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Original Paper

Factors Affecting the Exchange Rate: Technical Forecasting

Dr. Ioannis N. Kallianiotis[1*]

[1] Economics/Finance Department, The Arthur J. Kania School of Management, University of Scranton, Scranton, PA 18510-4602, USA

[*] Tel. (570) 941-7577; Fax (570) 941-4825; E-mail: ioannis.kallianiotis@scranton.edu

Abstract

This paper is using a technical forecasting technic by using time series and charts to forecast the exchange rate. It is used a linear time trend, a long linear time trend, a quadratic trend, a polynomial time trend, and some time-series models (Autoregressive, Moving Average, and a mixed Autoregressive-Moving Average) to determine the trend of the exchange rate and the relative accuracy of these models' forecasting. We compare their different statistics, the standard error of the regression (SER), the root mean squared error (RMSE), and other forecast errors to evaluate the results. The empirical results consider five different exchange rates between the U.S. dollar and the EMU (euro), the U.K. (pound), the Canadian (dollar), the Australian (dollar), and the Japanese (yen). The U.S. dollar shows its L-T weakness with respect the euro and the Japanese yen. The British pound, the Canadian dollar, and the Australian dollar are in a decline tendency with respect the U.S. dollar. The results of this technical analysis and the graphs, even though that they are not sophisticated economic models, are very helpful for the trends of the exchange rates.

Keywords: Demand for Money and Exchange Rate, Foreign Exchange, Forecasting and Simulation, Information and Market Efficiency, International Financial Markets

JEL (Classification): E4, F31, F47, G14, G15

1. Introduction

Forecasting can be thought of as the formal process of generating expectations and predictions by using economic theory, mathematics, statistics, and econometric analysis. When expectations for future economic variables (factors affecting them) are derived, we have an implicit forecast of the variable in question, here, the exchange rate. The rational expectations theory says that people form expectations of future values of the exchange rate and other variables in the same way that the "true" model of the economy generates these variables. Forecasting is very common and necessary in our times. People take forecasting into consideration, when they make economic decisions. These decisions then, influence the direction, in which the economy will move. Trade among nations and cash flows of all international transactions are affected by the expected value of the exchange rates; therefore, the forecasting of the exchange rate movements is very important for businesses, investors, individuals, and policy makers.

Multinational corporations (MNCs) need forecasts of exchange rates for their *hedging decision*. Firms face the decision of whether to hedge future payables and receivables, which are in foreign currencies. *Short-term financial and investment decisions* require exchange rate forecasting to determine the ideal currency for borrowing money and to allocate the one that maximize the return of an investment. *Capital budgeting decisions* need forecasting of exchange rate to determine the expected cash flows and make an accurate decision for these foreign investments. Also, *long-term financial decisions* require forecasting of the currencies to decide from where to borrow money (which will reduce the cost if the currency is depreciated) and if it is better to issue a bond denominated in foreign currency. Furthermore, *earnings assessments* want to forecast the foreign currency, in which the earnings are coming and to decide if earnings are going to be remitted back to the parent company or to be invested abroad.

Technical analysis or forecasting can be used to forecast trends and future spot exchange rates. Technical analysts, traditionally referred to as *chartists*, focus on price and volume data to determine past trends that are expected to continue into the future. The single most important element of technical analysis is that future exchange rates are based on the past and current exchange rate. Exchange rate movements, similar to equity price movements, can be subdivided into three periods: (1) day-to-day movement, which is seemingly random; (2) short-term movements extending from several days to trends lasting several months; (3) long-term movements, which are characterized by up and down long-term trends. Long-term technical analysis has gained new popularity as a result of recent research into the possibility that long-term "waves" in currency movements exist under floating exchange rates.

Technical forecasting involves use of historical exchange rate data (S_t) to predict future values. It is sometimes conducted in a "judgmental" manner, by determining and using time-series trends and time-series models without any impressive statistical analysis. From the corporate point of view, the use of technical forecasting may be limited in focuses on the near future, which is not that helpful for developing corporate policies. Many researchers represent the general solution to a linear stochastic difference equation as consisting of the four distinct parts (Note 1):

$s_t = trend + cyclical + seasonal + irregular$

The exchange rate series have no obvious tendency for mean reversion (Note 2). But, here, the log Linear Time Trends reveal the existence of mean reversions within a ±2 S.E. A critical task for econometricians is to develop simple stochastic difference equation models that can mimic the behavior of trending variables. The key feature of a trend is that it has a permanent effect on a series. Since the irregular component is stationary, the effects of any irregular components will "die out" while the trending elements will remain in long-term forecasts.

2. Time-Series Trends

One approach to forecasting the variance is to explicitly introduce an independent variable that helps to predict the volatility. Consider the simplest case, in which,

$$S_{t+1} = \varepsilon_{t+1} X_t \qquad (1)$$

where, S_{t+1} = the spot exchange rate (the variable of interest), ε_{t+1} = a white-noise disturbance term with variance σ^2, and X_t = an independent variable that can be observed at period t. If $X_t = X_{t-1} = X_{t-2} = \ldots =$ constant, the $\{S_t\}$ sequence is the familiar white-noise process with a constant variance. If the realizations of the $\{X_t\}$ sequence are not all equal, the variance of S_{t+1} conditional on the observable value of X_t is

$$Var(S_{t+1} | X_t) = X_t^2 \sigma^2 \qquad (2)$$

2.1 Deterministic Trends

One of the basic characteristics of S_t that can be described relatively easily is its long-term growth pattern. Despite the short-run up-and-down movement, it is possible that S_t might exhibit a clear-cut long-term trend. There are many models that describe this deterministic trend and can be used to forecast, for example extrapolate, S_t. They are the followings:

(1) Linear Time Trend (Note 3):

$$S_t = \alpha_0 + \alpha_1 t + \varepsilon_t \qquad (3)$$

(2) Log Linear Time Trend:

$$s_t = \beta_0 + \beta_1 t + \varepsilon_t \qquad (4)$$

(3) Quadratic Time Trend:

$$s_t = \gamma_0 + \gamma_1 t + \gamma_2 t^2 + \varepsilon_t \qquad (5)$$

(4) Polynomial Time Trend:

$$s_t = \delta_0 + \delta_1 t + \delta_2 t^2 + \ldots + \delta_n t^n + \varepsilon_t \qquad (6)$$

where, S_t = the spot exchange rate, t = time trend (1, 2, 3, ...), n = a n^{th} –degree polynomial, and $s_t = \ln S_t$ (lowercase letters are the natural logarithms of the uppercase counterparts).

2.2 Models of Stochastic Trend

The deterministic trend models can be augmented with lagged values of the $\{s_t\}$ sequence and $\{\varepsilon_t\}$ sequence. These equations become, now, models with stochastic trends (Note 4). One of these models is the Random Walk Model. The random walk model is a special case of the AR(1) process, eq. (7) (Note 5), (discussed in section III.1 bellow), which is:

$$s_t = \alpha_0 + \alpha_1 s_{t-1} + \varepsilon_t \tag{7}$$

with $\alpha_0 = 0$ and $\alpha_1 = 1$, the above equation becomes a random walk,

$$s_t = s_{t-1} + \varepsilon_t \tag{8}$$

where, $s_t - s_{t-1} = \Delta s_t = \varepsilon_t$

3. Time-Series Models

In this section, stochastic processes are introduced and some of their properties and their use in forecasting are discussed. The objective is to develop models that "explain" the movement of the time series s_t. Unlike the regression model, however, a set of explanatory variables will not be used. Instead we explain s_t by relating it to its own past values and to a weighted sum of current and lagged random disturbances.

3.1 The Autoregressive [$AR(p)$] Model

In the autoregressive process of order (p), the current observation s_t is generated by a weighted average of its past observations going back p periods, together with a random disturbance in the current period. This process is denoted as $AR(p)$ and its equation is written as:

$$s_t = \phi_1 s_{t-1} + \phi_2 s_{t-2} + \ldots + \phi_p s_{t-p} + \delta + \varepsilon_t \tag{9}$$

where, δ is a constant term, which relates to the mean of the stochastic process (Note 6).

The first-order process $AR(1)$ is (Note 7) as follows:

$$s_t = \phi_1 s_{t-1} + \delta + \varepsilon_t \tag{10}$$

Its mean is: $\mu = \dfrac{\delta}{1-\phi_1}$ and is stationary (Note 8) if $|\phi_1| < 1$.

Updating one period, we obtain,

$$s_{t+1} = \phi_1 s_t + \delta + \varepsilon_{t+1} \tag{11}$$

By running the regression, eq. (10), we make the coefficients δ and ϕ_1 known to us; then, we can forecast s_{t+1} conditioned on the information available at period t as (Note 9),

$$E_t s_{t+1} = \hat{\phi}_1 s_t + \hat{\delta} \tag{12}$$

where, $E_t s_{t+1}$= the forecasted s_{t+1} one period ahead, s_t = the current spot rate, $\hat{\delta}$ = the estimated constant term, and $\hat{\phi}_1$ = the estimated coefficient.

The same way the $AR(p)$ can be used to forecast the spot rate next period by using as many lags as they are statistically significant.

3.2 The Moving Average [$MA(q)$] Model

In the moving average process of order (q), each observation s_t is generated by a weighted average of random disturbances going back q periods. We denote this process as $MA(q)$ and its equation is written as,

$$s_t = \mu + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots + \theta_q \varepsilon_{t-q} \tag{13}$$

where the parameters $\theta_1, \ldots, \theta_q$ may be positive or negative.

The moving average process of order 1, $MA(1)$ is (Note 10) the following:

$$s_t = \mu + \varepsilon_t + \theta_1 \varepsilon_{t-1} \tag{14}$$

The same way, here, as with the $AR(1)$ process above; by updating one period, we obtain,

$$s_{t+1} = \mu + \varepsilon_{t+1} + \theta_1 \varepsilon_t \tag{15}$$

By running the regression, eq. (14), we know the coefficients μ and θ_1; then, we can forecast s_{t+1} conditioned on the information available at period t as,

$$E_t s_{t+1} = \hat{\mu} + \hat{\theta}_1 \varepsilon_t \tag{16}$$

where, $E_t s_{t+1}$ = the forecasted s_{t+1} one period ahead, s_t = the current spot rate, $\hat{\mu}$ = the estimated constant term, and $\hat{\theta}_1$ = the estimated coefficient.

The same way the $MA(q)$ can be used to forecast the spot rate next period by using as many lags as they are statistically significant and usually, there will be many lagged errors.

3.3 The Mixed Autoregressive-Moving Average [$ARMA(p,q)$] Model

Many stationary random processes cannot be modeled as purely autoregressive or moving average, since they have the qualities of both types of processes. The logical extension of the models presented in the last two sections can be the mixed Autoregressive-Moving Average process of order (p,q) and is represented by the following equation:

$$s_t = \phi_1 s_{t-1} + \phi_2 s_{t-2} + \ldots + \phi_p s_{t-p} + \delta + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \ldots + \theta_q \varepsilon_{t-q} \tag{17}$$

where, its mean is: $\mu = \phi_1 \mu + \ldots + \phi_p \mu + \delta$

or $\mu = \dfrac{\delta}{1 - \phi_1 - \ldots - \phi_p}$.

The $ARMA(1,1)$ process is (Note 11),

$$s_t = \phi_1 s_{t-1} + \delta + \varepsilon_t + \theta_1 \varepsilon_{t-1} \tag{18}$$

Estimating the coefficients in eq. (18), we can use them to forecast one period ahead the expected spot exchange rate, $E_t s_{t+1}$:

$$E_t s_{t+1} = \hat{\phi}_1 s_t + \hat{\delta} + \varepsilon_{t+1} + \hat{\theta}_1 \varepsilon_t \tag{19}$$

Formally, the $ARMA(p,q)$ process is forecasting the spot rate next period based on past values of the exchange rate and the error terms (Note 12):

$$E_t s_{t+1} = E(s_{t+1} \mid s_t, s_{t-1}, \ldots, s_{t-p}, \varepsilon_t, \varepsilon_{t-1}, \ldots, \varepsilon_{t-q}) \tag{20}$$

4. Forecasting Evaluation

Forecasts are made with errors because the economy is dynamic and unpredictable (manipulated), our information is restrained and many news are “fake” (Note 13), our models are only approximations of reality, and our actual knowledge is very limited (Note 14). Suppose the true model is given by,

$$s_t = \chi_t \beta + \varepsilon_t \tag{21}$$

where, β is a vector of unknown parameters, and ε_t is an independent and identically distributed with mean zero random disturbance [$E(\varepsilon_t) = 0$].

The true model generating s_t is not known, but we obtain estimates $\hat{\beta}$ of the unknown parameters β. Then, setting the error term equal to its mean value (zero), the forecasts of s_t are obtained as follows:

$$\hat{s}_t = \chi_t \hat{\beta} \tag{22}$$

The forecast error (e_t) is the difference between the actual and the forecasted value,

$$e_t = s_t - \chi_t \hat{\beta} \tag{23}$$

Assuming that the model is correctly specified, there are two sources of forecast errors: (1) residual or innovation uncertainty and (2) coefficient uncertainty.

(1) Residual or Innovation Uncertainty

This first source of errors arises because the innovations ε_t in the equation are unknown for the forecast period and are replaced with their expectations. While the residuals are zero in expected value, the individual values are non-zero; the larger the variation in the individual errors, the greater the overall error in the forecasts. The standard measure of this variation is the "Standard Error of the Regression" (SER) in the equation output. Residual uncertainty is usually the largest source of forecast errors. Our criterion, here, will be minimization of the SER because the smaller the SER in our output, the better the forecast of this model.

(2) Coefficient Uncertainty

The second source of forecast error is coefficient uncertainty. The estimated coefficients $\hat{\beta}$ of the equation deviate from the true coefficients β in a random fashion. The standard error of the estimated coefficient, given with the output from the regression, is a measure of the precision, with which the estimated coefficients measure the true coefficients. The effect of coefficient uncertainty depends on the exogenous variables. Since the estimated coefficients are multiplied by the exogenous variables χ_t in the computation of forecasts, the more exogenous variables deviate from their mean values, the greater is the forecast uncertainty.

When we construct a forecast of the $s_{t+1}^{e} = LEUSF$ by using different estimated equations, the computer output will give to us different forecast evaluation options (root mean squared error, mean absolute error, mean absolute percentage error, Theil inequality coefficient, etc.). The output will give to us the actual (s_t) and the forecasted value ($\hat{s}_t$) of the variable, with an F at the end (i.e., $LEUS$ and $LEUSF$). The reported forecast error statistic that we can look is the Root Mean Squared Error (RMSE) and it is computed as follows:

$$RMSE = \sqrt{\sum_{t=T+1}^{T+n} (\hat{s}_t - s_t)^2 / n} \tag{24}$$

This statistic (RMSE) depends on the scale of the dependent variable and it is used as a relative measure to compare forecasts for the same series across different models; the smaller the error, the better the forecasting ability of that model according to the RMSE criterion. Statistical programs offer dynamic and static forecasting. The *dynamic forecasting* is a multi-step forecast of $\hat{s}_{t+n}$. The *static forecasting* performs a series of one-step ahead forecast of the dependent variable $\hat{s}_{t+1}$. Both methods will always yield identical results in the first period of a multi-period forecast (Note 15).

Finally, there are currency forecasting services and many MNCs use forecasting services regularly. Forecasting is essential, but it is theoretically impossible; of course, it is better to have a view about the future instead ignoring it. A variety of opinions is generally useful when attempting to predict the future. Most forecasting services also provide added discipline to the forecasting process often missing within smaller corporate finance units. For example, the need to focus on the likely movement of an exchange rate within a specific time interval is typically stressed within a forecasting unit while not within a business unit's planning horizon. A treasurer might also use a forecasting service because "it exists". If the treasurer does not use it, and guesses wrong on an exchange rate, the treasurer could be criticized for not using available "expert advice".

5. Empirical Results

The data are monthly and are coming from *Economagic.com*, *Eurostat,* and *Bloomberg*. For the euro (€), the data are from 1999:01 to 2021:08 (since the introduction of euro electronically) and for the other five currencies (S, £, C$, A$, and ¥) are from 1973:03 to 2021:08 (since the exchange rate became floating). We started with the Log-Linear Time Trend, eq. (4), and the results are shown in Table 1. The forecasting of these trends are shown in the Appendix, Figures 1a, 2a, 3a, 4a, and 5a. The $/€ exchange rate trend shows depreciation of the dollar ($↓) and appreciation of the euro (€↑); the $/£ trend reveals $↑ and £↓; the C$/$ trend gives C$↓ and $↑; the $/A$ trend shows $↑ and A$↓; and the ¥/$ trend gives ¥↑ and $↓ in the long run.

Then, we continue with the estimation of the Polynomial Time Trend, eq. (6), with t^6 for the five exchange rates. The graphical presentations are given in Figures 1b, 2b, 3b, 4b, and 5b; their forecasting are in Figures 1c, 2c, 3c, 4c, and 5c, which show that the $↓ and €↑, the $↑ and £↓, the $↑ and C$↓, the $↑ and A$↓, and the $↓ and ¥↑ and after 2020, the dollar started gaining some value ($↑) with respect the Japanese yen (¥↓).

Next, we estimate eq. (9), the Autoregressive process, AR(p), which appeared in Table 2. The results give very small SERs and their graphs give a very good fit, Figures 1d, 2d, 3d, 4d, and 5d; their forecasting are shown in Figures 1e, 2e, 3e, 4e, and 5e, which have a very small RMSE. Now, eq. (13), the Moving Average process, MA(q) is given in Table 3. The SERs are again small and the forecasting of the spot exchange rates, Figures 1f, 2f, 3f, 4f, and 5f, have shown small RMSE, too. Lastly, a mixed Autoregressive-Moving Average process, ARMA (p,q), eq. (17) is presented in Table 4, with good SERs and all the other statistics; their graphs are shown in Figures 1g, 2g, 3g, 4g, and 5g with very small RMSEs.

Thus, this simple technical forecasting gives good trend results for our exchange rates. The dollar is expected to do well ($↑) with respect the British pound (£), Canadian dollar (C$), and Australian dollar (A$), but it is not expected to appreciate ($↓) with respect the euro (€); with the yen (¥), there is some cyclicality, but mostly the dollar was losing value ($↓) except lately, where it shows that the dollar has started to appreciate ($↑).

Table 1. Long Linear Time Trend, Eq. (4)

	s_t (EMU)	$s_t(UK)$	s_t (Canada)	s_t (Australia)	s_t (Japan)
c	0.105***(0.016)	0.666***(0.011)	0.162***(0.011)	0.015 (0.017)	5.492***(0.017)
t	0.001***(0.001)	-0.001***(0.001)	0.001***(0.001)	-0.001***(0.001)	-0.002***(0.001)
R^2	0.082	0.328	0.031	0.245	0.713
SER	0.132	0.134	0.128	0.208	0.204
F	24.051	282.824	18.592	188.020	1,437.879
$D-W$	0.033	0.031	0.016	0.015	0.016
N	272	582	582	582	582

Note. s_t = ln of the spot exchange rate, t = time (1, 2, 3, …), R^2 = R-squared, SER = standard error of the regression, F = F-Statistic, $D-W$ = Durbin-Watson Statistic, N = number of observations, *** = significant at the 1% level, ** = significant at the 5% level, and * = significant at the 10% level.

Source: *Economagic.com*, *Bloomberg*, and *Eurostat*.

Table 2. The Autoregressive Process [AR(p)], Eq. (9)

	s_t (EMU)	$s_t(UK)$	s_t (Canada)	s_t (Australia)	s_t (Japan)
c	0.170**(0.070)	0.519***(0.062)	0.181***(0.062)	-0.120 (0.129)	5.027***(0.246)
s_{t-1}	1.177***(0.056)	1.353***(0.036)	1.173***(0.022)	1.324***(0.032)	1.315***(0.036)
s_{t-2}	-0.198***(0.055)	-0.469***(0.067)	-0.181***(0.023)	-0.408***(0.059)	-0.317***(0.036)
s_{t-3}		0.204***(0.067)		0.078**(0.037)	
s_{t-4}		-0.100***(0.036)			
R^2	0.971	0.982	0.985	0.990	0.996
SER	0.024	0.022	0.016	0.025	0.025

F	2962.832	6,149.002	13,054.58	13,712.40	45,875.18
$D-W$	2.015	1.997	1.999	1.998	1.984
N	272	582	582	582	582

Note. See, Table 1.

Source: See, Table 1.

Table 3. The Moving Average Process [MA(q)], Eq. (13)

	s_t (EMU)	$s_t(UK)$	s_t (Canada)	s_t (Australia)	s_t (Japan)
c	0.174***(0.020)	0.504***(0.016)	0.201***(0.013)	-0.186*** (0.022)	4.938***(0.033)
ε_{t-1}	1.226***(0.059)	1.519***(0.039)	1.386***(0.028)	1.544***(0.035)	1.733***(0.042)
ε_{t-2}	1.300***(0.087)	1.709***(0.063)	1.639***(0.060)	1.829***(0.058)	2.343***(0.076)
ε_{t-3}	1.221***(0.111)	1.893***(0.082)	1.808***(0.082)	2.000***(0.080)	2.887***(0.111)
ε_{t-4}	1.199***(0.117)	1.968***(0.101)	1.960***(0.100)	2.084***(0.103)	3.254***(0.145)
ε_{t-5}	1.175***(0.126)	1.896***(0.115)	2.005***(0.113)	2.076***(0.115)	3.360***(0.174)
ε_{t-6}	1.237***(0.131)	1.773***(0.122)	1.900***(0.115)	2.006***(0.123)	3.177***(0.190)
ε_{t-7}	1.116***(0.133)	1.492***(0.124)	1.657***(0.110)	1.843***(0.125)	2.792***(0.195)
ε_{t-8}	1.024***(0.141)	1.197***(0.124)	1.341***(0.103)	1.565***(0.121)	2.285***(0.183)
ε_{t-9}	0.906***(0.134)	0.935***(0.114)	0.967***(0.096)	1.245***(0.115)	1.682***(0.158)
ε_{t-10}	0.773***(0.128)	0.590***(0.096)	0.723***(0.082)	0.936***(0.101)	1.075***(0.121)
ε_{t-11}	0.580***(0.103)	0.326***(0.073)	0.509***(0.057)	0.656***(0.073)	0.628***(0.082)
ε_{t-12}	0.257***(0.065)	0.154***(0.043)	0.217***(0.036)	0.318***(0.040)	0.274***(0.041)
R^2	0.968	0.978	0.981	0.986	0.993
SER	0.025	0.025	0.018	0.028	0.031
F	600.726	1,920.537	2,316.585	3,134.494	1,197.847
$D-W$	1.877	1.955	1.927	1.894	1.911
N	272	582	582	582	582

Note. ε_t = error term. See, Table 1.

Source: See Table 1.

Table 4. The Autoregressive-Moving Average Process [ARMA(p,q)], Eq. (17)

	s_t (EMU)	$s_t(UK)$	s_t (Canada)	s_t (Australia)	s_t (Japan)
c	0.170***(0.062)	0.516***(0.054)	0.175**(0.082)	-0.118 (0.130)	5.040***(0.265)
s_{t-1}	0.045***(0.022)	1.923***(0.102)		0.993***(0.004)	0.997***(0.003)
s_{t-2}		-0.925***(0.100)	0.985***(0.010)		
ε_{t-1}	1.154***(0.057)	-0.565*** (0.106)	1.166***(0.202)	0.321***(0.031)	0.308***(0.034)
ε_{t-2}	0.199***(0.061)	-0.322***(0.067)	0.166***(0.043)		

R^2	0.971	0.982	0.985	0.990	0.996
SER	0.024	0.022	0.016	0.024	0.025
F	2,212.463	6,131.129	9,787.663	18,292.65	45,670.03
$D-W$	1.959	2.007	1.982	1.978	1.957
N	272	582	582	582	582

Note. See, Tables 1 and 3.

Source: See, Table 1.

6. Conclusion

The intension of this first, from a series of papers, is to forecast the exchange rate by using a technical forecasting. The other methods (fundamental forecasting, market-based forecasting, and forecasting with currency betas) will follow later with the attempt to compare their results. The current technical analysis (chartist) focuses on past exchange rate data to determine trends and cycles that are expected to continue into the future. The short-term movements of exchange rates give the up and down of the long-term trends and cycles. This statistical (time-series) analysis and their graphs are helpful for developing investors' decisions and corporate policies (Note 16).

With the Polynomial Time Trend Forecasting, we see a cycle and a periodicity of the exchange rates. The $/€ exchange rate has a cycle of about 20 years and now, the dollar has started to depreciate again, Figures 1b and 1c. The reason must be the U.S. trade and monetary policy (TA < 0) and M^s > $20 trillion). The $/£ exchange rate follows a cycle, but its fluctuation is less deep. Its periodicity is different, and it is from 1985 to 2020, which is 35 years. The British pound was depreciated all these years and currently the dollar has shown a little decline in its value with respect the pound, Figures 2b and 2c. The C$/$ exchange rate gives a different cycle from 1990 to 2010; the troughs of Canadian dollar show its appreciation, but it is depreciated after 2010. Since 2020, the U.S. dollar shows some declines, Figure 3b and 3c. Now, the $/A$ exchange rate follows an approximate cycle from 1995 to 2020. In general, the A$ is depreciated except in the period 2010-2015 that was appreciated with respect the U.S. dollar. After 2015, the Australian dollar is depreciated again, Figures 4b and 4c. Lastly, the Japanese yen is doing very well since 1980. We do not have a complete cycle yet for the ¥/$ exchange rate; after 2015, the yen shows a tendency of depreciation with respect the U.S. dollar, Figures 5b and 5c.

In summary, the empirical results and their graphs show that the dollar is expected to appreciate with respect the British pound, the Canadian dollar, and the Australian dollar. The euro is doing better than the dollar by following the Deutsche Mark and the German economy, but it is hurting all the other Euro-zone economies. The Japanese yen is doing well (it is appreciated towards the dollar) so far, but lately, the U.S. dollar is starting to appreciate a little. With respect the RMSE, the Autoregressive process is the best forecasting Time-Series method because it minimizes this error. Hopefully, the future research will reveal other factors (country-specific ones, fundamentals) that affect the exchange rate and may give a comparable or a better forecasting than this chartist one. The current graphical presentations can only be interpreted as major policy changes between the two countries.

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I would like to acknowledge the assistance provided by Julia V. Betti and Janice Mecadon. Financial support (professional travel expenses, submission fees, etc.) are provided by Provost's Office (Faculty Travel Funds, Henry George Fund, and Faculty Development Funds). The usual disclaimer applies. Then, all remaining errors are mine.

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Notes

Note 1. See, Enders (1995), Chatfield (1985), and Kallianiotis (2019c).

Note 2. *Mean reversion* is a mathematical concept sometimes used for stock investing, but it can be applied to other assets (why not to exchange rates). In general terms, the essence of the concept is the assumption that both a stock's high and low prices are temporary and that a stock's price will tend to move to the average price over time. Mean reversion involves first identifying the trading range for a stock, and then computing the average price using analytical techniques, as it relates to assets, earnings, etc. When the current market price is less than the average price, the stock is considered attractive for purchase, with the expectation that the price will rise. When the current market price is above the average price, the market price is expected to fall. In other words, deviations from the average price are expected to revert to the average.

Note 3. A Least Squares estimation of eq. (3) for S_t (\$/€) is as follows:

$$\underset{(0.020)}{S_t = 1.093^{***}} + \underset{(0.001)}{0.001^{***}}\, t$$

$R^2 = 0.150,\quad SER = 0.157,\quad F = 41.582,\quad D-W = 0.039,\quad N = 238$

Note 4. Kallianiotis (2013, and 2019c) discusses five models of stochastic trends.

Note 5. The Least Squares estimation of eq. (7) the random walk for ln S_t (\$/€) is:

$$s_t = \underset{(0.003)}{0.002} + \underset{(0.011)}{0.985}\, s_{t-1}$$

$R^2 = 0.971,\quad SER = 0.025,\quad F - 7{,}792.332,\quad D-W = 1.571,\quad N = 237$

Note 6. For this process, See, Kallianiotis (2013).

Note 7. The results of $AR(1)$ for the $\ln S_t$ (\$/€) are:

$$s_t = \underset{(0.092)}{0.164^{*}} + \underset{(0.010)}{0.982^{***}}\, AR(1)$$ \

$R^2 = 0.971,\quad SER = 0.970,\quad F = 3{,}895.024,\quad D-W = 1.571,\quad N = 238,\quad RMSE = 0.02497$

Note 8. The random walk with drift is a first-order autoregressive process that is not stationary.

Note 9. The EViews gives $LEUSF$ for the $E_t S_{t+1}$ and a graph of the fitted value of the $E_t S_{t+1}$.

Note 10. The $MA(1)$ of the LEUS gives the following results:

$$s_t = 0.177^{***} + 0.881^{***}\varepsilon_{t-1}$$
$$(0.011) \quad (0.032)$$

$$R^2 = 0.686, \quad SER = 0.082, \quad F = 259.997, \quad D-W = 0.401, \quad N = 241$$

Note 11. The results of an $ARMA(1,1)$ for the $LEUS$ are as follows:

$$s_t = 0.168^{**} + 0.977^{***} s_{t-1} + 0.186^{***}\varepsilon_{t-1}$$
$$(0.082) \quad (0.012) \quad (0.057)$$

$$R^2 = 0.972, \quad SER = 0.024, \quad F = 2{,}744.589, \quad D-W = 1.952, \quad RMSE = 0.024270, \quad N = 241$$

Note 12. Kallianiotis (2013) gives also another process, the Autoregressive Integrated Moving Average $ARIMA(p,d,q)$ model.

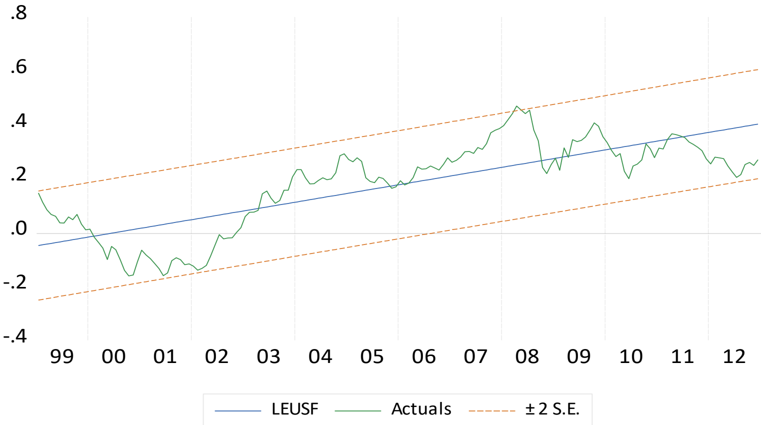
Note 13. The public media are completely controlled, thus most of the News are very subjective lies (pure propaganda), which have wrong effects on individuals' decisions, perceptions, and confidence; also on policies and science, as it is happening today, with the suspicious COVID-19 and its interpositions. (*Sic*). For example, see, "We are grateful to the Washington Post, the New York Times, Time Magazine and other great publications whose directors have attended our meetings and respected their promises of discretion for almost forty years. It would have been impossible for us to develop our plan for the world if we had been subjected to the lights of publicity during those years. But, the world is more sophisticated and prepared to march towards a world government. The supranational sovereignty of an intellectual elite and world bankers is surely preferable to the national auto-determination practiced in past centuries." David Rockefeller, Speaking at the June, 1991 Bilderberger meeting in Baden, Germany (a meeting also attended by then-Governor Bill Clinton and by Dan Quayle). https://rense.com//general17/quote.htm. The 2020 was a "very successful" year for them, the "forerunners". (*Sic*).

Note 14. Even Socrates said, «ἓν οἶδα, ὅτι οὐδέν οἶδα». ("I know one thing, that I know nothing"). Σωκράτης (Socrates; 470–399 B.C.). Today, we have the illusion or the arrogance of our uncontrolled pride that we know everything; this is actually the ignorance of the 21st century or of the current millennium.

Note 15. See, Kallianiotis (2013) for Unit Root (Stationarity) Test and for Cointegration Test, too.

Note 16. Unfortunately, individuals' and corporations' (mostly, small businesses') decisions, today, depend on many other factors controlled by the "economic elites". (*Sic*). This recently inventive COVID-19 crisis will change the socio-economic structure and culture of the nations and will affect negatively human's freedoms, values, and wellbeing.

APPENDIX

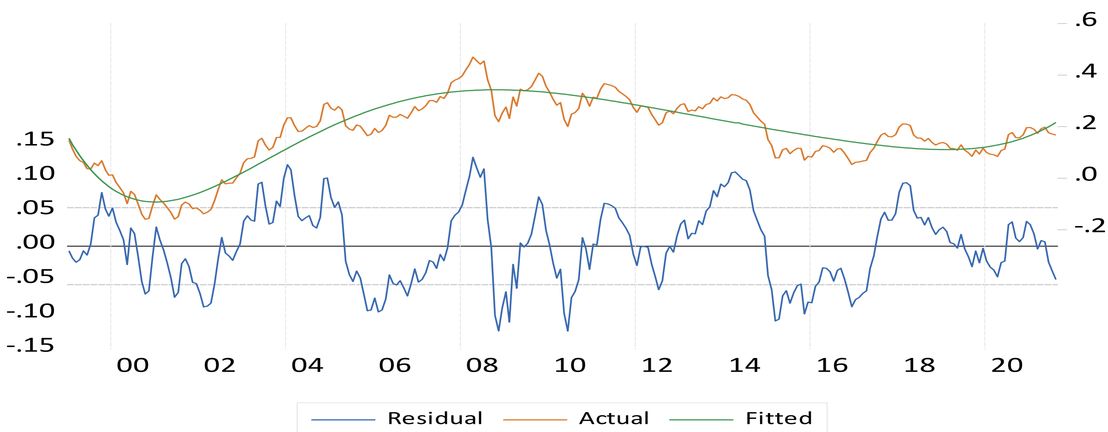


Forecast: LEUSF	
Actual: LEUS	
Forecast sample: 1999M01 2021M12	
Adjusted sample: 1999M01 2012M12	
Included observations: 168	
Root Mean Squared Error	0.099438
Mean Absolute Error	0.082589
Mean Abs. Percent Error	104.1479
Theil Inequality Coef.	0.214842
Bias Proportion	0.000000
Variance Proportion	0.113524
Covariance Proportion	0.886476
Theil U2 Coefficient	3.399489
Symmetric MAPE	74.74944

Note. LEUSF = ln of dollar/euro spot exchange rate, Actual = LEUS = ln of European Spot Rate ($/€) and Fitted = Time Trend. $/€↑ =>$↓ and €↑

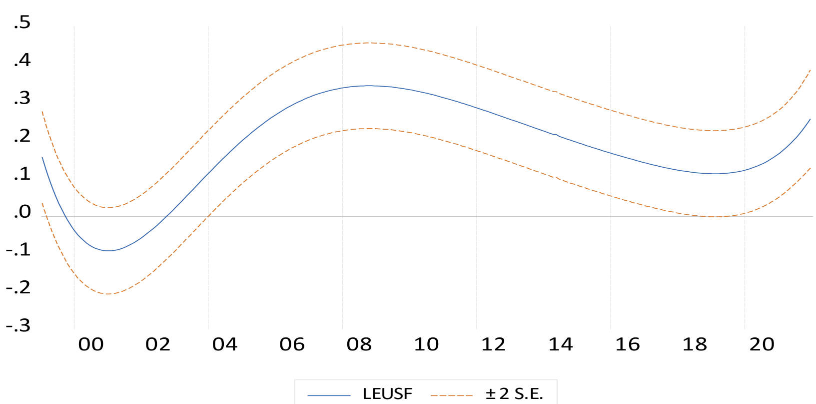
Source: *Economagic.com*

Figure 1a. Log Linear Time Trend Forecasting: Dollar/euro ($/€) Exchange Rate



Note. $/€↑ =>$↓ and €↑

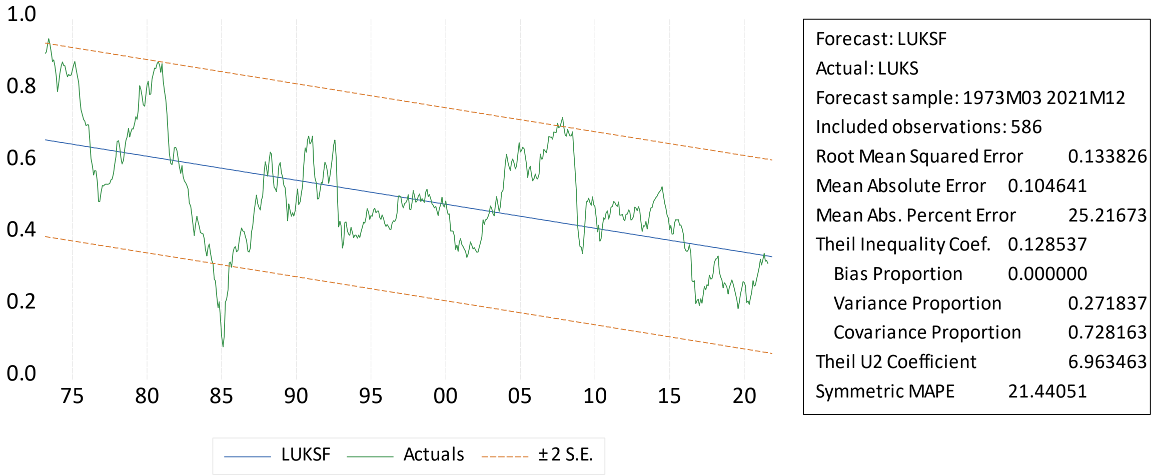
Figure 1b. Polynomial Time Trend ($/€) where t^6



Forecast: LEUSF	
Actual: LEUS	
Forecast sample: 1999M01 2021M12	
Included observations: 276	
Root Mean Squared Error	0.055267
Mean Absolute Error	0.045988
Mean Abs. Percent Error	36.66772
Theil Inequality Coef.	0.127130
Bias Proportion	0.000000
Variance Proportion	0.044071
Covariance Proportion	0.955929
Theil U2 Coefficient	0.645837
Symmetric MAPE	33.48530

Note. $/€↑ =>$↓ and €↑

Figure 1c. Polynomial Time Trend Forecasting ($/€) where t^6

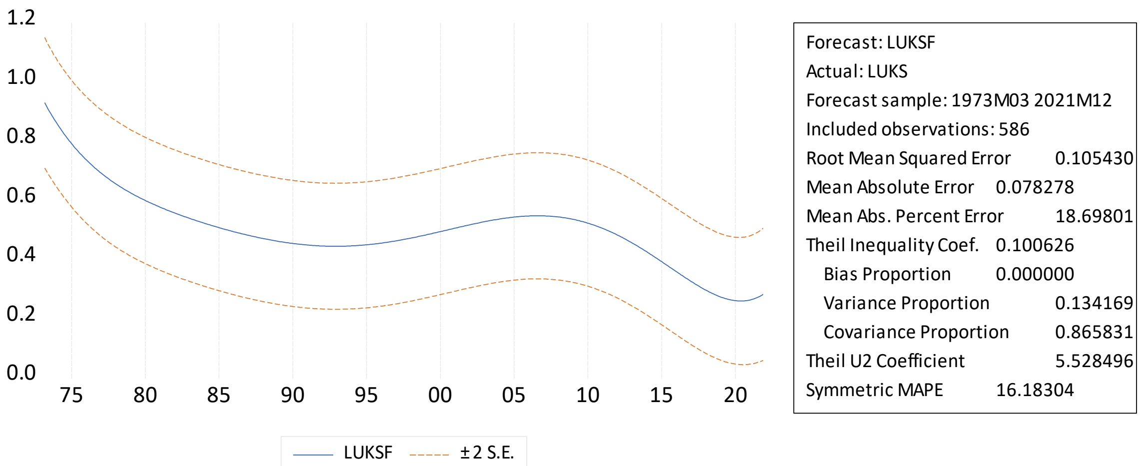


Note. \$/£↓ => \$↑ and £↓

Figure 2a. Log Linear Time Trend Forecasting: \$/£ Exchange Rate

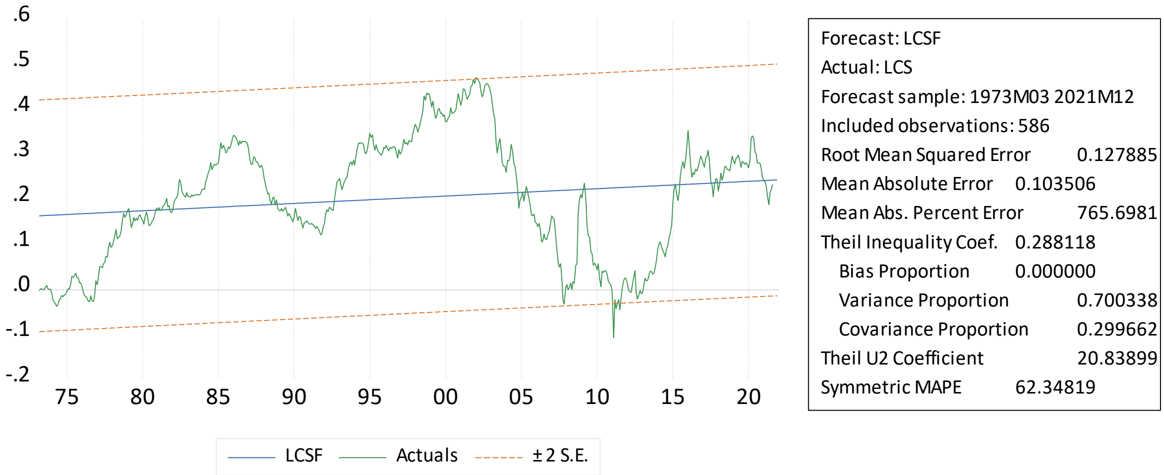
Note. \$/£↓ => \$↑ and £↓ and currently \$↓

Figure 2b. Polynomial Time Trend (\$/£) where t^6



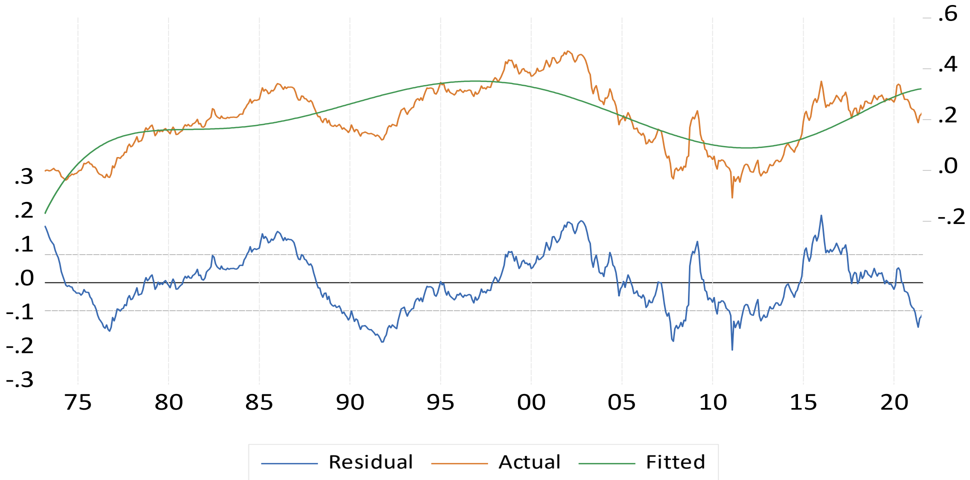
Note. \$/£↓ => \$↑ and £↓ and currently \$↓

Figure 2c. Polynomial Time Trend Forecasting (\$/£) where t^6



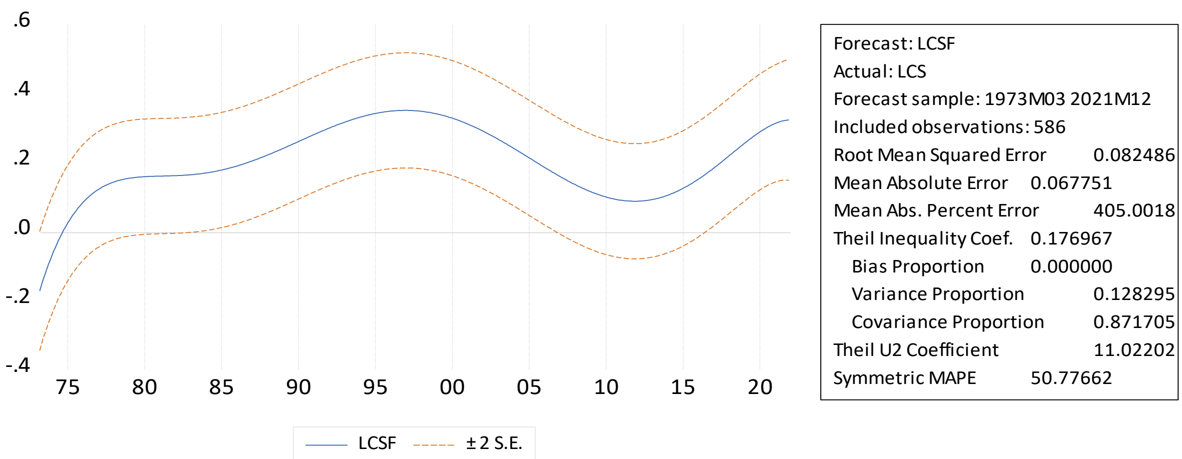
Note. C$/$↑ => C$↓ and $↑

Figure 3a. Log Linear Time Trend Forecasting: C$/$ Exchange Rate



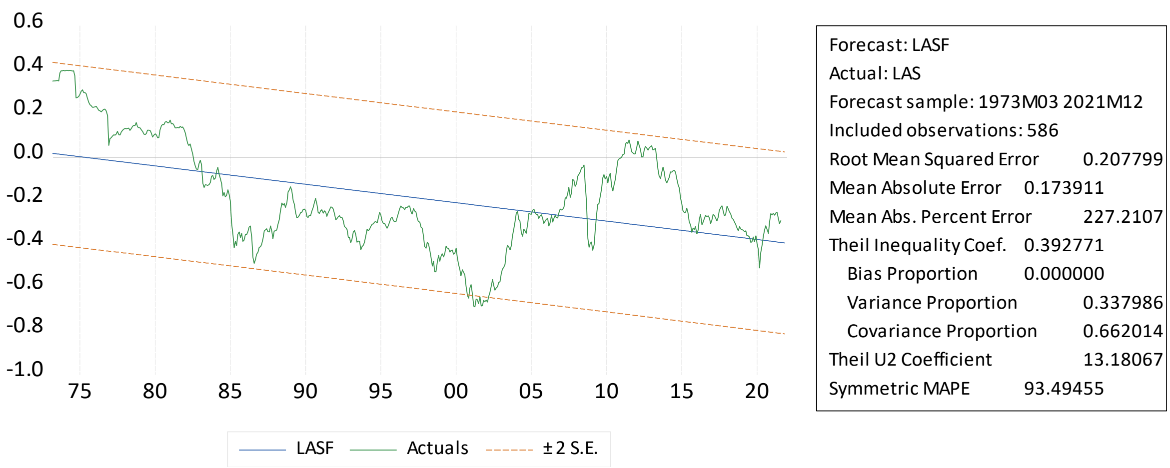
Note. C$/$↑ => C$↓ and $↑

Figure 3b. Polynomial Time Trend (C$/$) where t^6



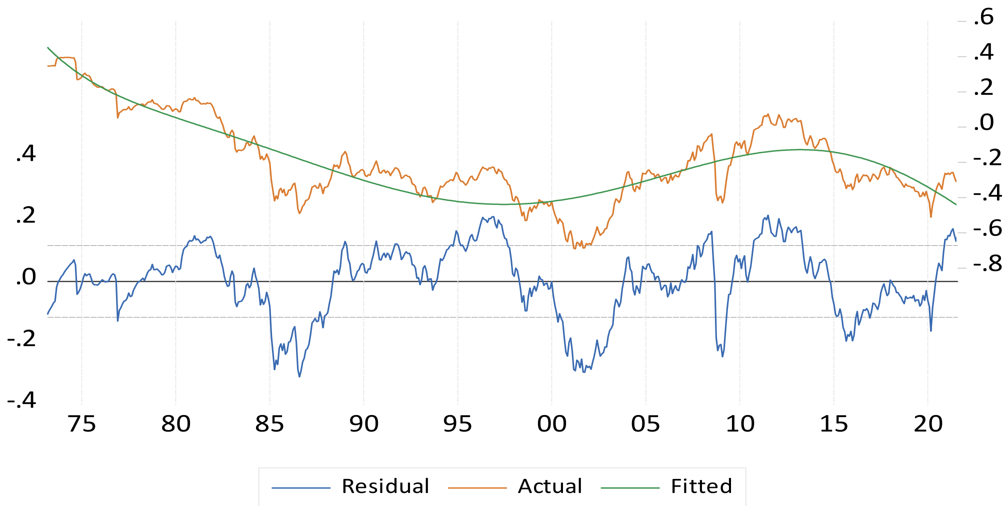
Note. C$/$↑ => C$↓ and $↑

Figure 3c. Polynomial Time Trend Forecasting (C$/$) where t^6



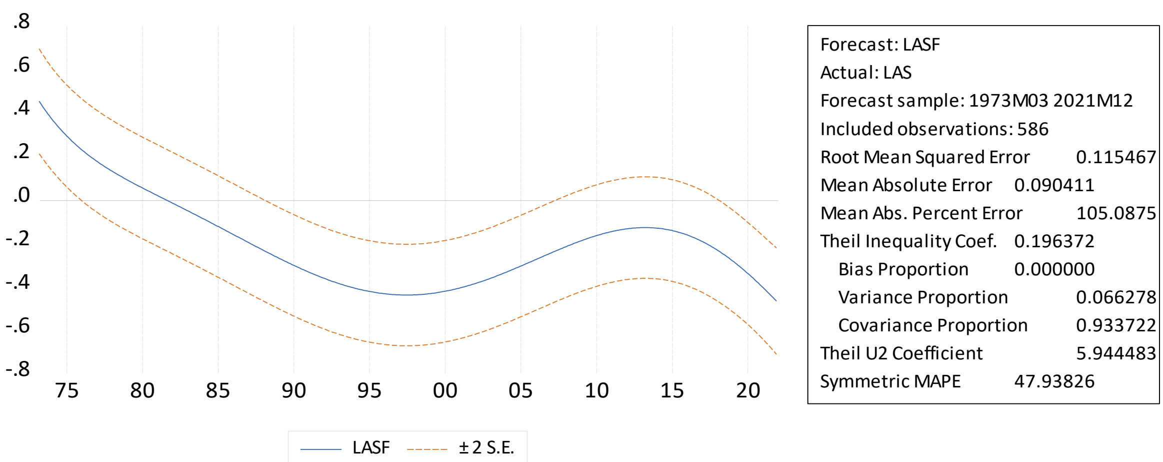
Note. \$/A\$↓ => \$↑ and A\$↓

Figure 4a. Log Linear Time Trend Forecasting: \$/A\$ Exchange Rate



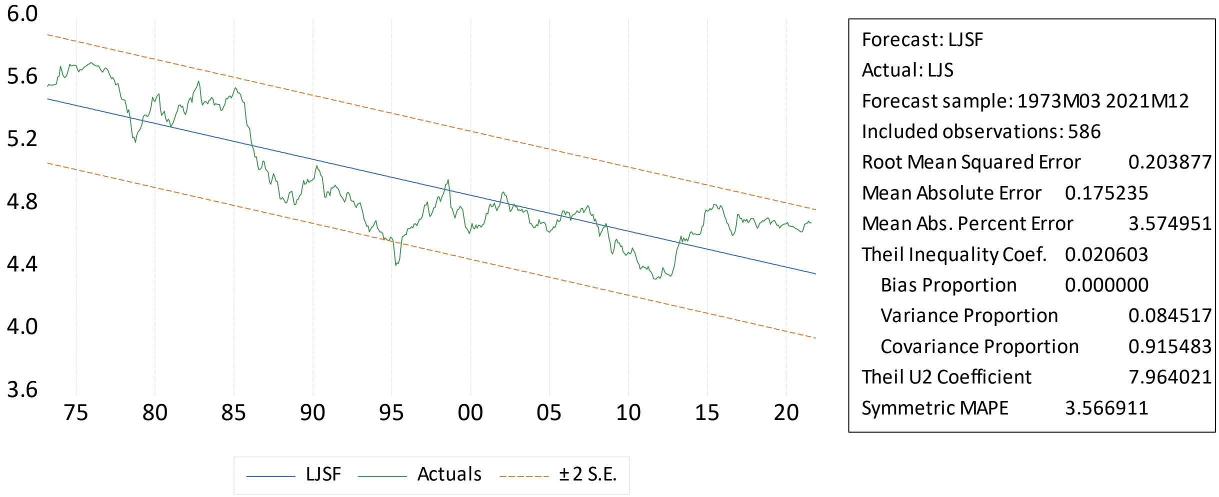
Note. \$/A\$↓ => \$↑ and A\$↓

Figure 4b. Polynomial Time Trend (\$/A\$) where t^6



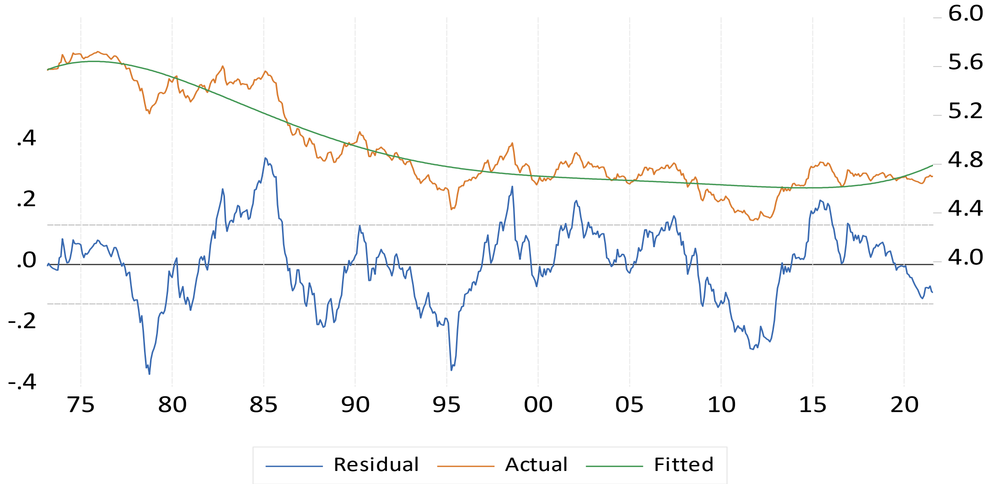
Note. \$/A\$↓ => \$↑ and A\$↓

Figure 4c. Polynomial Time Trend Forecasting (\$/A\$) where t^6



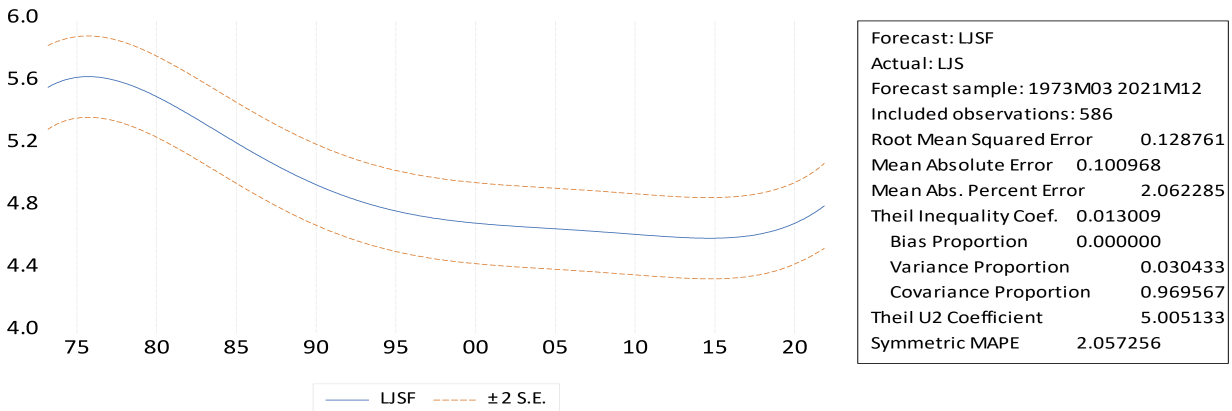
Note. ¥/$↓ => ¥↑ and $↓

Figure 5a. Log Linear Time Trend Forecasting: ¥/$ Exchange Rate



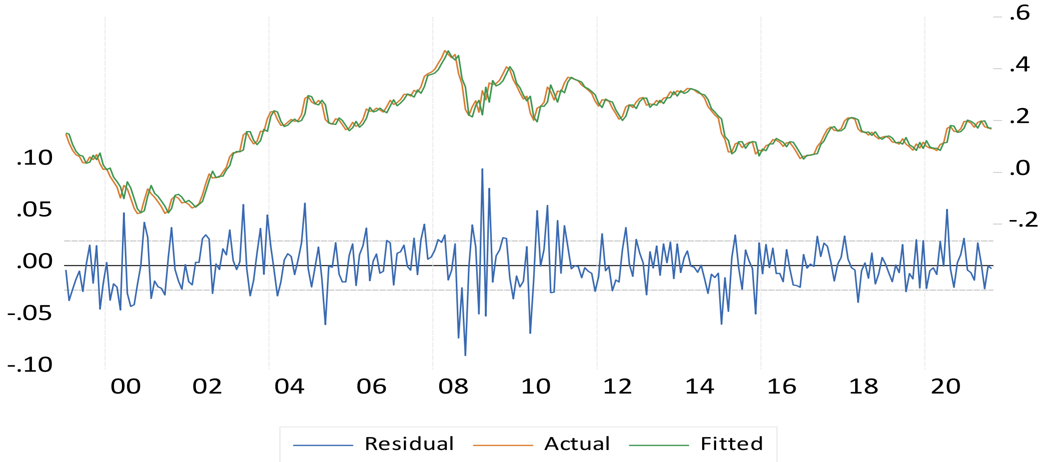
Note. ¥/$↓ => ¥↑ and $↓ and currently ¥↓ and $↑

Figure 5b. Polynomial Time Trend (¥/$) where t^6



Note. ¥/$↓ => ¥↑ and $↓ and currently ¥↓ and $↑

Figure 5c. Polynomial Time Trend Forecasting (¥/$) where t^6



Note. Actual = LEUS = ln of European spot exchange rate ($/€) and Fitted = LEUSF= forecasted ln of European spot exchange rate by using the AR(2) process..

Source: *Economagic.com*

Figure 1d. AR(2) Process: LEUS ($/€) Exchange Rate, Eq. (9)

Figure 1e. AR(2) Process: Forecasting LEUS ($/€) Exchange Rate, Eq. (9)

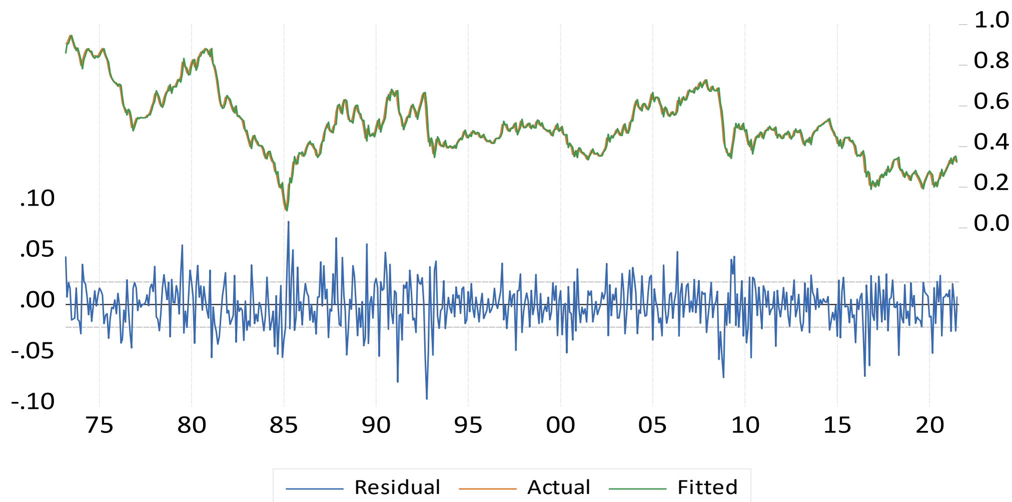
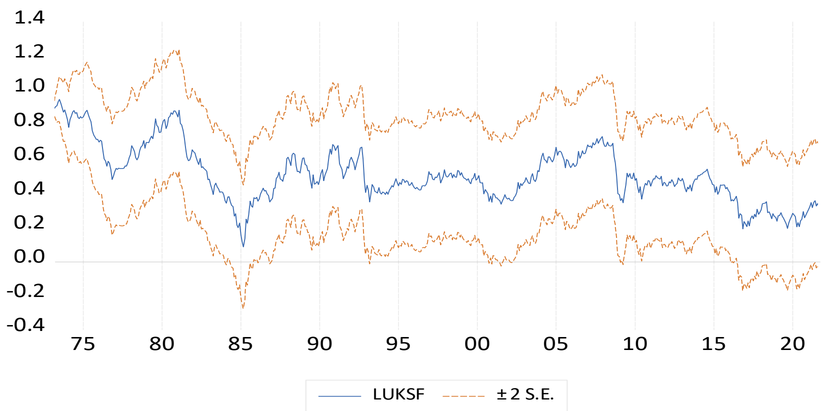


Figure 2d. AR(4) Process: LUKS ($/£) Exchange Rate, Eq. (9)



Forecast: LUKSF	
Actual: LUKS	
Forecast sample: 1973M03 2021M12	
Adjusted sample: 1973M03 2021M09	
Included observations: 583	
Root Mean Squared Error	0.022050
Mean Absolute Error	0.017191
Mean Abs. Percent Error	3.995369
Theil Inequality Coef.	0.020823
Bias Proportion	0.001398
Variance Proportion	0.000970
Covariance Proportion	0.997632
Theil U2 Coefficient	0.936654
Symmetric MAPE	3.973990

Figure 2e. AR(4) Process: Forecasting LUKS ($/ £) Exchange Rate, Eq. (9)

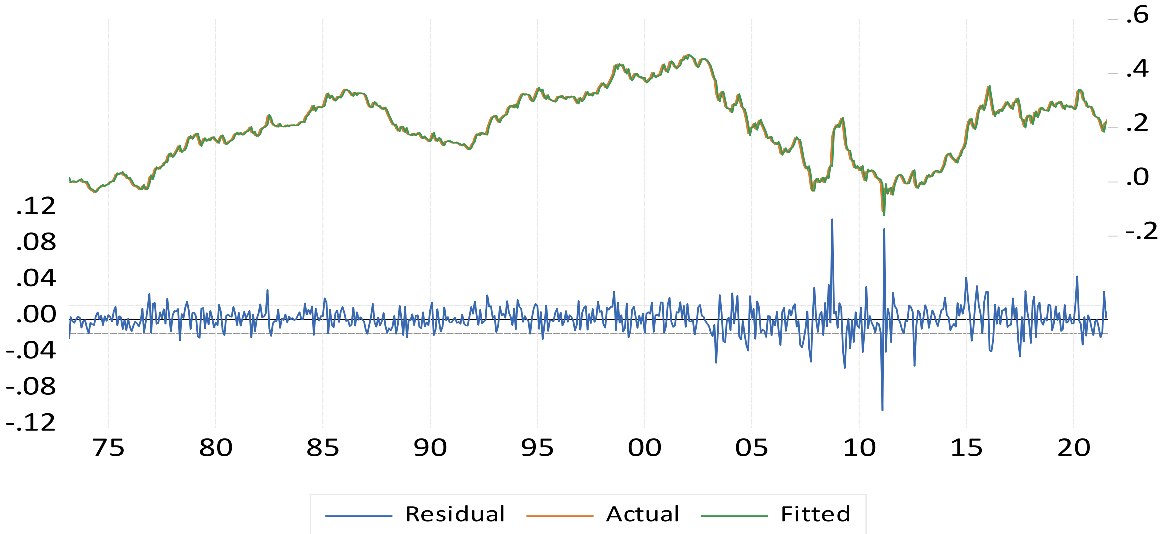
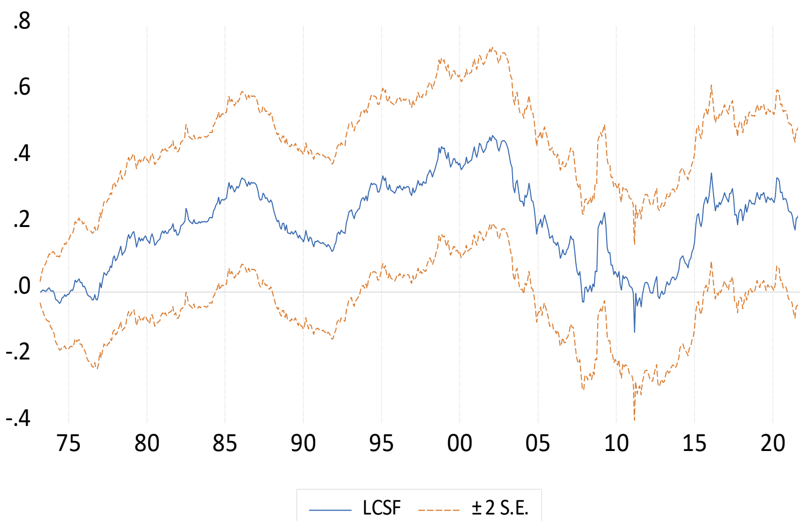


Figure 3d. AR(2) Process: LCS (C$/$) Exchange Rate, Eq. (9)



Forecast: LCSF	
Actual: LCS	
Forecast sample: 1973M03 2021M12	
Adjusted sample: 1973M03 2021M09	
Included observations: 583	
Root Mean Squared Error	0.015642
Mean Absolute Error	0.010974
Mean Abs. Percent Error	32.12207
Theil Inequality Coef.	0.032593
Bias Proportion	0.001092
Variance Proportion	0.001910
Covariance Proportion	0.996998
Theil U2 Coefficient	1.000224
Symmetric MAPE	18.93490

Figure 3e. AR(2) Process: Forecasting LCS (C$/$) Exchange Rate, Eq. (9)

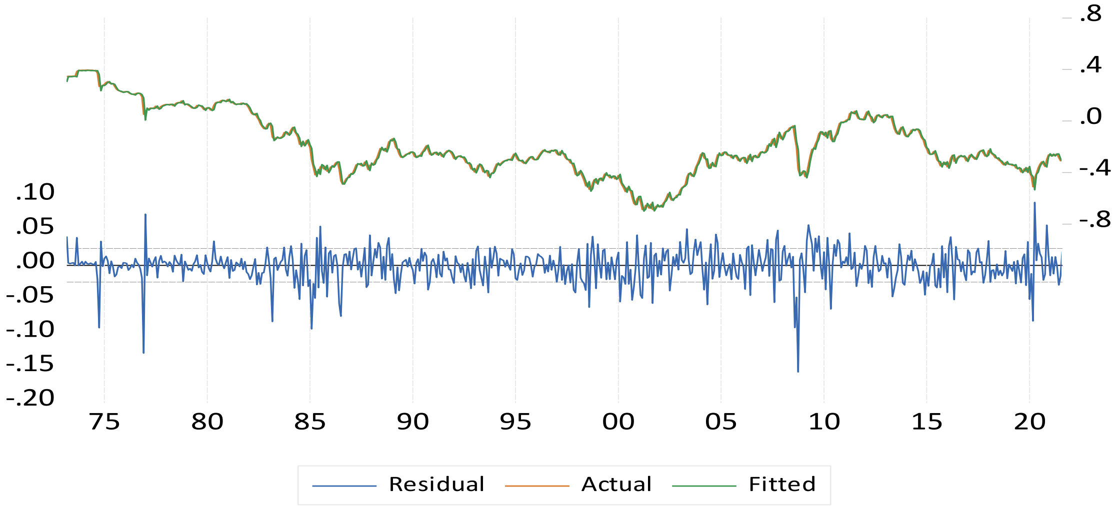


Figure 4d. AR(3) Process: LAS ($/A$) Exchange Rate, Eq. (9)

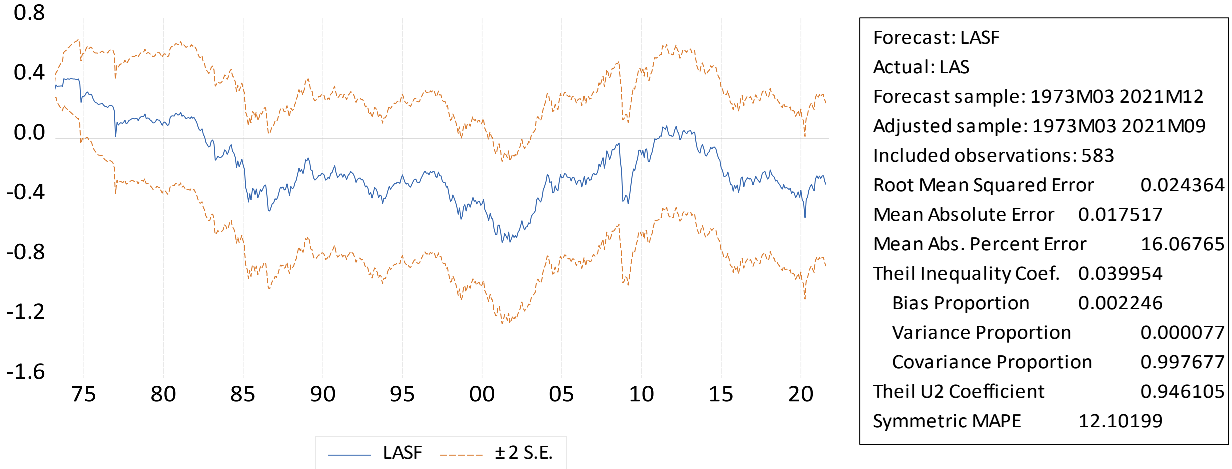


Figure 4e. AR(3) Process: Forecasting LAS ($/A$) Exchange Rate, Eq. (9)

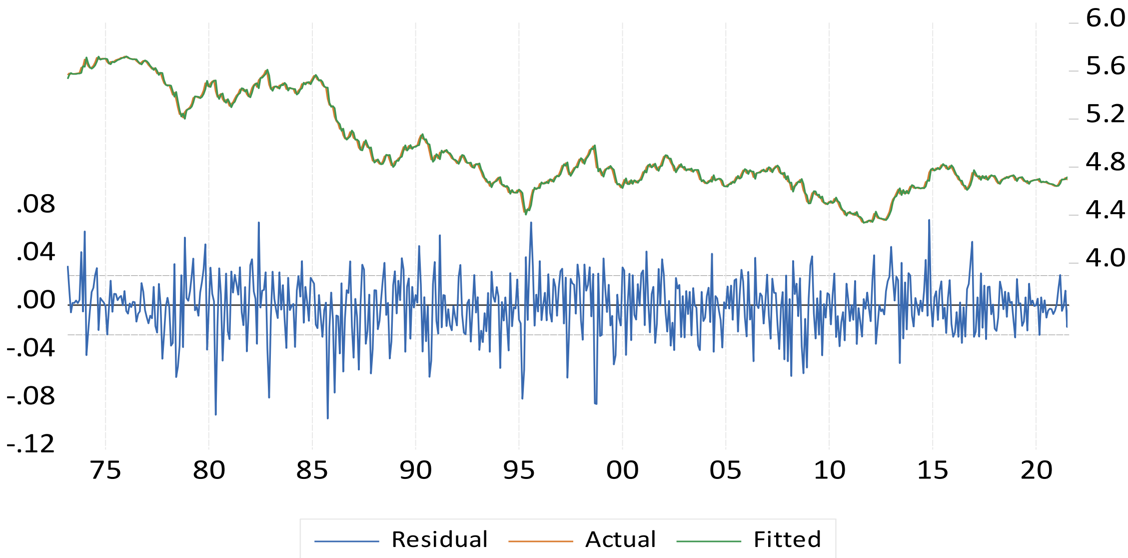


Figure 5d. AR(2) Process: LJS (¥/$) Exchange Rate, Eq. (9)

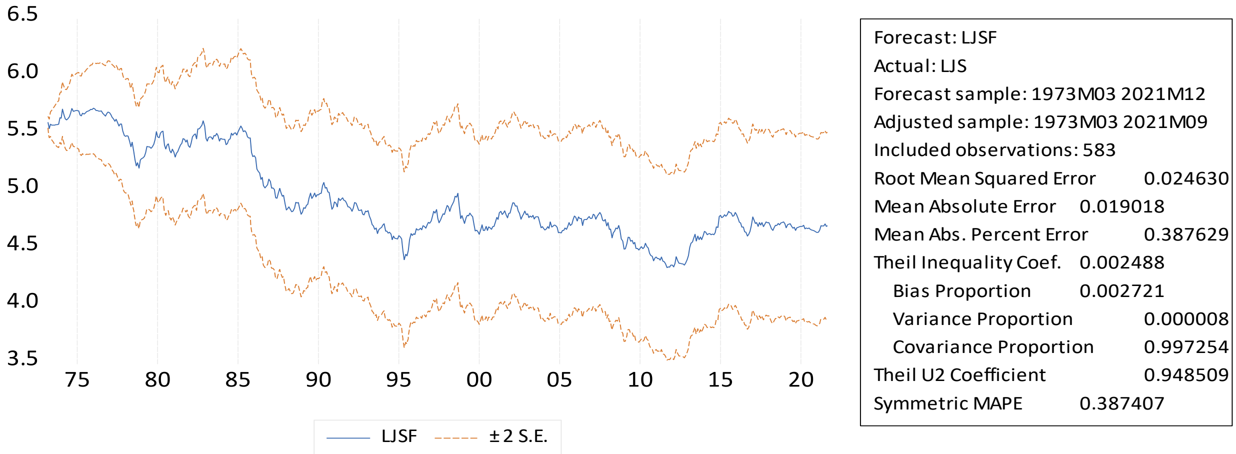
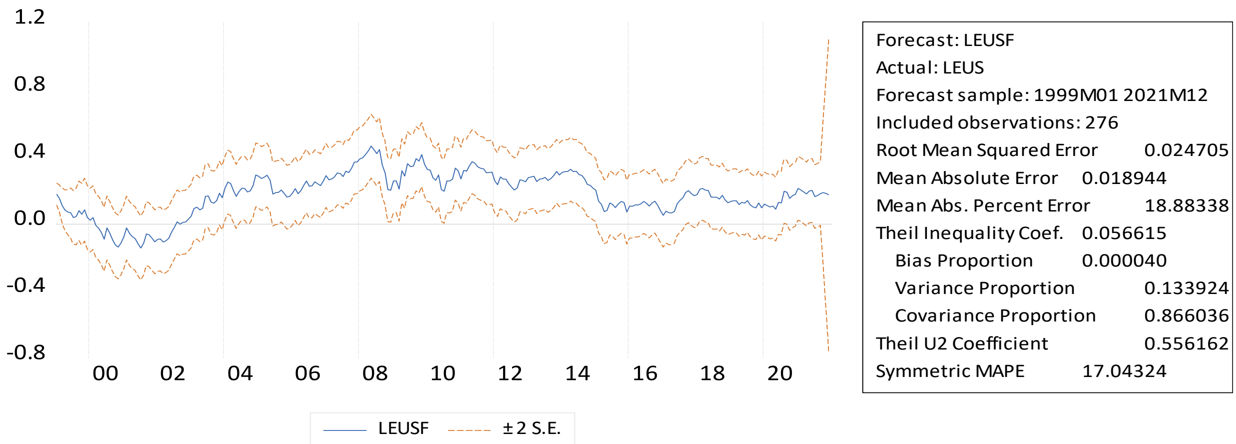


Figure 5e. AR(2) Process: Forecasting LJS (¥/$) Exchange Rate, Eq. (9)



Note. LEUSF= forecasted ln of European spot exchange rate by using the MA(12) process..

Source: *Economagic.com*

Figure 1f. MA(12) Process: Forecasting LEUS ($/€) Exchange Rate, Eq. (13)

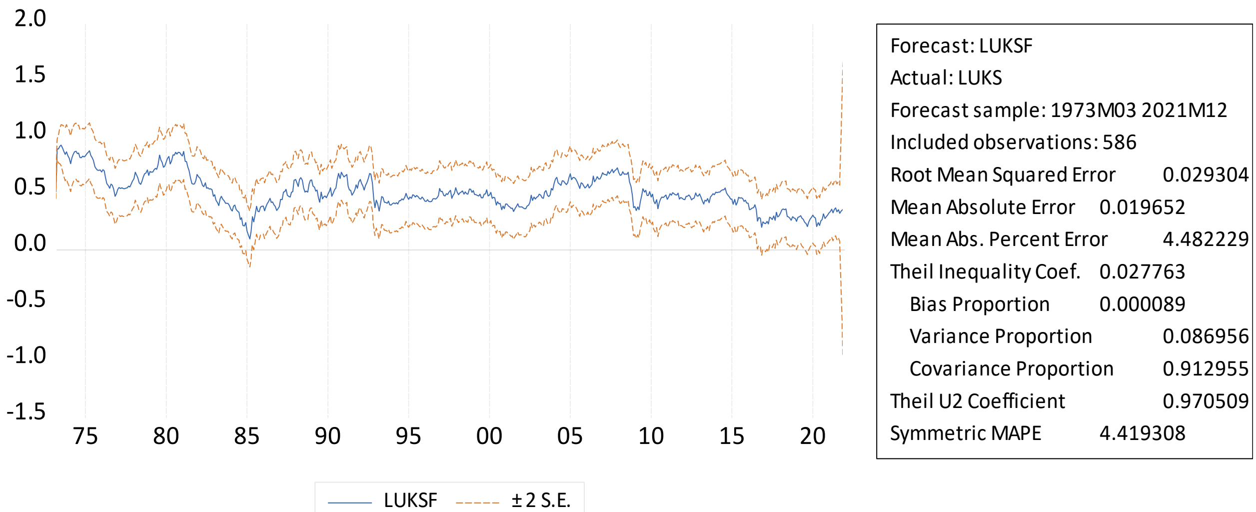
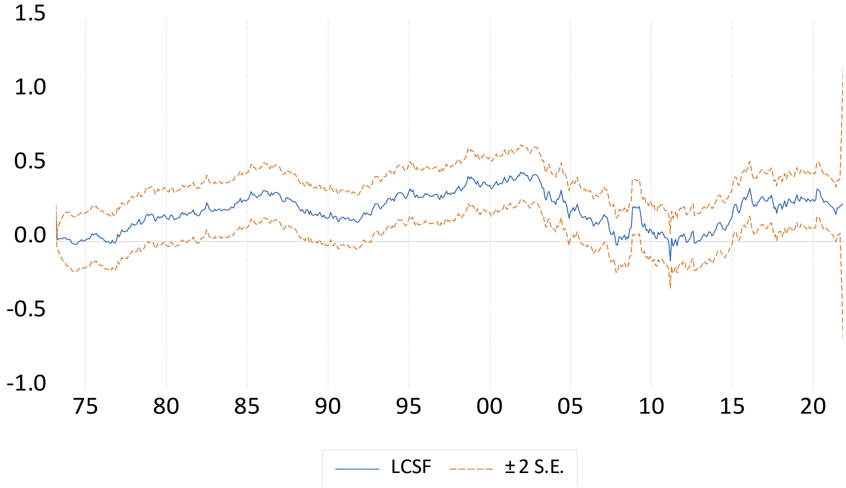
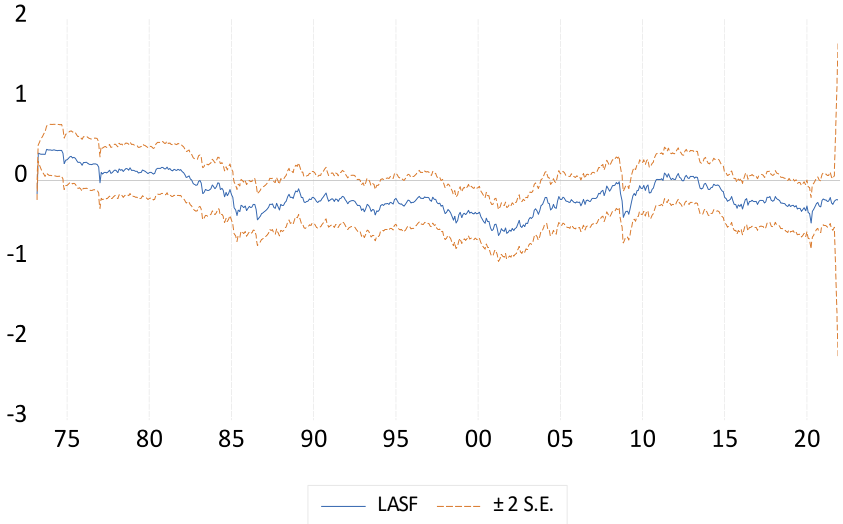


Figure 2f. MA(12) Process: Forecasting LUKS ($/£) Exchange Rate, Eq. (13)



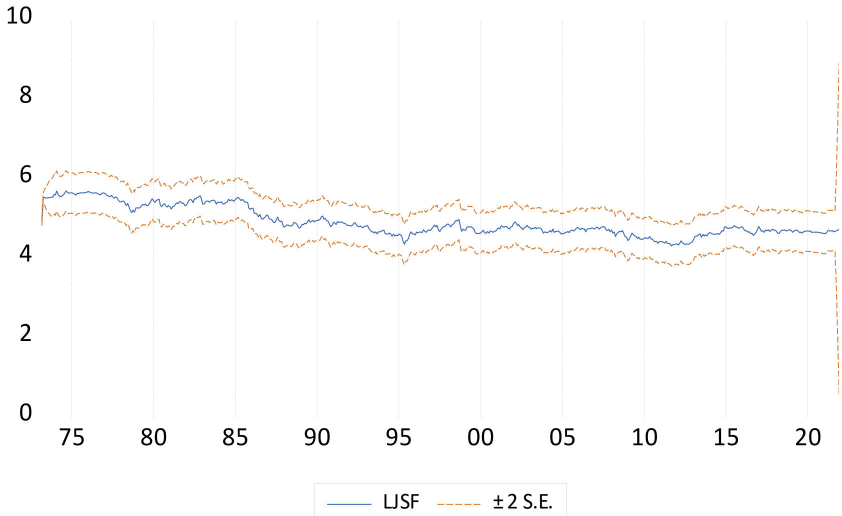
Forecast: LCSF	
Actual: LCS	
Forecast sample: 1973M03 2021M12	
Included observations: 586	
Root Mean Squared Error	0.019541
Mean Absolute Error	0.013122
Mean Abs. Percent Error	73.81132
Theil Inequality Coef.	0.040948
Bias Proportion	0.000046
Variance Proportion	0.120960
Covariance Proportion	0.878994
Theil U2 Coefficient	1.537520
Symmetric MAPE	21.70038

Figure 3f. MA(12) Process: Forecasting LCS (C$/$) Exchange Rate, Eq. (13)



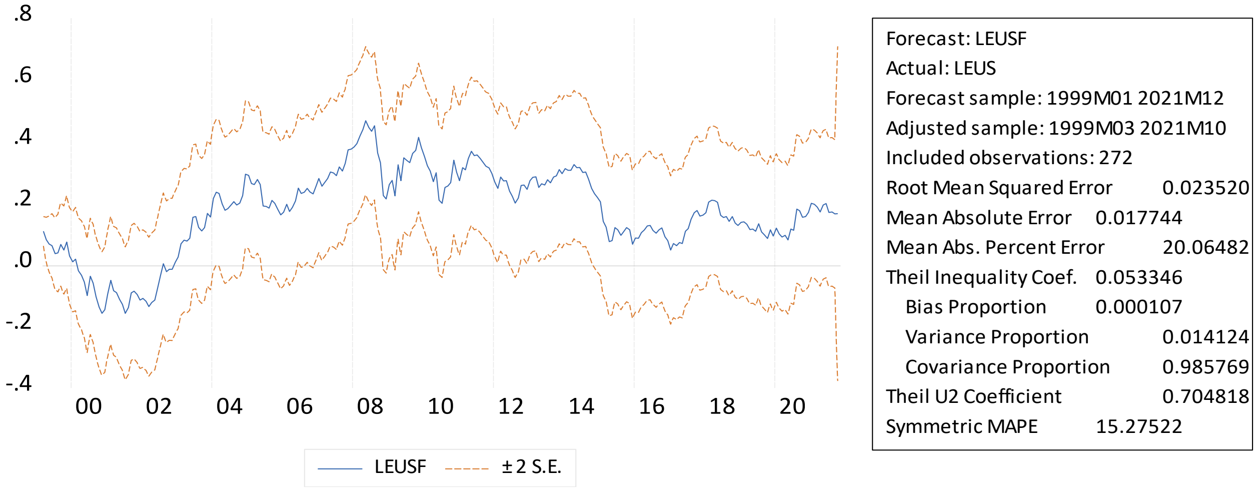
Forecast: LASF	
Actual: LAS	
Forecast sample: 1973M03 2021M12	
Included observations: 586	
Root Mean Squared Error	0.035479
Mean Absolute Error	0.022207
Mean Abs. Percent Error	17.24581
Theil Inequality Coef.	0.058954
Bias Proportion	0.000123
Variance Proportion	0.109604
Covariance Proportion	0.890273
Theil U2 Coefficient	1.511721
Symmetric MAPE	15.64730

Figure 4f. MA(12) Process: Forecasting LAS ($/A$) Exchange Rate, Eq. (13)



Forecast: LJSF	
Actual: LJS	
Forecast sample: 1973M03 2021M12	
Included observations: 586	
Root Mean Squared Error	0.040246
Mean Absolute Error	0.025636
Mean Abs. Percent Error	0.515158
Theil Inequality Coef.	0.004066
Bias Proportion	0.000300
Variance Proportion	0.118652
Covariance Proportion	0.881042
Theil U2 Coefficient	1.169440
Symmetric MAPE	0.516121

Figure 5f. MA(12) Process: Forecasting LJS (¥$) Exchange Rate, Eq. (13)



Note. LEUSF= forecasted ln of European spot exchange rate by using the ARMA(2,2) process..

Source: *Economagic.com*

Figure 1g. ARMA(2,2) Process: Forecasting LEUS ($/€) Exchange Rate, Eq. (17)

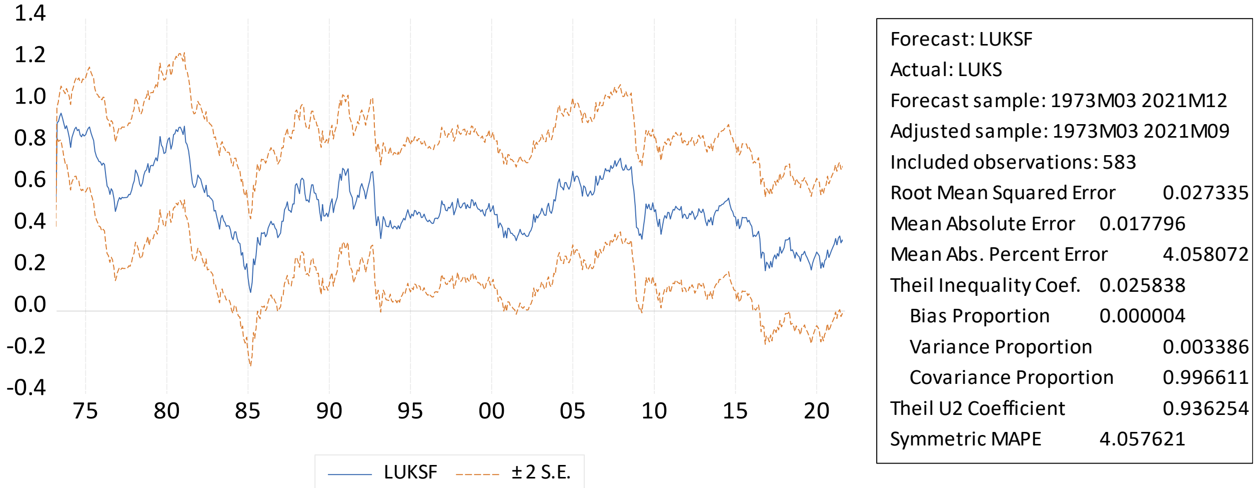


Figure 2g. ARMA(2,2) Process: Forecasting LUKS ($/£) Exchange Rate, Eq. (17)

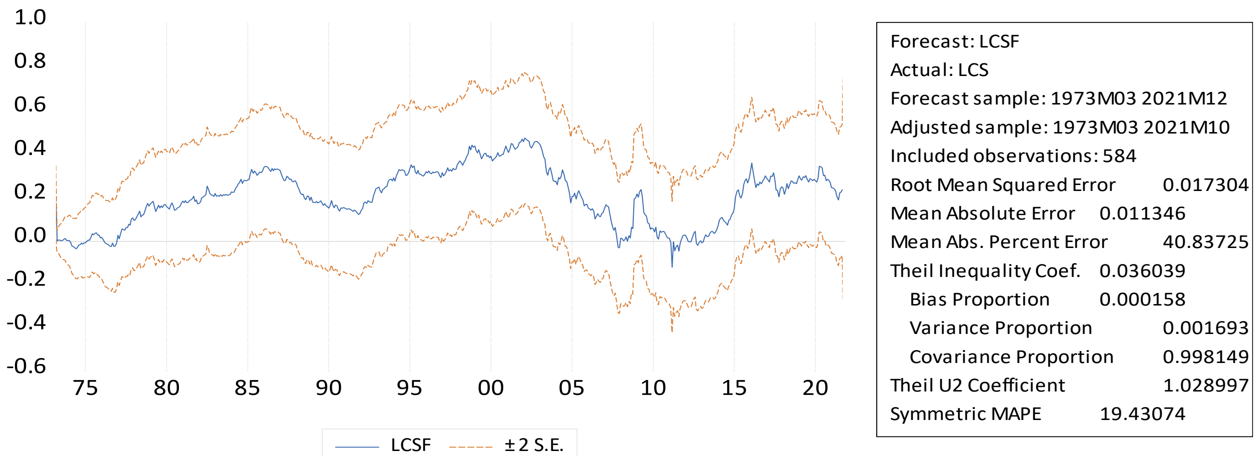


Figure 3g. ARMA(2,2) Process: Forecasting LCS (C$/$) Exchange Rate, Eq. (17)

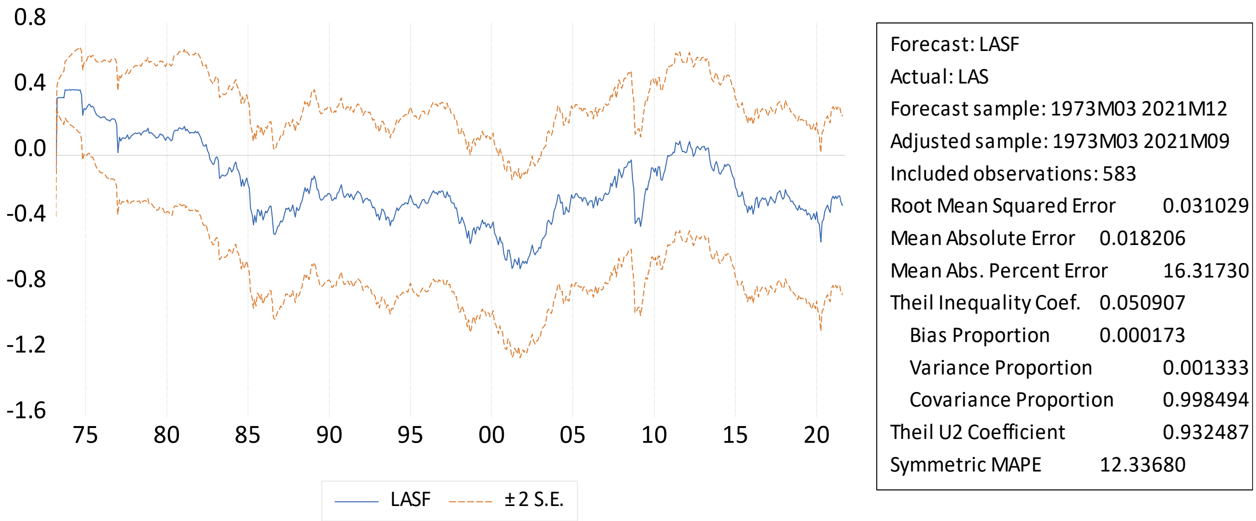


Figure 4g. ARMA(1,1) Process: Forecasting LAS ($/A$) Exchange Rate, Eq. (17)

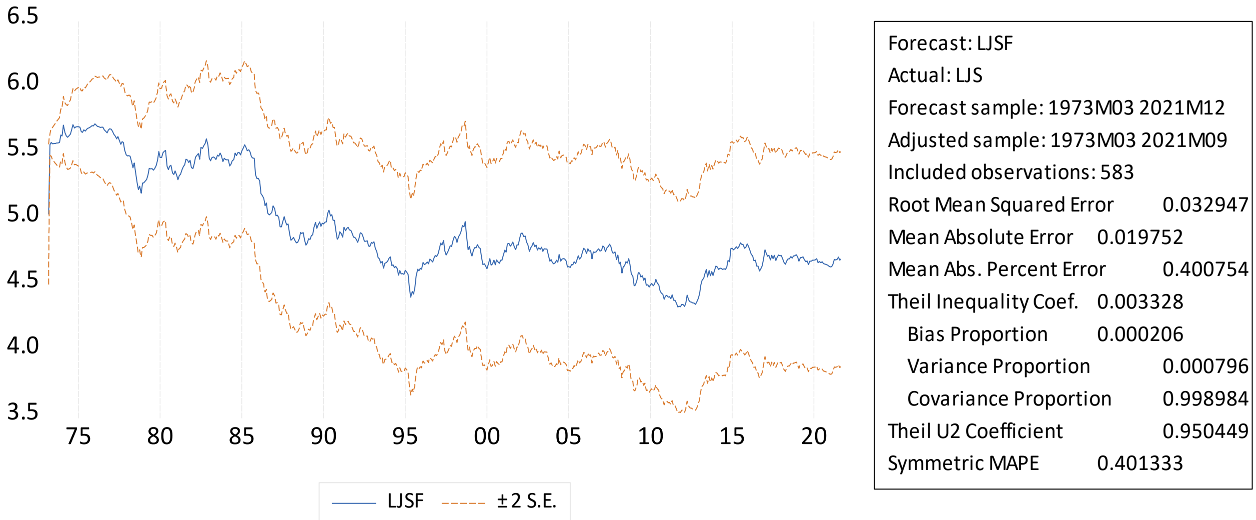


Figure 5g. ARMA(1,1) Process: Forecasting LJS (¥/$) Exchange Rate, Eq. (17)