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Daily Exchange Rate EURO/USD: ARDL Methodology to Co-Integration

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Abstract

The study research showed the importance of the ARDL model with co-integration in the monitoring of the relationship between the highest daily value of the exchange rate (HIGH) for the EURO against the US dollar (EURO to USD) and the opening price (OPEN) in the short and long terms. The error correction model (ECM) showed high efficiency in forecasts (ex-post forecasts) over a very long run covering three hundred and seventy-three days, as indicated by the mean absolute percentage error. Finally, the ECM model revealed an important speed of adjustment in modifying the deviation and returning to equilibrium after a certain shock in the relevant time series, so that approximately 15.35% of the deviation from the target, between the two variables (HIGH) and (OPEN), would be corrected within one day. Finally, our results also revealed that the Chow predictive and cumulative sum (CUSUM) tests roughly supported the parameters stability of the estimated Restricted Error Correction (REC) Model.

Keywords: EURO/USD exchange rate; ARDL model; Co-integration; Forecasts

Introduction

In financial markets, it is known that exchange rates fluctuate freely moment by moment, especially if the exchange system is flexible where economic indicators play a central role in the exchange rate of a currency. To avoid the risk of sudden changes in the exchange rate, some countries resorted to a fixed exchange rate system that linked the nation's currency to one strong and stable currency. For example, the Lebanese pound pegged to the US dollar, which was established after the TAIF agreement and settled at 1,500 Lebanese pounds versus one US dollar since 1992. In a similar context, the Kuwaiti dinar pegged to the US dollar, which was adopted by Kuwait on January 5, 2003 until May 20, 2007, in preparation for monetary union with the rest of the Gulf Cooperation Council. On June 16, 2007, the Kuwaiti dinar pegged to a basket of major international currencies (USD, EURO, Swiss franc and other currencies) reflecting trade and financial relations with Kuwait. Thus, speculators play a key role in purchasing and selling of currency hoping for a fair profit, allowing the currency to be equated in all financial markets, which explains why there is a fully competitive global market for foreign exchange. We do not want to deal with economic reasons such as the imports of a particular country and the increase of demand for foreign currencies, or the increase of exports and the accompanying increase in foreign exchange offer, which affects the exchange rate of a country under the relationship between imports and exports. It is important to mention that an increase in imports causes the devaluation of the national currency against the rest of other currencies, while the opposite effect is seen in case of an increase in exports since this increases the value of the national currency against other currencies, which pushes the balance of payments to equilibrium. One of the disadvantages of free exchange regimes lies in the case of exchange rate fluctuations that adversely affect the stability of international trade. The goal of this paper is limited to reduce the risks of exchange rate fluctuations associated with EURO/USD, where sudden exchange rate fluctuations are a risk that all companies, investors and speculators try to avoid as much as possible by monitoring forecasts from reliable monitoring and forecasting centres. We do not want to elaborate on this, but we will deal with the EURO/USD prices over a long period from 1-1-2001 until 23/09/2011, i.e. during 2800 consecutive days (except on Saturday and Sunday of each week), noting that the database is available in a study prepared by Mourad and Harb [1]. We are interested in the calculation of forecasts using the ARDL/Bounds Testing Methodology proposed by Pesaran et al., Strom [2-5]. We will only adopt two variables: The high daily exchange rate Y_t as a dependent variable and the opening price X_t. Why is this choice? Since the opening price is known, it will be used as an exogenous variable, while Y_t will be considered as an endogenous variable. In the end, the parameters stability of the Error Correction Model will be tested through Chow Predictive Test and the use of recursive residuals to effectuate Cumulative Sum (CUSUM).

Research objectives

The research has three objectives

α) Is there long-term equilibrium between the variables Y_t and X_t?

β) Is there co-integration between these two variables?

χ) Is it possible to have excellent forecasts under the ARDL model with co-integration?

Research Methodology

The methodology of the research depends first on the analytical statistical approach to the time series, and on the technique of co-integration according to the ARDL/Bounds Testing Methodology proposed by Pesaran et al. [4].

Research hypothesis

The unexpected sudden fluctuations in the EURO-dollar exchange rate result from sudden economic and political shocks causing significant financial losses or gains. Does the model envisaged in this study allow a safety cover to avoid or, at least, reduce losses? Or does it allow an increase in the probability of obtaining significant profits or at least no losses?

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Structure of the research

This paper is divided into the following five sections:

The first section deals with a general introduction to the topic that allows for a general understanding of the problem of the study and its purpose. The second section briefly addresses the literature review and the implementation of ARDL approach to co-integration. Then the third section is devoted to the practical aspect where the ARDL estimate model with co-integration is presented, and in the fourth section, the stability of the Restricted Error Correction (REC) model parameters is tested. In fifth section, conclusions are drawn by calculating forecasts and determining the Mean Absolute Percent Error (MAPE) for the period of 24-9-2011 until 1-3-2013 i.e. 373 days and finally ending up with some recommendations and suggestions.

Literature Review and Implementation of ARDL Approach to Co-integration

The steps followed will be elaborated when using the ARDL technique with co-integration according to the ARDL/Bounds Testing Methodology and after accessing the Error Correction Model (ECM). In the applied research field, there is considerable research leading ARDL with co-integration. Kwofie and Ansah [6] examined the effect of exchange rate and inflation on stock market returns in Ghana, Damane [7] analysed the private consumption in Lesotho, Baig et al. [8] studied the causal relationship between natural disasters and economic growth in Pakistan, Ghumro and Karim [9] dealt with the real broad money supply as a dependent variable and the gross domestic product discount rate and inflation rate in Pakistan, Sunge et al. [10] established the relationship among the annual time series associated to the household final consumption expenditure as a dependent variable, the gross domestic product, the government expenditure, the government tax revenue, total government debt, that is, the size of public debt and interest payments on outstanding government debt, Mourad [11] analyzed the deposits in Lebanese commercial banks, Dritsakis [12] modeled the real money supply in Hungary with the economic and financial variables composed from the real income at constant prices, the nominal exchange rate and the inflation rate with the main objective was to ensure a long-run equilibrium relationship among these variables, Shahbaz et al. [13] established a strong relationship between the development of the stock market and the economic growth in Pakistan, Tang [14] investigated the money demand function for five Southeast Asian countries and his findings revealed that real M_2 aggregate, real expenditure components, exchange rate, and inflation rate were co-integrated for Malaysia, Philippines and Singapore, Oskooee and Wing [15] detected an equilibrium relationship among demand for money, interest rates and exchange rates using quarterly data in Hong Kong. Using the Engle-Granger two-stage procedure to co-integration, Mourad [16] accepted the null hypothesis of no co-integration between the gross domestic saving and each of the gross national expenditure and the household final consumption expenditures as a proportion of the gross domestic product in Jordan, finally Mourad [17] studied the long-run equilibrium between the GDP annual growth rate and the annual growth rate of GDP per capita in each of the GGC countries.

In this context, the first question that needs to be answered is: How do we use the PSS technique to construct the ARDL model with co-integration between variables that can be either I(1) or I(0)? The PSS procedure aims to test the null hypothesis that there exists no co-integrating relationship between variables versus the alternative hypothesis which recommends a long-term equilibrium relationship between variables, i.e. co-integration. The PSS procedure tests the existence of this equilibrium relationship regardless of whether the underlying variables are I(1), I(0) or I(d), (0<d<1((Fractionally integrated). This means that if one variable is I(2), then the PSS procedure becomes invalid. Below we present the important steps needed to implement PSS procedure.

Step 1: The stationarity of the variables is tested to confirm statistically the existence of time series that follow I(0) or I(1) and without variables integrated of order two in the model.

Step 2: Since we have only two variables, the Unrestricted Error Correction Model (UECM) will be considered:

$$\Delta Y_t = c_0 + \sum_{i=1}^{p}\varphi_i \Delta Y_{t-i} + \sum_{j=0}^{q}\beta_j \Delta X_{t-j} + \theta_0 Y_{t-1} + \theta_1 X_{t-1} + \varepsilon_t \quad (1)$$

The values of the orders (p) and (q) are determined using an automatic criterion such as the AIC or SBC taking into account that the residues are not correlated according to Ljung-Box statistic.

Step 3: We test for a long-run equilibrium relationship between variables in levels:

H_0: $\theta_0 = \theta_1 = 0$, no long run relationship

H_a: $\theta_0 \neq 0$ or $\theta_1 \neq 0$, long run relationship

Using the PSS approach, we calculate the Bounds testing statistic symbolized by $F_Y(Y|X)$. This statistic is not subject to the classical distribution of Fisher, but it is subject to a non-standard distribution related by the order integration I(1) or I(0), by the number of estimated parameters in the model and by the presence or absence of constraints on the intercept and trend.

The PSS procedure defines two sets of critical values: The first set represents the minimum values resulted by assuming that all variables are I(0) and, therefore, there is no co-integration. The second set is composed of large values and assuming all variables is I(1) and, therefore, there is co-integration. If the calculated F is outside of the bound specified by PSS procedure, then three findings will be concluded:

- If the calculated F is greater than the upper critical value of the bound, then co-integration will be accepted.
- If the calculated F is smaller than the minimum critical value of the bound, then co-integration will be rejected.
- Finally, if the F statistic is included in the bound, then the decision will be inconclusive, indicating that the F statistic depends on the order of integration I(0) or I(1).

The PSS procedure allows also the Bounds t-test examining the significance of the intercept θ_0:

H_0: $\theta_0 = 0$ no co-integration

H_a: $\theta_0 < 0$ co-integration

Decision rule:

- If the calculated t-statistic is outside the upper critical value of the bound, then co-integration will be accepted.
- If the calculated t-statistic is outside the minimum critical value of the bound, then co-integration is rejected and we conclude that the time series in the model considered as I(0).

Step 4: After determining the optimal values (p,q), the long-run linear relationship between the variables at levels will be estimated:

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$Y_t = \alpha_o + \alpha_1 X_t + \eta_t$

Thus, using the OLS method, the estimated residues $\hat{\eta}_t$ are obtained and symbolized by EC_t

$$EC_t = Y_t - \hat{\alpha}_0 - \hat{\alpha}_1 X_t \quad (2)$$

is now considered: (Conventional ECM) The traditional error correction model

$$\Delta Y_t = c_0 + \sum_{i=1}^{p} \varphi_i \Delta Y_{t-i} + \sum_{j=0}^{q} \beta_j \Delta X_{t-j} + \gamma EC_{t-1} + \varepsilon_t \quad (3)$$

And then it will be estimated by OLS method. The parameter γ indicates the speed of adjustment to restore equilibrium if a deviation from equilibrium is produced. The sign of γ must be negative and with significance level 5% according to the Student distribution in order to ensure the dynamic adjustment towards equilibrium. In general, $-1 < \gamma < 0$, if its estimated value is close to (-1.0) then the return to equilibrium will be almost complete and immediate.

ARDL model and PSS bound test on co-integration

The steps outlined in the previous section will be implemented:

Step 1: The Augmented Dickey-Fuller (ADF) test for unit root, Dickey and Fuller [18] showed that the variables X_t and Y_t are non-stationary at level, but they should be stationary in their first difference [1].

Step 2: The Unrestricted Error Correction Model (UECM) are used as shown in Equation (1). Since the sample size for the time series is 2800 observations, we have set (p=200) for the maximum order of AR process and, therefore, the number of parameters in the model will be between 6 and 404. So, to economize the degrees of freedom, the Stepwise regression will be used [19], and the parameters with significance level 5% only are retained in the model calculating the (AIC) and (SBC) statistics. The Figure 1 reveals the optimum orders of p are 170 and 10 according to AIC and ABC respectively, while the values become 32 and 6 without imposing the significance constraints on the parameters (Figure 2). Since $t_{\hat{c}_0} = 0.82, \hat{c}_0 = 0.00055$, the parameter C_0 is removed from the model.

Investigating the Table 1, it is clear that the Ljung-Box statistics favor the choice (p=32), especially without restrictions on the parameters and for degrees of freedom (50,100):

$$LB(200) < \chi^2_{0.05;200} \text{ and } LB(df) < \chi^2_{0.05;df};\ df = 50,100$$

Step 3: The ARDL (32,32) will be estimated using OLS method and the null hypothesis (H_0:θ_0=θ_1=0) will be tested using the statistic $F_Y(Y|X)$ (Tables 2 and 3).

The null hypothesis of no co-integration is rejected because $F_Y(Y|X)>4.11$ at 5% level of significance. We can also test the significance of the parameter θ_0. We compare just $t_{\hat{\theta}_0} = -3.045$ to the critical values proposed by PSS (Table CII(1), p 303 for PSS(2001) denoting that at 10%, 5% and 1% levels of significance, the bounds for the t-statistics are respectively [-1.62, -2.28], [-1.95, -2.6] and [-2.58, -3.32]. We conclude that there is a long-run equilibrium between the daily high value of the EURO to USD exchange rate and the opening price X_t.

Using the findings in Table 2, the long-run relationship between Y_t and X_t is given by:

$$-0.14928\ Y + 0.15008X = 0 \Leftrightarrow Y \cong 1.0054X \quad (4)$$

If the opening price (EURO/USD) increases one unit, then the daily high exchange rate will rise to around 1.0054 units. This result is very important for the monitors of financial markets, reporting that a high opening price of (EURO/USD) will be reflected in the daily high exchange rate.

Step 4: The simple linear regression model with Y_t dependent variable and X_t independent variable is now estimated by OLS method:

$$\hat{Y} = \underset{(2.51)}{0.00175} + \underset{(1802.9)}{1.00364X} \quad R^2 = 99.91\ \% \quad (5)$$

The estimated residues at time *t* are given by:

$$EC_t = Y_t - 0.00175 - 1.00364X_t \quad (6)$$

The estimated Restricted Error Correction (REC) Model is now presented in Table 4:

Since the sign of the error correction parameter is negative and statistically significant at 5% level, we accept the long-run equilibrium between the variables X_t and Y_t. The estimated value of the γ implies that the system will adjust itself toward equilibrium by 15.35% from the error made in the previous day and this correction is clearly shown in Figure 3 over the period 2775-2800.

Testing Parameters of Stability and Forecasts

Let's refer to the REC model estimated in Table 4 and see if the null hypothesis of parameters stability can be accepted. Before this matter is resolved, we note that Pesaran [20] recognized the short-run dynamic impact on the testing for stability of long-run parameters and, therefore, allowed using the structural stability test entitled cumulative sum (CUSUM) test on the REC model of both long-run and short-run. We also see many applications on this subject, for example, Pesaran and Pesaran [21] studied the Error Correction Model between expected inflation and nominal interest rates in Nigeria, Alimi [22] used data on the human capital and economic growth of Malaysia to estimate a REC model, Sieng and Yussof [23] considered the ARDL approach to co-integration in the study of the main determinants of inflation in

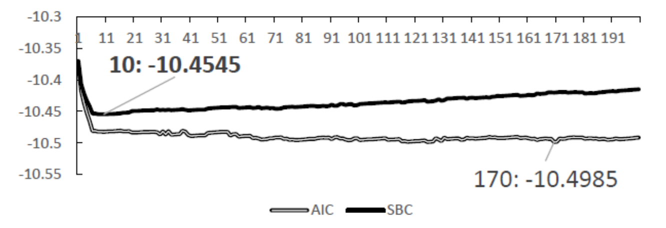

Figure 1: The AIC and SBC statistics using stepwise regression.

Without constraints on the parameters					With constraints on the parameters				
p	Degrees of freedom				p	Degrees of freedom			
	50	100	150	200		50	100	150	200
6	79.7	182.6	247.4	305.3	10	86.8	184.0	248.0	305.9
32	23.0	110.6	182.1	231.3	170	63.4	131.2	178.6	229.7
Critical values of Chi Square distribution at 5% level of significance are 67.1, 124.3, 179.3 and 233.7 respectively for the Degrees of freedom above.									

Table 1: Ljung-Box statistics (LB).

Dependent variable: ΔY_t P=32, T=2800, Usable observations=2767, df=2700p					
T-Stats	**coefficient**	**Lags ΔX**	**T-Stats**	**coefficient**	**Lags ΔY**
50.7702	0.97448	0	-14.515	-0.82065	1
12.8544	0.76073	1	-11.227	-0.70158	2
10.4409	0.6697	2	-9.88	-0.65583	3
9.51454	0.64239	3	-9.2754	-0.6427	4
9.07711	0.63598	4	-8.4038	-0.60012	5
7.97585	0.57398	5	-7.2019	-0.52518	6
5.98961	0.43866	6	-5.7663	-0.42672	7
6.24157	0.46218	7	-5.9996	-0.44856	8
5.65847	0.42349	8	-5.893	-0.44444	9
5.72523	0.43211	9	-5.1504	-0.39175	10
5.48468	0.41699	10	-6.0885	-0.46552	11
6.44411	0.49256	11	-6.4189	-0.4934	12
6.42005	0.49291	12	-5.8396	-0.4501	13
5.74168	0.44201	13	-5.4788	-0.42265	14
5.65368	0.43532	14	-5.6278	-0.4335	15
5.75639	0.44242	15	-5.7419	-0.44152	16
5.82236	0.44669	16	-5.1812	-0.39705	17
5.52387	0.4224	17	-5.708	-0.4354	18
5.59253	0.42544	18	-5.5056	-0.41762	19
5.12784	0.38722	19	-4.5916	-0.34513	20
4.33847	0.32436	20	-4.8165	-0.35759	21
4.74965	0.34915	21	-4.7112	-0.34384	22
4.93597	0.35603	22	-5.3327	-0.38266	23
5.54875	0.39286	23	-5.9938	-0.42151	24
5.7906	0.4009	24	-5.786	-0.39793	25
5.4663	0.3691	25	-5.1144	-0.34298	26
5.38325	0.35312	26	-5.264	-0.34084	27
4.96189	0.31258	27	-4.8845	-0.30121	28
4.74499	0.28129	28	-3.7753	-0.21677	29
2.55305	0.13793	29	-2.3114	-0.11944	30
3.31944	0.15648	30	-3.4035	-0.14991	31
3.39253	0.12657	31	-1.9783	-0.06273	32
1.18456	0.02389	32			
3.04658	0.15008	X_{t-1}	-3.0455	-0.14928	Y_{t-1}

RSS=0.07193, R_R^2 =0.5331, R_R^2 =0.5217, DW=2.0013

Without X_{t-1} and Y_{t-1} we find R_R^2 = 0.5313962

$$F(2,2700)=\frac{\left(R_U^2-R_R^2\right)}{2}\times\frac{df}{\left(1-R_U^2\right)}=4.915=F_Y\left(Y|X\right)$$

Table 2: OLS Estimate of UECM.

F-statistic	**Lag**	**Significant level**	**Bound critical values (No intercept and no trend)**	
			I(0)	I(1)
4.915	32	1%	4.81	6.02
		5%	3.15	4.11
		10%	2.44	3.28
Note: Number of independent variables (k):1				

Table 3: Bounds test for co-integration.

Dependent variable: ΔY_t P=32, T=2800, Usable observations=2767, df=27					
T-Stats	**coefficient**	**Lags** X	**T-Stats**	**coefficient**	Lags Y
50.7818	0.97434	0	-14.421	-0.8162	1
2.76508	0.7564	1	-11.134	-0.697	2
0.35192	0.66521	2	-9.7877	-0.6511	3
9.42493	0.63776	3	-9.1838	-0.6379	4
8.98785	0.63125	4	-8.3141	-0.5952	5
7.88922	0.56916	5	-7.1153	-0.5202	6
5.9081	0.43379	6	-5.6836	-0.4217	7
6.15885	0.45725	7	-5.916	-0.4435	8
5.57711	0.41851	8	-5.8097	-0.4393	9
5.64366	0.42708	9	-5.0693	-0.3866	10
5.40445	0.41197	10	-6.006	-0.4604	11
6.36257	0.48759	11	-6.337	-0.4883	12
6.34057	0.48802	12	-5.7616	-0.4451	13
5.66677	0.43726	13	-5.4048	-0.4179	14
5.58203	0.43076	14	-5.5562	-0.4289	15
5.68764	0.43804	15	-5.6729	-0.4371	16
5.7565	0.44249	16	-5.116	-0.3928	17
5.46132	0.41835	17	-5.6442	-0.4313	18
5.53276	0.42158	18	-5.4452	-0.4137	19
5.07154	0.38354	19	-4.5352	-0.3414	20
4.28574	0.32086	20	-4.762	-0.354	21
4.69874	0.34583	21	-4.6592	-0.3404	22
4.88717	0.3529	22	-5.2822	-0.3794	23
5.50166	0.3899	23	-5.9453	-0.4185	24
5.746	0.39813	24	-5.7407	-0.3951	25
5.42509	0.36655	25	-5.0726	-0.3403	26
5.34544	0.35081	26	-5.2255	-0.3385	27
4.92821	0.31057	27	-4.8503	-0.2992	28
4.7156	0.27962	28	-3.7452	-0.2151	29
2.52833	0.13662	29	-2.2856	-0.1181	30
3.29946	0.15555	30	-3.3824	-0.149	31
3.37867	0.12604	31	-1.9634	-0.0623	32
1.18221	0.02384	32			
DW=2.0013			-3.13305	$\hat{\gamma}$ = -0.15355	EC_{t-1}

Table 4: Estimate of REC model M.

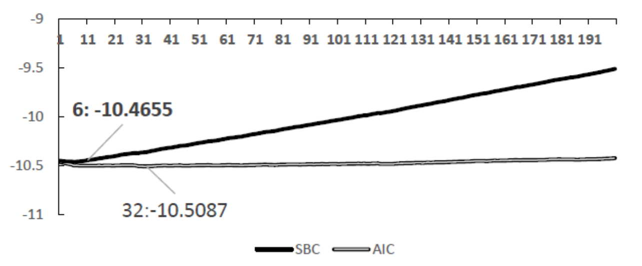

Figure 2: The AIC and SBC statistics without significance constraints on the parameters.

Iran, Pahlavani and Rahimi [24] studied the equilibrium relationship between energy consumption and economic growth in Iran including on the important economic variables like the real domestic product, energy consumption, stock of capital Water, oil revenues and financial development, Mehrara and Musai [25] studied the demand for money in Cambodia, Samreth [26] investigated the relationship between economic growth and foreign direct investment flows in Ghana, Fosu and Magnus [27] compared the recursive CUSUM test with the OLS-based CUSUM test and he concluded the preference for the latter in the event of an unknown breakpoint in the time series, Zeileis [28] measured the fluctuations in the residues relating to the co-integrating

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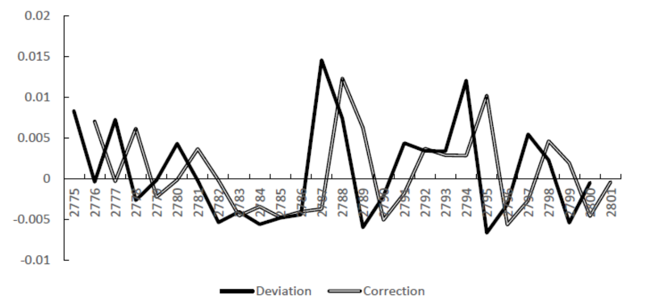

Figure 3: Return to equilibrium.

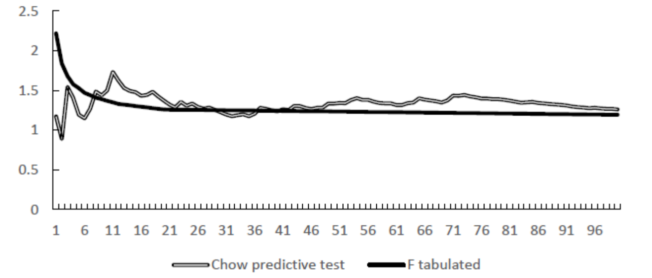

Figure 4: Chow F statistic.

regression, and accordingly, the authors used (CUSUM) to accept or reject the hypothesis of no co-integration. Before proceeding to use the CUSUM test, we would we intend first to use Chow Predictive Test (CPT).

Chow predictive test

This test adopted by Xiao and Philips [29] and based on rolling estimates aims for detecting structural changes in the time series. It consists of the following steps:

Step 1: The estimated RECM is done for overall period data (pooled sample) and we retain the Residual Sum of Squares (RSS_p).

Step 2: The estimated RECM is done on the first n_1 observations, and then we calculate the forecasts for (h = 5i,i = 1,…100) with (n_1=2800-h), and we designate by (RSS_1) the Residual Sum of Squares.

Step 3: We calculate the test statistic CPT:

$$\mathbf{CPT} = \frac{(\mathbf{RSS_P} - \mathbf{RSS_1})/\mathbf{h}}{\mathbf{RSS_1}/\mathbf{ndf_1}} = \frac{(\mathbf{RSS_P} - \mathbf{RSS_1})}{\mathbf{RSS_1}} \times \frac{\mathbf{ndf_1}}{\mathbf{h}}$$

Where K and (ndf_1=n_1-K) represent respectively the number of parameters and the degrees of freedom in the model. If CHT ≤ $F_{0.05,h,n1\text{-}K}$ then the null hypothesis of constant parameters is not rejected. In Figure 4, the presented Chow F statistics reveal that the parameters stability of the REC model oscillates between rejection and acceptance of the null hypothesis. This is expected because the variable Y_t is subject to sudden fluctuations due to the sensitivity of the financial markets to any political, economic or worldwide security event, leading to severe shocks to exchange rates or to the price indices of countries, both in terms of rise or fall. However, if we take a 1% level of significance, then Fischer's critical values range between 3.03 and 1.32 with degrees of freedom h and n_1-K respectively. At this level of significance, we tend to accept the null hypothesis of constant parameters.

CUSUM test statistics

The test requires the recursive residues which differ from the classic residues [30-34]. The null hypothesis attempts to show that no variation exists among V_τ the vector of parameters associated to the first

(t-τ) usable observations.

$$H_0 : \mathfrak{V}_\tau = \mathfrak{V}_{+1} = \ldots = \mathfrak{V}_T = \mathfrak{V}$$

Under the assumption of equal variances of residues $\left(\sigma_\tau^2 = \sigma_{\tau+1}^2 = \ldots = \sigma_T^2 = \sigma_\varepsilon^2\right)$, $\mathrm{Cusum}_t \sim N(0, t-\tau)$ Under the null hypothesis of coefficient constancy, Cusum_t values are within the specified following two lines:

$$(\text{Upper line})\ \underset{\tau}{y} = a\sqrt{T-\tau} + \frac{2a(t-\tau)}{\sqrt{T-\tau}}$$

$$(\text{Lower line})\ y = -a\sqrt{T-\tau} - \frac{2a(t-\tau)}{\sqrt{T-\tau}}$$

So that the critical values of a are 1.14, 0.95 and 0.85 at of 1%, 5% and 10% significant levels respectively. Investigating Figure 5, the null hypothesis is not rejected with critical bounds at 5% significance level.

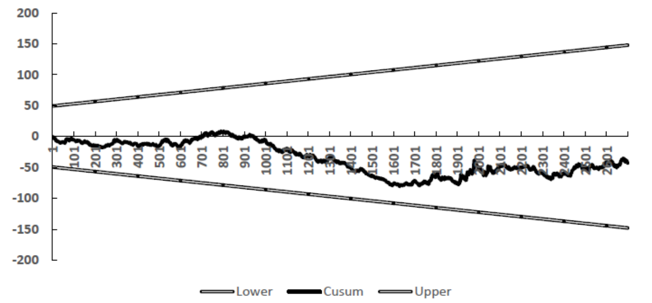

Figure 5: CUSUM test statistics and confidence intervals.

Evaluating forecast performance

We have already disclosed that Mourad [1] carried out several predictive modes for the high daily value of EUR/USD reached during a 24-hour day. These models used the techniques of ARI-ARCH, ARI-ARCH.M, ARI-EARCH without and with asymmetry and ARI-GJR-EARCH with asymmetry. Ex-post forecasts were made step by step, on 373 days from September 24, 2011 until March 01, 2013. The forecasts performance was measured by the Mean Absolute Percentage Error (MAPE) criterion. the MAPE value was 0.38% the different proposed models. Using Engle-Granger two step approach to co-integration, the authors considered four systems of variables as indicated below in Table 5 [35].

The accuracy of the ex-post forecasts resulted from the REC model is measured also by MAPE that reaches 0.28%.

Conclusion

The largest exchange rate EURO/USD reached in a 24-hour period (HIGH variable Y_t) and the daily opening price of the (EURO/USD) exchange rate (OPEN variable X_t) are co-integrated. The system composed of these two variables adjusts itself toward equilibrium

The Engle-Granger two-stage procedure to co-integration	
MAPE	**Systems**
0.30%	Y_t=$High_t$ X_t=$OPEN_t$
0.38%	Y_t=$High_t$ X_{1t}=$OPEN_t$ X_{2t}=Low_t
0.42%	Y_t=$High_t$ X_{1t}=$OPEN_t$ X_{2t}=Low_t X_{3t}=$Close_t$
The ARDL methodology to co-integration	
0.28%	Y_t=$High_t$ X_t=$OPEN_t$

Table 5: Forecast accuracy of different models.

by 15.35% from the error made in the previous day. This result is so interesting because it indicates a return to the Target after a deviation, thus, giving a certain security, which reduces the risk for those intervening in the stock market. Since the variable X_t is viewable just at the beginning of the opening of EURO/USD exchange rate on a trading day, it plays the role of an exogenous variable. Since it is linked with the variable Y_t by an equilibrium relationship, it would be a valve of some security for sellers and buyers or for the speculators in the stock market. Since the identified optimal orders of the REC model were (p=q=32) according to the Akaike Information Criterion, they are very small when compared with (p = 376, q = 339) used in the paper by Mourad and Harb. The estimated REC model contains only sixty-five parameters plus the speed of adjustment to restore equilibrium (parameter γ) and by consequence, there is a substantial gain in the degrees of freedom. The small value of MAPE (0.28%) indicates ex-post forecast performance, that is, the REC model can be considered as a good forecasting model. Finally, the findings brought by Chow Predictive Test and CUSUM test validate the null hypothesis of parameters stability.

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