has a strong impact on the status of the currency in which it is paid.

The layout of the paper is as follows. Section 2 reviews the more relevant existing literature for this study. Section 3 contains the methodology applied in the analysis. In Section 4 we provide a detailed description of the data. In Section 5 we include the empirical results. Section 6 concludes the manuscript and provides an overview of policy implications.

2. Literature review

This paper belongs to the extensive literature that studies the macroeconomic impacts of the energy sector factors (see for instance, Hamilton, 1983, 2003; Hooker, 2002; Hamilton and Herrera, 2004; Aguiar-Conraria and Wen, 2007). For instance, Tiwari (2013) performs a wavelet analysis to break down the effects of oil prices in the German macroeconomy; Kilian (2008) compares how an exogenous shock in oil supply affects the GDP of the seven major industrialized economies; Fagnart and Germain (2016) use an input-output model to observe the macroeconomic implications of the quality of energy production. Magazzino (2017) also investigates the energy consumption-economic growth link in Italy and find a single long-run relationship. Regarding international trade, the empirical work of Sato and Dechezleprêtre (2015) estimates, through a panel dataset, the relation between the asymmetry of energy prices and international transactions. Islam et al. (2020) explain that the increasing use of energy is crucial for current financial and economic development, and find a strong relation between energy policy and international trade. We also analyze the relevance of the energy sector for international trade and the world economy and we find that there is a connection between them.

However, our work is even more related to the area that documents the link between oil and foreign exchange rates (Zalduendo, 2006; Turhan et al., 2014; Kumar, 2019). Yang et al. (2017) study the different effects of oil prices on foreign exchange rates of oil-importing and oil-exporting countries. Unlike them, we analyze how exchange rates of energy-exporting countries are affected by the currency in which the Euro Area pays its energy bill. Wen et al. (2020) provide evidence on the risk spillovers between exchange rates and oil prices, finding them stronger from exchange rate to crude oil than vice versa. Kunkler and MacDonald (2019) remove the effect of the US dollar oil price to estimate the multilateral relationship between oil and G10 currencies. Basher et al. (2012) use an SVAR (Structural Vector AutoRegression) model to support the fact that oil prices positive shocks depress US dollar exchange rates in the short run. We share with all these studies the premise that the energy sector exerts a major influence on the exchange rate market. The novelty of our analysis lies in the use of fractional differentiation and fractional cointegration methods to investigate this relationship.

An important strand of the literature examines the impact of the energy sector on the US dollar. The theoretical model of Krugman (1983) and Golub (1983) examines how changes in oil prices imply a wealth redistribution from oil importers to oil exporters, based on the value of the dollar exchange rate. Lizardo and Mollick (2010) add oil prices to the basic monetary model of exchange rate determination to show that oil prices explain movements in the US dollar exchange rates.

Lizardo and Mollick (2010) and Ahmad and Hernández (2013) examine the cointegration long run relationship between oil prices and exchange rates using TAR and M-TAR models. Using cointegration techniques, Sadorsky (2000) , Rautava (2004) and Chen and Chen (2007) find that oil prices are cointegrated with exchange rates, providing evidence of a long-run equilibrium relationship between both variables.

Regarding the fractional cointegration methodology, the literature that implements this type of analysis to study the relation of the energy sector with the macroeconomy is scant. Kiran (2012) uses a fractional cointegration framework to investigate the relationship of energy consumption and GDP for Turkey and provide evidence of cointegrating relationships between them. De Menezes and Houllier (2016) evaluate spot price series and month-ahead prices series of the electricity market. They state that spot prices are fractionally integrated and mean-reverting series, while one-month-ahead prices have become more resilient to shocks and follow more stable trends.

Gil-Alana and Yaya (2014), through a long memory integration and cointegration approach for oil prices and stock markets in Nigeria, find that both series exhibit long-memory but they reject the cointegration hypothesis. Oloko et al. (2021) employs a FCVAR (Fractional Cointegration Vector AutoRegressive) approach to assess the effect of oil price shocks on the inflation persistence of the top ten oil-exporting and oil-importing countries. They find that inflation rate persistence does not increase due to oil price shocks. Baranzini et al. (2013) apply fractional cointegration techniques to investigate the link between energy consumption and economic growth in Switzerland and provide evidence for a long-run relationship.

Other papers that use fractional cointegration to analyze the properties of exchange rate series are Caporale and Gil-Alana (2004) who provide a fractional integration and cointegration analysis for exchange rates and real interest rates and labour productivity differentials, and Gil-Alana and Carcel (2020) that find a long run equilibrium relationship for the exchange rates of five industrialized currencies to the US dollar by using fractional cointegration methods while standard cointegration is rejected with the classical methodology of Johansen (1996).

3. Methodology

3.1 Fractional Integration

Fractional integration or fractional differentiation is a time series methodology that allows for a fractional number of differences in the data. Given a time series, x_t, t = 1, 2, …, it is said to be integrated of order d, and denoted as I(d) if its d-differences are covariance stationary and integrated of order 0, i.e., I(0).

A second order stationary process is I(0), and also termed short memory, if the sum of all its autocovariances is a finite value; this definition is based on the time domain representation of the data. Alternatively, it can be defined using the frequency domain. A process is I(0) if the spectral density function, which is the Fourier transform of the autocovariances, is positive and bounded, and within this category of short memory processes, we can consider the case of no autocorrelation, e.g., a white noise process, but also, other models which are weakly autocorrelated such as the ARMA-type of stationary and invertible models.

A series is fractionally integrated or integrated of a fractional order d, I(d), if it can be expressed as:

$$(1 - L)^d x_t = u_t, \quad t = 1, 2, \ldots, \tag{1}$$

with L being the lag-operator, i.e., $L^k x_t = x_{t-k}$ and where u_t is a short memory I(0) process. In this context, if u_t is ARMA(p,q), we can refer to x_t in (1) as an AutoRegressive Fractionally Integrated Moving Average, ARFIMA(p, d, q) model. Then, if d = 1 in equation (1) the model becomes the classical ARIMA(p, 1, q), though as mentioned previously, d can be a fractional number, and using a Binomial expansion,

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

equation (1) can be denoted as:

$$x_t = d x_{t-1} - \frac{d(d-1)}{2} x_{t-2} + \ldots + u_t. \tag{3}$$

Thus, the parameter d plays a crucial role in terms of the degree of dependence (persistence), since the higher the value of d, the higher the level of association in the data. Therefore, by allowing d to adopt fractional values there is a much wider range of possibilities in the model specification. If d is a negative value, x_t is considered as “anti-persistent”; if d is equal to 0, x_t possesses short memory, and positive values of d indicates long memory; within this category, if $0 < d < 0.5$ covariance stationary holds while d equal to or higher than 0.5 indicates nonstationary, and higher the value of d is, the higher the nonstationarity is in the sense that the variance of the partial sums in x_t increases with

d. Also, this approach allows to evaluate whether shocks that hit the series will have transitory effects ($d < 1$) or permanent effects ($d \geq 1$).

Numerous papers have appeared in the last few years analyzing energy issues through fractional differentiation methods. Some of those papers are Barros, Gil-Alana and Wanke (2016), Belbute and Pereira (2016), Gil-Alana, Perez de Gracia and Monge (2017), Gil-Alana and Monge (2019), Bozoklu, Yilanci and Gorus (2020), Adekoya (2020), Gil-Alana, Sakiru and Lafuente (2020), Quintino and Ferreira (2021), etc.

For the application conducted in Section 5 we estimate the parameters using the Whittle function by implementing a simple version of Robinson's (1994) tests widely used in applications in the last twenty years (see, Cunado et al., 2012; Caporale et al., 2013; Gil-Alana and Huijbens, 2018; etc.). An advantage of the methodology of Robinson (1994) is that it is still appropriate in nonstationary environments (i.e., with $d \geq 0.5$), not requiring a priori differentiation to the estimation; in fact, it is a testing procedure based on the Lagrange Multiplier (LM) principle; in addition it follows an asymptotic standard normal distribution and this holds whether or not the inclusion of non-stochastic terms such as an intercept (constant) and/or a time trend; finally, it is the most efficient approach in the sense of Pitman against local departures from the null.

3.2 Fractional Cointegration

Since the classical article of Engle and Granger (1987) studying long run co-movement between economic variables, cointegration has been extended in numerous fronts, starting with the multivariate generalization of Johansen (1996), and including also nonlinear cointegration (Escanciano and Escribano, 2009; Choi and Saikonnen, 2010; etc.), Bayesian cointegration (Koop, 1991, 1994; Geweke, 1996; Bauwens and Lubrano, 1996;

etc.) and other approaches. The natural generalization of cointegration to the fractional case is denominated fractional cointegration.

Fractional cointegration was first mentioned by Cheung and Lai (1993), Baillie (1996) and Dueker and Startz (1998), and later studied in Dittmann (2000), Gil-Alana (2003) and others. Thereafter, it was formalized this issue in a proper way by Marinucci and Robinson (2001), Robinson and Hualde (2003, 2007) and Robinson and Iacone (2005).

The FCVAR model introduced in Johansen (2008) and later developed in Johansen and Nielsen (2010; 2012) allows a fractional process of order d that cointegrates with order $d - b$ and positive b instead of the CVAR model of Johansen (1996). This model has the advantage of using both stationary and non-stationary series.

The non-fractional CVAR model is the prelude of the fractional CVAR model and that we explain below.

Being Y_t, $t = 1, \dots, T$ a p-dimensional I(1) time series, the CVAR model is:

$$\Delta Y_t = \alpha\beta' Y_{t-1} + \sum_{i=1}^{k} \Gamma_i \, \Delta Y_{t-i} + \varepsilon_t = \alpha\beta' L Y_t + \sum_{i=1}^{k} \Gamma_i \, \Delta L^i Y_t + \varepsilon_t. \qquad (4)$$

and using Δ^b and $L_b = 1 - \Delta^b$ to indicate the difference and L the lag operator,

$$\Delta^b Y_t = \alpha\beta' L_b Y_t + \sum_{i=1}^{k} \Gamma_i \, \Delta L_b^i Y_t + \varepsilon_t, \qquad (5)$$

which is then applied to $Y_t = \Delta^{d-b} X_t$ obtaining:

$$\Delta^d X_t = \alpha\beta' L_b \Delta^{d-b} X_t + \sum_{i=1}^{k} \Gamma_i \, \Delta^b L_b^i Y_t + \varepsilon_t, \qquad (6)$$

where, ε_t is an i.i.d. zero mean p-vector with variance-covariance matrix Ω. α and β are parameters that are represented by $p \times r$ matrices, where $0 \leq r \leq p$. The columns of the matrix β are represented the cointegrating relations and $\beta' X_t$ refers to the stationary combination, i.e., the long-run equilibrium relationship, which is supposed to be integrated to order d. The short terms are integrated to order $d - b$. α's coefficients are the speed of adjustment to equilibrium. Therefore, $\alpha\beta'$ is the adjustment long-run and Γ_i indicates the short-run behaviour.

Two more parameters are found in the FCVAR with respect to the CVAR model. First, the parameter d that represents the order of differentiation of the series. Finally, b that is the reduction in the order of integration of $\beta' X_t$ compared to X_t.

Assuming that the individual series are nonstationary I(1), the relevant ranges of values for b is (0, 0,5). Then, the equilibrium errors are integrated of order above 0.5 and thus, they are mean reverting though with a nonstationary pattern. On the other hand, if b is in the range (0.5, 1), then the errors display an order smaller than 0.5 and are therefore stationary (Dolatabadi et al., 2016). Finally, if $d = b = 1$, the FCVAR model is reduced to the classical CVAR.

As an alternative step, we consider model (2) with d = b, implying no persistence in the cointegration vectors and a constant mean term:

$$\Delta^d X_t = \alpha(\beta' L_d X_t + \rho') + \sum_{i=1}^{k} \Gamma_i \Delta^d \, {L_d}^i X_t + \varepsilon_t. \tag{7}$$

The model under study adopts the form:

$$\Delta^d (X_t - \mu) = L_d \alpha\beta' (X_t - \mu) + \sum_{i=1}^{k} \Gamma_i \Delta^d \, {L_d}^i X_t + \varepsilon_t, \tag{8}$$

where μ indicates the level parameter, and $\beta'\mu = -\rho'$ refers to the cointegrating relationship. Several papers including Jones, Nielsen and Popiel (2014); Baruník and Dvořáková (2015); Aye et al. (2017); Maciel (2017); Dolatabadi et al. (2018); Gil-Alana and Carcel (2020); Poza and Monge (2020); Monge and Gil-Alana (2021a,b); Monge et al. (2022), etc. have employed this model and a MATLAB code for its computation is provided in Nielsen and Popiel (2018).

4. Data

The fractional integration and cointegration analysis used in this work aim to delve more deeply into the relation of energy trade and exchange rates to the US dollar. Therefore, we first use monthly data for the series of Mineral fuels, lubricants and related materials (according to SITC product group classification) of the Euro Area along with its six most relevant suppliers (Algeria, Libya, Norway, Russia, Saudi Arabia and the UK) together with that same series within the Euro Area for the period from 1999 to 2021. The source of the data is Eurostat. The series used are reported at trade value in millions of Euros. Figure 1 shows the evolution of Euro Area's energy imports with its main partners.

FIGURE 1 ABOUT HERE

Secondly, we use the monthly series of the foreign exchange rates of those Euro Area trade partners' currencies to the US dollar together with the Euro/US dollar exchange rate, again for the period 1999-2021. The source of the data here is the Bank of International Settlements (BIS) Statistics Warehouse. They are the average of observations throughout the period.

The first column of Table 1 includes the six main trade energy partners of the Euro Area (EA), together with the percentage of total EA energy trade between the EA countries. The second column contains the participation of each energy supplier in the EA total amount of energy imports. The third column is the exchange rate considered for each energy trade partner.

TABLE 1 ABOUT HERE

The appendix contains the main statistics of the data series for a better understanding of their behaviour (see Tables 8 and 9). Figure 2 in Appendix I provides a visual approach the relevance on the energy imports of the Euro Area from each of the six economies selected for the analysis and the Euro Area during year 2020. Lastly, the

Appendix includes the graphical trends, from 1999 to 2021, of the seven exchange rates to the USD considered in this analysis that correspond to the currencies of the six main energy trade partners of the Euro Area and the euro itself (Figures 3 to 9).

5. Empirical results

As a preliminary analysis of the series, we conducted various unit root test procedures, in particular, the methods proposed by Dickey and Fuller (ADF, 1979), Phillips and Perron (PP, 1988) and Kwiatkowski et al. (KPSS, 1992). Though not reported in the paper, the results support the unit root hypothesis in all cases in the two variables, supporting the nonstationary character of the series. Nevertheless, it is a well-known fact that most unit root methods have very low power if the alternatives are fractional (Diebold and Rudebush, 1991, Hassler and Wolters, 1994; Lee and Schmidt, 1996) and because of this, we perform the analysis based on fractional integration.

We first start with the individual analysis of the two variables, by estimating the model,

$$y_t = \beta_0 + \beta_1 t + x_t; \qquad (1 - B)^d x_t = u_t, \qquad t = 1, 2, \ldots, \qquad (9)$$

where y_t indicates the time series under examination, and β_0 and β_1 are unknown parameters that represent a constant term (α) and a linear time trend (β); in addition, d is an additional parameter to be estimated from the data, assuming then that x_t is (potentially fractionally) integrated of order d.

Tables 2 and 3 present the estimated values of d for the original and log transformed data, respectively; the upper part refers to the exchange rates while the lower parts to imports. We examine three alternatives which are standard in the unit root literature of: i) no intercept and no trend, ii) and intercept (or a constant) and iii) including both, a constant with a linear time trend, appearing in bold in the tables the chosen specification for each series.

Starting with the original series, in Table 2, we notice that the time trend is not required in any of the series, the constant being the only significant deterministic term in the majority of the cases. Focusing first on the exchange rates, we observe that there is only one country showing mean reversion, i.e., $d < 1$, Saudi Arabia, with an estimated order of integration of 0.64; for Libya the hypothesis of a unit root cannot be rejected, while this hypothesis ($d = 1$) results rejected in the rest of the cases in favour of $d > 1$. In the case of imports, the degree of integration is generally smaller than for the exchange rates, and while the I(1) null cannot be rejected for the Euro Area and Libya, it is rejected now in favour of $d < 1$ and mean reversion in the rest of the series though in all them within the nonstationary range ($0.5 \leq d < 1$).

TABLES 2 AND 3 ABOUT HERE

For the logged series, in Table 3, the results are very similar. Thus, for the exchange rate, mean reversion only takes place in the case of Saudi Arabia, the hypothesis of I(1) or unit roots cannot be rejected for Libya, and evidence of values of d above 1 is found in all the other series. For imports, the Euro Area and Libya show evidence of I(1) behaviour and there is mean reversion in the rest of cases.

As a robustness method, we also tried with alternative methods such as Sowell's (1992) maximum likelihood in the time domain (see below) and Geweke and Porter-Hudak's (GPH, 1983) and Phillips and Shimotsu's (2005) semiparametric approaches. In all three cases the results were fairly similar to those reported in this paper. Similarly, seasonality was also investigated by permitting a seasonal AR(1) process for the error term u_t in (9) and the seasonal coefficient was found to be close to 0 in almost all the series investigated. Finally, we also permitted a non-linear deterministic term, replacing the first equality in (9) by the Chebychev's polynomials in time, such that the new model becomes (Cuestas and Gil-Alana, 2016):

$$y_t \;=\; \sum_{i=0}^{m} \theta_i \, P_{iT}(t) \;+\; x_t \,, \quad (1-L)^d x_t \;=\; u_t \,, \qquad t \;=\; 1,\, 2,\, \ldots, \tag{10}$$

where T is sample size, and m is the orthogonal Chebyshev polynomials order in time, which are expressed as:

$$P_{0,T}(t) \;=\; 1, \tag{11}$$

$$P_{i,T}(t) \;=\; \sqrt{2}\cos\left(i\,\pi\,(t-0.5)/T\right), \qquad t \;=\; 1,\, 2,\, \ldots,\, T; \quad i \;=\; 1,\, 2,\, \ldots \tag{12}$$

These polynomials were presented in Hamming (1973) and Smyth (1998), while Bierens (1997), Tomasevic et al. (2009) pointed out that it is possible to estimate highly non-linear trends with rather low degree polynomials. The results for the original data using this non-linear approach, with m = 3, are reported in Table 4. Note that the estimated values of d are very similar to those reported in Table 3, and there is no evidence of non-linearities in any single case (except for the case of imports in the UK where θ_2 results statistically significant). Performing the same analysis with the logged values, the results were again similar to the linear case in terms of the estimated values of d, and evidence of non-linearities was not found in any single case.

TABLE 4 ABOUT HERE

As a summary of the univariate framework, the exchange rate series are, in general, highly persistent and the effect of shocks will be permanent. The only exception is the Saudi Arabia foreign exchange rate case, for which shocks tend to be transitory and long lived. This implies that the trend followed by almost all the exchange rate series is highly determined by exogenous factors that affect the variable. Therefore, the change in the behaviour of the European energy imports time series might influence the direction of the US exchange rates to the rest of currencies, 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, except for the Euro Area and Libya. 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 5 summarizes the results for the individual series using Robinson (1994). We see in this table that the orders of integration of the two variables are only similar in the cases of Euro, Lybia and Saudi Arabia. (We say they are similar in the sense that the confidence intervals for the differencing parameters overlap. Performing the statistical test of Robinson and Yajima (2002) the same conclusions hold). However, as a robustness method, we also implemented other approaches. Thus, using Sowell's (1992) maximum likelihood method the results, though similar to those obtained before, indicate that the orders of integration are statistical equal in the cases of the previous three countries along with Norway and the UK.

TABLE 5 ABOUT HERE

Table 6 summarizes the selected d with different ARFIMA(p, d, q) processes with p, q ≤ 3, marking in bold the countries where the orders of integration were found to be equal. Employing semiparametric methods (Geweke and Porter-Hudak, 1983; Shimotsu and Phillips, 2005), though the results were highly sensitive to the choice of the bandwidth numbers, generally support the same conclusion, finding evidence of equal degrees of integration in the cases of Euro, Lybia, Norway, Saudi Arabia and the UK.

Thus, in what follows, we perform the cointegration analysis restricted to these five countries.

TABLE 6 ABOUT HERE

We focus on the FCVAR approach. Using alternatives (semiparametric) approaches (Marinucci and Robinson, 2001; Robinson and Hualde, 2003, 2007), the results were very sensitive to the choice of the bandwidth numbers, producing very inconclusive results. Table 7 summarizes the results of the FCVAR model.

TABLE 7 ABOUT HERE

In the upper part 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 Norway (0.835) and particularly Saudi Arabia (0.764). If the coefficients for d and b are supposed to be different, some support for a low order of cointegration is found in Libya (d = 0.981 and b = 0.739). 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 assumption of $d \neq b$, for the case of the UK and Libya we cannot reject the hypothesis where the shock duration is mean-reverting in the long-run. In all other cases, the shock duration has a short-lived effect due to its short-run stationary behaviour.

The economic reading of this result is that, in general, there is a strong relationship between the foreign exchange rate series and the energy imports series. Therefore, the strategic changes in the European energy imports bill might affect the exchange rate of the US dollar not only with respect to the euro but also with respect to other countries' currencies. This finding confirms Juncker's statement that paying the energy invoice in euros could increase its value and thus strengthen the international relevance of the Eurozone. Thus, the currency in which transactions are carried out might affect the international position of countries that play a role in those trade operations. Finally, the important effects that the energy imports might have on the exchange rates, imply that the energy sector is crucial for the relationship between the different economies. Through this foreign exchange rate effect, energy contributes to the undeniable dependence that countries have on each other.

6. Policy implications and conclusions

We have examined in this paper the degree of persistence in the energy imports in the EU area along with the exchange rates with respect to the US. We have also focused attention on the relationship between the two variables in the cases of Algeria, the Euro Area, Libya, Norway, Russia, Saudi Arabia and the United Kingdom. The methodology used deals with long memory processes, and is based on the concepts of fractional differentiation and fractional cointegration, which allow us to determine, among other things, if shocks in the individual series (or in the long run equilibrium relationships) have permanent or transitory effects over time.

The univariate analysis for the exchange rate series yields the first relevant conclusion of this work which is that the series are very persistent with degrees of differentiation close to or above 1 in most cases. However, there is some evidence of reversion to the mean (that is, estimates of d significantly below 1) in the case of Saudi Arabia's exchange rates to the US dollar, and in the case of Libya the results support the unit root hypothesis. It is worth noting that Saudi Arabia and Libya are the countries that represent the lowest percentage of total energy imports to the Euro Area. For the remaining exchange rate cases, shocks will have permanent effects, thus, the corresponding central bank should consider whether or not to take specific actions to nullify the consequences of shocks in its exchange rate to the US dollar and coordinate its decision with the Federal Reserve System. Changes in the dynamics of the Euro Area's energy imports are, therefore, very likely to affect the exchange rates of its main trading partners. But it is the bivariate analysis that must confirm this fact.

Regarding the energy import series, there is mean reversion in all countries, except for the Euro Area and Libya. This result has also relevant policy implications as it means that, in general, there is no need to introduce specific measures to control the energy imports of the Euro Area as the effects of shocks will not be long-lived.

Performing the FCVAR methodology developed in Johansen and Nielsen (2010, 2012), long run equilibrium relationships are found in almost all cases. This implies a strong relationship between the Euro Area's energy imports, most of them billed in US dollars, and the US dollar's foreign exchange rates. Hence, we can conclude that this empirical experiment confirms Jean Claude Juncker's statement that paying the energy invoice in euros will positively affect the international position of this currency. Moreover, the currency in which international transactions are billed might have important consequences for the Euro area, strengthening its relevant role in trade and affecting the position of its main trade partners and, especially, of the US. Finally, we can also conclude that the energy sector is key for international relations, foreign exchange rates and the dependence of all countries on foreign economies. Based on our work, it may be interesting for the European Commission to support a possible decision to switch from invoices in US dollars to euro invoices in international energy trade. Considering that approximately 80% of Europe's energy import bill is currently paid in US dollars, a switch to an invoice in euros might also weaken the US dollar's importance in international energy trade.

Some interesting issues to be addressed in the future are derived from this paper. First, a promising area to study is the relevance of imports from other sectors for international currencies. Additionally, the impact of the energy imports on currencies of other countries that may also pay their bill in US dollars could also be analyzed. Methodologically, the presence of structural breaks and/or non-linear structures in the context of fractional degrees of differentiation and cointegration is another interesting avenue for future research.

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FIGURES AND TABLES

Figure 1: Evolution of Euro Area's energy imports with its main partners

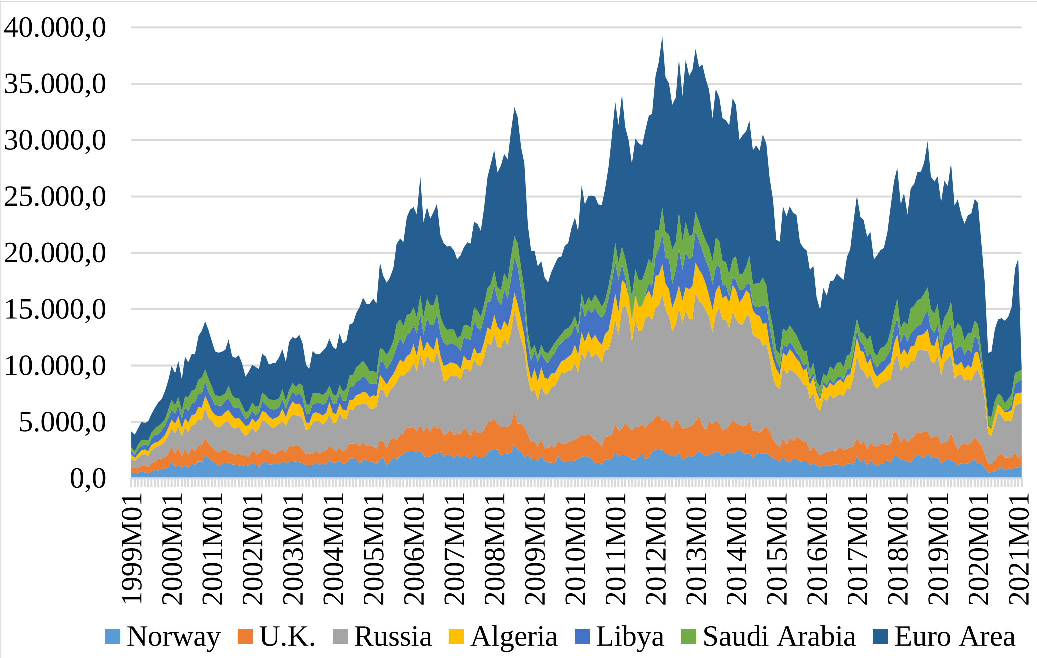

Table 1: Data used in for the fractional integration and cointegration analysis

Country	Percentage of total imports of the EA	Foreign exchange rate
ALGERIA	5.21%	Algerian dinar/US dollar
EURO AREA	31.81%	Euro/US dollar
LIBYA	4.88%	Libyan dinar/US dollar
NORWAY	6.25%	Norwegian Krone/US dollar
RUSSIA	21.06%	Russian rouble/US dollar
SAUDI ARABIA	5.06%	Saudi riyal/US dollar
U.K.	6.76%	Pound/US dollar

Table 2: Estimates of the differencing parameter: Original data

i) Exchange rates			
Country	No constant, no time trend	With a constant	With a constant and trend
ALGERIA	1.06 (0.99, 1.16)	**1.30 (1.20, 1.44)**	1.30 (1.20, 1.44)
EURO	1.06 (0.98, 1.16)	**1.21 (1.10, 1.35)**	1.21 (1.10, 1.35)
LIBYA	0.99 (0.91, 1.09)	**1.00 (0.92, 1.10)**	1.00 (0.92, 1.10)
NORWAY	1.04 (0.95, 1.15)	**1.24 (1.12, 1.42)**	1.24 (1.12, 1.42)
RUSSIA	1.12 (1.01, 1.28)	**1.32 (1.15, 1.58)**	1.33 (1.15, 1.58)
SAUDI ARABIA	0.98 (0.88, 1.09)	**0.64 (0.47, 0.86)***	0.64 (0.47, 0.86)
U.K.	1.01 (0.92, 1.11)	**1.18 (1.08, 1.30)**	1.18 (1.08, 1.30)
ii) Imports			
Country	No constant, no time trend	With a constant	With a constant and trend
ALGERIA	0.67 (0.59, 0.75)	**0.66 (0.59, 0.75)***	0.66 (0.59, 0.75)
EURO	1.06 (0.96, 1.19)	**1.04 (0.94, 1.17)**	1.04 (0.94, 1.16)
LIBYA	**0.96 (0.87, 1.08)**	0.96 (0.86, 1.08)	0.96 (0.86, 1.07)
NORWAY	0.65 (0.58, 0.73)	**0.63 (0.56, 0.71)***	0.63 (0.57, 0.71)
RUSSIA	**0.86 (0.78, 0.96)***	0.85 (0.78, 0.95)	0.86 (0.78, 0.95)
SAUDI ARABIA	0.71 (0.64, 0.80)	**0.71 (0.63, 0.80)***	0.71 (0.64, 0.80)
U.K.	0.66 (0.60, 0.74)	**0.65 (0.59, 0.73)***	0.66 (0.59, 0.73)

Values in parenthesis correspond to the 95% confidence bands. In bold, for each series, the model selected according to the t-values of the deterministic terms. * means evidence of mean reversion at the 95% level.

Table 3: Estimates of the differencing parameter: Logged values

i) Exchange rates			
Country	No constant, no time trend	With a constant	With a constant and trend
ALGERIA	1.00 (0.91, 1.10)	**1.31 (1.20, 1.44)**	1.31 (1.20, 1.44)
EURO	1.14 (1.04, 1.27)	**1.20 (1.10, 1.34)**	1.20 (1.10, 1.34)
LIBYA	1.00 (0.92, 1.09)	**1.01 (0.94, 1.10)**	1.01 (0.94, 1.10)
NORWAY	1.01 (0.92, 1.11)	**1.26 (1.14, 1.42)**	1.26 (1.14, 1.42)
RUSSIA	0.99 (0.91, 1.10)	**1.42 (1.24, 1.66)**	1.42 (1.24, 1.66)
SAUDI ARABIA	0.98 (0.88, 1.09)	**0.64 (0.47, 0.86)***	0.64 (0.47, 0.86)
U.K.	1.05 (0.97, 1.16)	**1.19 (1.09, 1.31)**	1.19 (1.09, 1.31)
ii) Imports			
Country	No constant, no time trend	With a constant	With a constant and trend
ALGERIA	0.94 (0.86, 1.03)	0.68 (0.61, 0.77)	**0.70 (0.63, 0.78)***
EURO	1.01 (0.92, 1.10)	**1.01 (0.93, 1.10)**	1.01 (0.93, 1.10)
LIBYA	0.99 (0.90, 1.11)	**0.93 (0.80, 1.08)**	0.93 (0.80, 1.08)
NORWAY	0.96 (0.88, 1.06)	**0.66 (0.59, 0.75)***	0.68 (0.61, 0.75)
RUSSIA	0.99 (0.92, 1.08)	**0.90 (0.82, 1.00)**	0.91 (0.83, 1.00)
SAUDI ARABIA	0.96 (0.89, 1.06)	**0.74 (0.66, 0.83)***	0.75 (0.68, 0.84)
U.K.	0.97 (0.89, 1.07)	**0.69 (0.62, 0.78)***	0.71 (0.64, 0.79)

Values in parenthesis correspond to the 95% confidence bands. In bold, for each series, the model selected according to the t-values of the deterministic terms. * means evidence of mean reversion at the 95% level.

Table 4: nonlinear I(d) model. Estimated coefficients

i) Exchange rates					
Country	d	θ_0	θ_1	θ_2	θ_3
ALGERIA	1.25 (1.12, 1.34)	**6.0122 (2.02)**	-1.1453 (-0.60)	1.2701 (1.48)	-4.009 (-0.94)
EURO	1.16 (1.03, 1.25)	**0.5699 (1.99)**	0.0624 (-0.28)	0.1115 (1.21)	0.0233 (0.41)
LIBYA	0.97 (0.88, 1.10)	**1.0194 (3.06)**	-0.1756 (-0.80)	-0.0988 (-0.95)	-0.1279 (-1.04)
NORWAY	1.21 (1.16, 1.36)	5.5745 (1.13)	-0.6897 (-0.22)	1.2586 (1.02)	0.3822 (0.51)
RUSSIA	1.33 (1.21, 1.44)	2.4257 (0.60)	-3.1772 (-0.12)	-2.6465 (-0.29)	6.9978 (-1.32)
SAUDI ARABIA	0.64 (0.55, 0.77)	**3.7505 (19.47)**	-0.0224 (-0.02	0.0098 (0.12)	0.0033 (0.47)
U.K.	1.17 (1.03, 1.28)	**0.5887 (2.29)**	--0.0506 (-0.31)	0.0523 (0.78)	-0.0134 (0.31)
ii) Imports					
Country	d	θ_0	θ_1	θ_2	θ_3
ALGERIA	0.68 (0.54, 0.73)	**1135.26 (3.01)**	--294.3 (-1.31)	-356.96 (-1.34)	152.97 (1.30)
EURO	0.97 (0.85, 1.08)	7137.45 (1.47)	--2664.1 (-0.92)	-1718.7 (-1.14)	353.50 (0.34)
LIBYA	0.94 (0.83, 1.06)	1118.63 (0.63)	--29.766 (-0.02)	-457.44 (-0.81)	-136.80 (0.35)
NORWAY	0.58 (0.53, 0.65)	**1425.44 (5.15)**	--106.41 (-0.66)	-376.81 (-1.07)	-403.18 (-0.40)
RUSSIA	0.80 (0.92, 0.91)	**4882.82 (2.52)**	--1570.3 (-1.40)	-1699.5 (-1.41)	37.608 (0.73)
SAUDI ARABIA	0.73 (0.64, 0.82)	**1026.89 (2.89)**	--259.17 (-0.79)	-238.70 (-1.09)	40.229 (0.29)
U.K.	0.60 (0.52, 0.69)	**1571.00 (4.92)**	--242.14 (-1.31)	**-457.0 (-3.30)**	28.961 (0.26)

The values in parenthesis in columns 3 – 6 are t-values. In bold, significant coefficients at the 5% level.

Table 5: Summary results in terms of d for the individual series using Robinson (1994)

Country (ORIGINAL)	Exchange Rates	Import Rates
ALGERIA	1.30 (1.20, 1.44)	0.66 (0.59, 0.75)
EURO	**1.21 (1.10, 1.35)**	**1.04 (0.94, 1.17)**
LIBYA	**1.00 (0.92, 1.10)**	**0.96 (0.87, 1.08)**
NORWAY	1.24 (1.12, 1.42)	0.63 (0.56, 0.71)
RUSSIA	1.32 (1.15, 1.58)	0.86 (0.78, 0.96)

SAUDI ARABIA	**0.64 (0.47, 0.86)**	**0.71 (0.63, 0.80)**
U.K.	1.18 (1.08, 1.30)	0.65 (0.59, 0.73)
Country (LOGGED)	Exchange Rates	Import Rates
ALGERIA	1.31 (1.20, 1.44)	0.70 (0.63, 0.78)
EURO	**1.20 (1.10, 1.34)**	**1.01 (0.93, 1.10)**
LIBYA	**1.01 (0.94, 1.10)**	**0.93 (0.80, 1.08)**
NORWAY	1.26 (1.14, 1.42)	0.66 (0.59, 0.75)
RUSSIA	1.42 (1.24, 1.66)	0.90 (0.82, 1.00)
SAUDI ARABIA	**0.64 (0.47, 0.86)**	**0.74 (0.66, 0.83)**
U.K.	1.19 (1.09, 1.31)	0.69 (0.62, 0.78)

Table 6: Estimates of d using Sowell's (1992) maximum likelihood approach

Country (ORIGINAL)	Exchange Rates	Import Rates
ALGERIA	1.09 (0.94, 1.24)	0.69 (0.51, 0.87)
EURO	**1.01 (0.90, 1.12)**	**0.79 (0.50, 1.07)**
LIBYA	**1.00 (0.92, 1.08)**	**0.95 (0.79, 1.10)**
NORWAY	**0.98 (0.88, 1.09)**	**0.72 (0.52, 0.91)**
RUSSIA	1.32 (1.19, 1.44)	0.86 (0.78, 0.95)
SAUDI ARABIA	**0.66 (0.54, 0.78)**	**0.51 (-0.05, 1.07)**
U.K.	**1.17 (1.08, 1.27)**	**0.53 (-0.33, 1.39)**
Country (LOGGED)	Exchange Rates	Import Rates
ALGERIA	1.09 (0.94, 1.24)	0.69 (0.51, 0.87)
EURO	**1.01 (0.90, 1.12)**	**0.79 (0.50, 1.07)**
LIBYA	**1.00 (0.92, 1.08)**	**0.95 (0.79, 1.10)**
NORWAY	**0.98 (0.88, 1.09)**	**0.72 (0.52, 0.91)**
RUSSIA	1.32 (1.19, 1.44)	0.86 (0.78, 0.95)
SAUDI ARABIA	**0.66 (0.54, 0.78)**	**0.51 (-0.05, 1.07)**
U.K.	1.17 (1.08, 1.27)	0.53 (-0.33, 1.06)

Table 7: FCVAR results

Series	$\boldsymbol{d = b}$	$\boldsymbol{\beta}$	$\boldsymbol{\alpha}$	$\boldsymbol{\mu}$
EURO	0.951 (0.018)	$Var\ 1 = 1.000$ $Var\ 2 = 0.000$	$Var\ 1 = -0.015$ $Var\ 2 = -216.69$	$Var\ 1 = 0.856$ $Var\ 2 = 1495.65$
LIBYA	0.970 (0.077)	$Var\ 1 = 1.000$ $Var\ 2 = -0.001$	$Var\ 1 = -0.002$ $Var\ 2 = 74.980$	$Var\ 1 = 0.450$ $Var\ 2 = 377.736$
NORWAY	0.835 (0.090)	$Var\ 1 = 1.000$ $Var\ 2 = 0.001$	$Var\ 1 = 0.003$ $Var\ 2 = -14.469$	$Var\ 1 = 7.399$ $Var\ 2 = 697.132$
SAUDI ARABIA	0.764 (0.090)	$Var\ 1 = 1.000$ $Var\ 2 = 0.000$	$Var\ 1 = -0.388$ $Var\ 2 = -24170$	$Var\ 1 = 3.750$ $Var\ 2 = 367.276$
U.K.	0.852 (0.060)	$Var\ 1 = 1.000$ $Var\ 2 = -0.000$	$Var\ 1 = -0.013$ $Var\ 2 = -116.69$	$Var\ 1 = 0.605$ $Var\ 2 = 546.578$

Series	$d \neq b$	β	α	μ
EURO	$d = 0.951\ (0.085)$ $b = 0.951\ (0.100)$	$Var\ 1 = 1.000$ $Var\ 2 = 0.000$	$Var\ 1 = -0.015$ $Var\ 2 = -216.69$	$Var\ 1 = 0.856$ $Var\ 2 = 1495.65$
LIBYA	$d = 0.981\ (0.103)$ $b = 0.739\ (0.365)$	$Var\ 1 = 1.000$ $Var\ 2 = -0.001$	$Var\ 1 = -0.003$ $Var\ 2 = 161.180$	$Var\ 1 = 0.450$ $Var\ 2 = 382.571$
NORWAY	$d = 1.480\ (0.074)$ $b = 0.011\ (0.001)$	$Var\ 1 = 1.000$ $Var\ 2 = 0.002$	$Var\ 1 = 29769.34$ $Var\ 2 = -66691547$	$Var\ 1 = 7.396$ $Var\ 2 = 633.533$
SAUDI ARABIA	$d = 0.764\ (0.121)$ $b = 0.764\ (0.133)$	$Var\ 1 = 1.000$ $Var\ 2 = 0.000$	$Var\ 1 = -0.388$ $Var\ 2 = -24170$	$Var\ 1 = 3.750$ $Var\ 2 = 367.276$
U.K.	$d = 1.116\ (0.093)$ $b = 0.355\ (0.034)$	$Var\ 1 = 1.000$ $Var\ 2 = -0.000$	$Var\ 1 = -0.526$ $Var\ 2 = -777.921$	$Var\ 1 = 0.605$ $Var\ 2 = 501.522$

APPENDIX I. Main statistics and graphical trends of the data.

Table 8: Summary statistics of the Euro area's energy imports series

	Main statistics			
Partner	**Maximum**	**Minimum**	**Mean**	**Standard deviation**
ALGERIA	2,954.9	284.0	1,342.1	537.4
EURO AREA	15,178.3	1,417.7	8,229.0	3,537.3
LIBYA	3,258.1	0.0	1,256.7	746.8
NORWAY	3,009.0	425.9	1,610.7	493.1
RUSSIA	11,369.1	651.3	5,427.7	2,577.0
SAUDI ARABIA	3,225.9	315.2	1,305.2	538.0
U.K.	3,268.6	437.6	1,742.4	620.3

Table 9: Summary statistics of exchange rates against USD series

	Main statistics			
Exchange rate	**Maximum**	**Minimum**	**Mean**	**Standard deviation**
Algerian dinar/US dollar	133.5	60.9	85.4	19.4
Euro/US dollar	1.2	0.6	0.8	0.1
Libyan dinar/US dollar	1.4	0.5	1.2	0.3
Norwegian Krone/US dollar	10.4	5.1	7.2	1.3
Russian rouble/US dollar	77.7	23.0	39.4	16.5
Saudi riyal/US dollar	3.8	3.7	3.8	0.0
Pound/US dollar	0.8	0.5	0.6	0.1

Figure 2: Euro Area's energy imports with its main partners in 2020

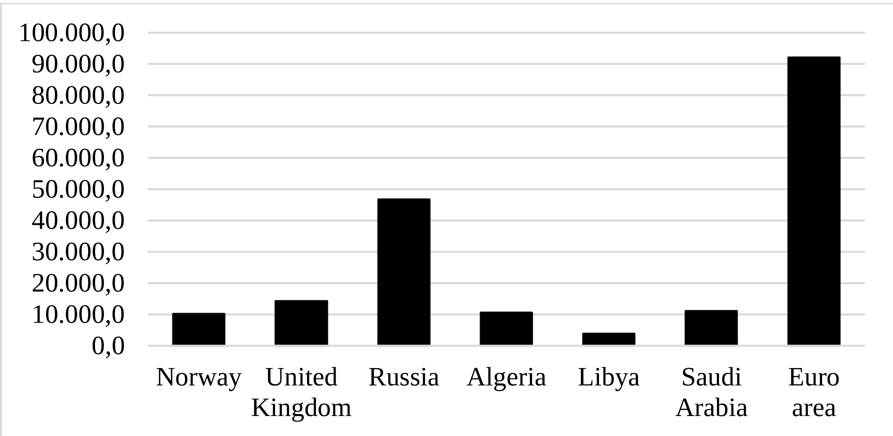

Figure 3: Evolution of Norwegian Krone/US Dollar Exchange rate

Figure 4: Evolution of Pound/US Dollar Exchange rate

Figure 5: Evolution of Russian Ruble/US Dollar Exchange rate

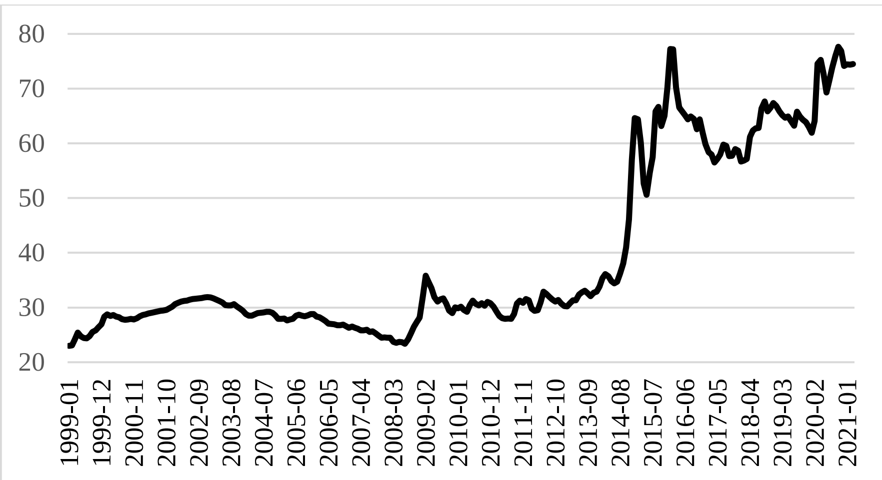

Figure 6: Evolution of Algerian Dinar/US Dollar Exchange rate

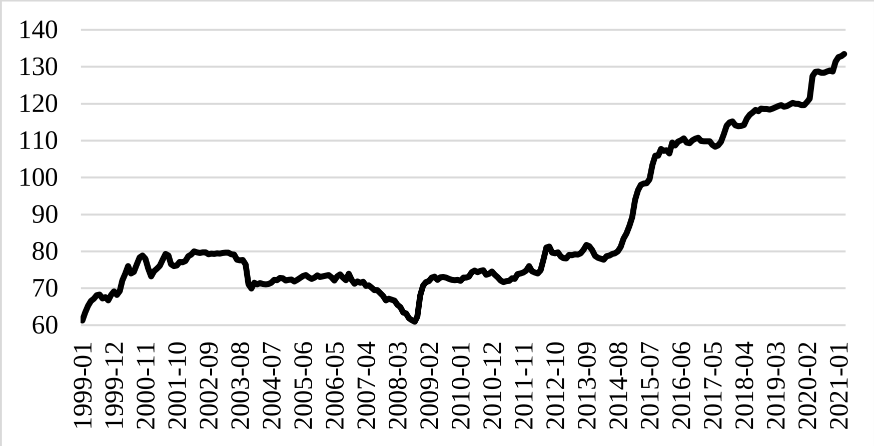

Figure 7: Evolution of Lybian Dinar/US Dollar Exchange rate

Figure 8: Evolution of Saudi Riyal/US Dollar Exchange rate

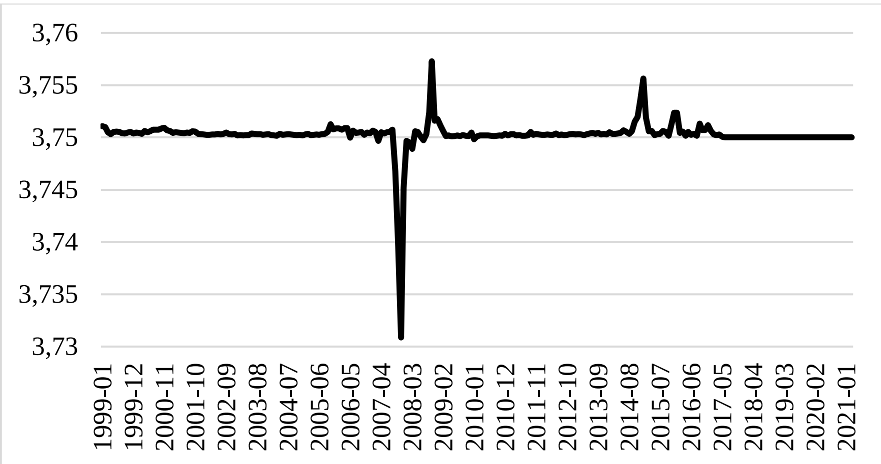

Figure 9: Evolution of Euro/US Dollar Exchange rate