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ARIMA Model in the Analysis of Behaviour of NEER and REER of Euro

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Abstract

In this paper author examined the behaviour of NEER and REER of euro in Euro Area during the period of 1994m01-2023m03 using the monthly data where Hamilton decomposition and ARIMA models were applied including the trends of nonlinearity. Moreover, the forecast ARIMA model was used to analyse the converging process during the course of volatility of the exchange rate. Whether the forecast ARIMA model is suitable for convergence towards equilibrium with or without pass through the Hamilton regression filter model have been verified.

Keywords: NEER • REER • ARIMA • Cycles • Cyclical • Trend • Forecast

JEL codes: C22; C32; D53; E32; E42; E44; E47; F31; G15; G20

Introduction

The behaviour of NEER and REER is a signal of the status of international trade in commodity market as well as in the capital and money market. Inflation and inflation expectation in home and foreign markets can be explained through them. Policy target on inflation and interest rate is easily accessible with them which can be treated as instrumental variable. The trade weighted indices of NEER and REER can infer the impact on those countries whose trade weighted indices have been included. Although, the recent analysis on Behavioural Equilibrium Exchange Rate (BEER) is an improvement over them where BEER entails an econometric analysis of the REER behaviour considering significant REER deviations from its PPP equilibrium level as a consequence of changes in economic fundamentals.

Since the NEER and REER follow random walk then their complete behaviour for future are not predictable correctly in most of the models, yet ARIMA (p,d,q) has advantages of both autoregressive and moving average characters to analyse and can be forecasted about the nature of equilibrating process with the clarification of volatility. Moreover, if the decomposition of Hamilton model can be adjusted with ARIMA (p, d, q) forecast model then reduced volatility and minimised cyclical trends would be able to predict much better than other previous models.

In this paper, author tried to test ARIMA (p, d, q) model to analyse the behaviour of NEER and REER of euro in Euro Area and also the same is applied adjusting through the Hamilton filter model taking monthly data from 1994m01 to 2023m03.

Some studies on NEER and REER of Euro

Bénassy-Quéré A, et al. [1] explored that depreciation of REER reacts demand positively and real interest rate negatively. The change in REER is proportional to openness of the economy. Volatility increased moving from floating to EMU. The consumer price inflation and the output gap (rather than the REER) increased in the volatility of the US REER which is obtained when moving to EMU in the case of symmetric demand shocks. It was observed that the US REER is more sensitive to macroeconomic symmetric shocks within EMU than with the floating regime.

Chinn M [2] examined the relation between exchange rate and productivity and found that each one percentage point increase in the productivity differential between the United States and the Eurozone economies results in a real dollar appreciation of between 2 and 5 percent during 1985-2001.

Janus T and Riera-Crichton D [3] examined the volatility of real effective exchange rate and economic growth in a panel of OECD countries during 1980-2011 and found that their relationship is negative, i.e., a one standard deviation volatility decrease is associated with a two-percentage points growth increase. On the other hand, the REER of euro volatility before great recession declined in the short run where the coefficient of lagged REER volatility was about 0.4 which implied that euro has stabilised its members' REER significantly and played a role of growth enhancing prior to 2008-2010. This study is a corollary to the survey of Eichengreen B [4] who found that REER stability is likely to be a facilitating condition for growth.

Ca'Zorzi M, et al. [5] examined the exchange rate using DSGE model and concluded that real exchange rates are mean reverting, there are various ways to beat the random walk in nominal exchange rate forecasting for horizons greater than one or two years. The model is unable to predict domestic and foreign inflation.

Michael F, et al. [6] showed that misalignments of HCI is significantly smaller in euro area since 1999 in comparison to other countries in even in recent recessionary phase. Within the euro area "stressed" countries recorded larger misalignments than "core" countries, yet only until 2009, after which a sharp downward correction was enacted in the former set of economies. This result could be due to cyclical factors, linked to the severe recession.

Ortega E and Osbat C [7] verified in the reduced form models that a 1% depreciation in the euro raises total import prices in the euro area and its member countries on average by around 0.3% within a year, and the headline HICP by around 0.04%.

Bhowmik D [8] examined the trends of NEER and REER of RMB during 2014m1 -2020m5 and found that NEER is inverse S shaped with significant upward and downward trends. Hamilton filter showed that cyclical trend is downward followed from upswing and the cycle consists of many peaks and troughs and the seasonal variation is v shaped. ARIMA (2, 0, 0) forecast for 2025 model passes through the regression filter which was found convergent, stationary and significant. It had no heteroscedasticity problem. Similarly, REER was found cubic showing upswing followed by downswing and then

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upswing significantly whose CUSUM of squares test is stable. Decomposition of REER of RMB under Hamilton filter showed cyclical trend having three phases with inverse S shaped with short duration recovery and long duration downswing. The cycle has many peaks and troughs and the seasonal variation is v shaped. ARIMA (2, 0, 1) forecast model for 2025 passes through Hamilton regression filter which showed convergent, stationary and significant reducing volatility. This forecast model had no heteroscedasticity problem.

Bhowmik D [9] examined the determinants of NEER and REER of RMB during 1990-2012 using cointegration and VECM and found that NEER has four significant cointegrating equations among the determinants of trade balance, foreign direct investment, liquidity, stock exchange index (Shanghai Composite Index), trade openness and terms of trade respectively. FDI has short run causalities with NEER and BOT but total liquidity and TOT have short run causalities with BOT and SCI respectively. Moreover, SCI, TO and TOT have long run causal relationships with NEER, BOT, FDI and liquidity respectively. The four cointegrating equations tend to equilibrium significantly with exception that equation one marginally deviates from equilibrium due to insignificant TOT. Similarly, REER has four cointegrating equations with those determinants. BOT has short run causal relations with FDI, liquidity, and TOT. FDI is relating to cause and effect with REER, BOT, and TOT. Even TO has short run causal relations with REER, BOT and SCI respectively. Two among four cointegrating equations move towards equilibrium significantly which imply that REER, BOT, FDI and liquidity have long run causal relation with SCI, TO and TOT respectively.

Objective of the paper

The paper endeavours to examine the behaviour of NEER and REER of euro in Euro Area from 1994m01 to 2023m03 which enabled to show the nonlinear trend, cyclical trends, cycles and seasonal fluctuations. Also the paper explores the AR and MA characters of the series and finally found out the prediction trend of ARIMA (p, d, q) for 2027m05 which was also tested in the decomposed model of Hamilton filter during the same period.

Data and Methodology

The non-linear trend was fitted by the semi-log regression model.

The estimated equation can be written as: $\log(x_i)=a+bt+ct^2+dt^3+et^4+ft^5+u_i$ where x_i=variable to be estimated, a, b, c, d, e and f are constants, t=time(year), u_i=random error, for all values of i=1,2,3,.....n.

Box GEP and Jenkins GM [10] methodology of ARIMA (p, d, q) can be estimated as below.

$x_t= a+ b_i x_{t-i}+ \varepsilon_t+ b_{oi}\varepsilon_{t-i}+ \grave{e}_t$ where x_t is the variable, a is constant, b_i are the coefficients of AR process and b_{oi} are the co-efficient of MA process and $\grave{e}_t$ is residual and i=1, 2,.....n, and t= time. If b_i and b_{oi} are less than zero and significant at 5% level then the model is convergent and significant. If the roots of AR and MA are less than one then the model is stable and stationary.

Ljung GM and Box GEP [11] Q-statistic is calculated as

$Q=T(T+2)\ \Sigma r^2_k/(T-k)$ where k=1 to s

Autocorrelation Function (ACF) can be derived from the formula

$ACF=\rho_s=a1\rho_{s-1}+a2\rho_{s-2}$ where s=1, 2, 3.....

And Partial Autocorrelation Function (PACF) can be derived from the formula

$\Phi ss=(\rho_s-\Sigma\phi_{s-1'j}\rho_{s-j})/(1-\Sigma\phi_{s-1'j}\rho_j)$ where s=3,4,5,....., $\phi_{sj}=\phi_{s-1,j}-\phi_{ss}\phi_{s-1's-j}$,j=1,2,3....s-1.

Hamilton JD [12] regression filter for decomposition was applied to get cycles, cyclical trend and seasonal variation utilising the STL method. In brief, the model can be stated as follows.

$y_{t+8}=\alpha_0+\alpha_1y_t+\alpha_2y_{t-1+}\alpha_3y_{t-2}+\alpha_4y_{t-3}+v_{t+8}$ where y=variable to be regressed.

Or, $v_{t+8}=y_{t+8}-(\alpha_0+\alpha_1y_t+\alpha_2y_{t-1}+\alpha_3y_{t-2}+\alpha_4y_{t-3})$

So, $y_t=\alpha_0+\alpha_1y_{t-8}+\alpha_2y_{t-9+}\alpha_3y_{t-10}+\alpha_4y_{t-11}+v_t$

Therefore, $v_t= y_t-(\alpha_0+\alpha_1y_{t-8}+\alpha_2y_{t-9}+\alpha_3y_{t-10}+\alpha_4y_{t-11})$ where α_i are estimated.

$v_{t+h}=y_{t+h}-y_t$ is the difference i.e., how the series changes over h periods. For h=8, the filter $1-L^h$ wipes out any cycle with frequencies exactly one year and thus taking out both long run trend as well as any strictly seasonal components.

It also applies random walk: $y_t=y_{t-1}-\varepsilon_t$ where d=1 and $\omega_t^h=\varepsilon_{t+h}+\varepsilon_{t+h-1}+.....+\varepsilon_{t+1}$

Regression filter reduces to a difference filter when applied to a random walk. Hamilton suggested h=8 for business cycles and h=20 for studies in financial cycles. Regression v_t converges in large samples to α_i=1 and all other α_j =0. Thus, the forecast error is $v_{t+h}=y_{t+h}-y_t$.

The residual equation v_t can be decomposed into trend, cycle and seasonally adjusted through SEATS/TRAMO or STL or census X-13 packages. The STL method is developed by Cleveland RB, et al. [13].

Also, the Hamilton regression filter residual is passed through ARIMA (p, d, q) model for forecasting at date using Box GEP and Jenkins GM [10] model.

The monthly data on NEER and REER of euro from 1994m01 to 2023m03 of Euro Area were collected from the Federal Reserve Bank of St. Louis. Both NEER and REER indices were taken as 2020=100. Real effective exchange rates are calculated as weighted averages of bilateral exchange rates adjusted by relative consumer prices. Nominal effective exchange rates are calculated as geometric weighted averages of bilateral exchange rates.

Observations and Results

In Figure 1, REER of Euro is higher than NEER of Euro till 2020 because the increase or development of REER may imply that imports become cheaper and the exports become more exclusive and expensive than imports. Hence, it can be stated that an increase can indicate a loss which is related to trade competitiveness. After 2020, NEER is marginally higher than REER. As the difference between NEER and REER of euro declines and it implies that increasing inflation of Euro with other countries gradually diminishes where in Euro Area exports were more expensive and imports were cheaper during increasing REER. This trend was improved gradually (Figure 1).

The non-linear estimated trend line of REER of Euro from 1994m1 to 2023m3 is given below where all the coefficients are significant at 5% level. So, the trend line of REER has four distinct phases.

$\text{Log(reer)}=4.8108-0.0065t+7.73e^{-05}t^2-3.27e^{-07}t^3+4.46e^{-10}t^4$

(352.18)* (-12.28)*(12.51)* (-12.41)*(11.99)*

R^2=0.46,F=75.99*,DW=0.075,*=significant at 5% level. n=351

In Figure 2, the nonlinear trend line of REER of Euro is depicted where its phases are shown clearly where it has started with decreasing phase (Figure 2).

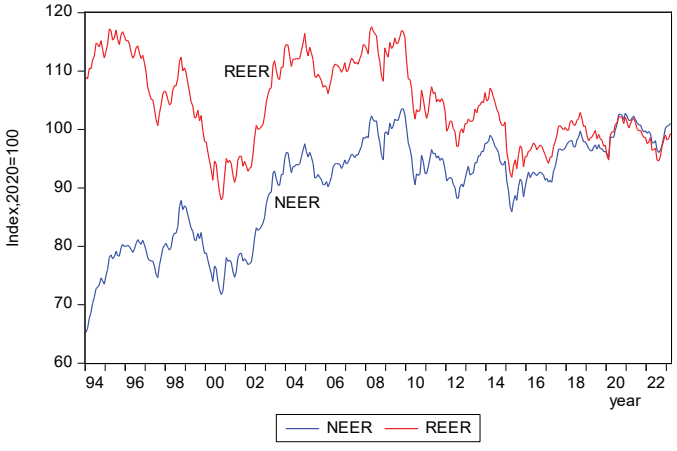

Figure 1. The NEER and REER of Euro.

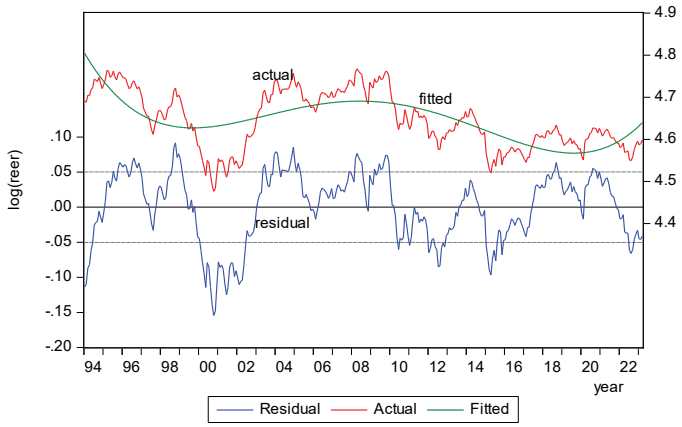

Figure 2. The trendline of REER.

The estimated nonlinear trend line of NEER of Euro from 1994m1 to 2023m3 has been given below where it begins with decreasing phase but it is insignificant and other phases are significant.

$$Log(NEER)=4.315-0.00027t+3.06e^{-05}t^2-1.66e^{-07}t^3+2.53e^{-10}t^4$$

(327.12)*(-0.52) (5.13)* (-6.53)* (7.05)*

R^2=0.77, F=299.39*, DW=0.072,*=significant at 5%, n=351

In figure 3, the trend line of NEER of Euro has been depicted and as a whole it is upward (Figure 3).

Both the NEER and REER of Euro contain unit root in level series but they had no unit roots in first difference series which implies that the level series are non-stationary during 1994m1-2023m3 which is represented in Table 1 (Table 1).

The break unit root test of REER of euro implies that it has unit root and has a break point in 2009m10 in which the ADF break unit root test estimation is given below.

$$log(reer)=0.175+0.962591log(reer)_{t-1}+0.220665dlog(reer)_{t-1}-0.003570(interceptbreak)+0.012909(dummybreak)$$

(3.14)*(80.80)* (4.22)* (-2.19)* (0.96)

R^2=0.96, F=2255.92*, DW=1.95, n=349,*=sig at 5% level, ADF=-3.14(p=0.602), So it has unit root. AIC= -5.79, SC=-5.74

It has a break at 2009m10 assuming Lag Length: 1 (Automatic - based on Schwarz information criterion, maxlag=16).

In the Figure 4, the break unit root test of REER of Euro has been depicted under ADF auto-regressive coefficient (Figure 4).

The break unit root test of NEER of euro implies that it has unit root and has a break point in 2002 in m04 in which the ADF break unit root test estimation is given below.

$$log(neer)=0.3146+0.928log(neer)_{t-1}+0.220665dlog(neer)_{t-1}+0.1036(interceptbreak)-0.0129(dummybreak)$$

(5.53)*(71.16)* (5.65)* (4.67)* (-1.04)

R^2=0.98, F=5855.36*, DW=1.94, n=349,*=sig at 5% level, ADF=-5.51(p=0.01), So it has unit root. AIC=-5.98, SC=-5.93

It has a break at 2002m04 assuming Lag Length: 1 (Automatic - based on Schwarz information criterion, maxlag=16).

In the Figure 5, the break unit root test of NEER of Euro has been depicted under ADF auto-regressive coefficient (Figure 5).

Selecting automatic ARMA model to apply ARMA maximum likelihood method for NEER of euro during 1994m02 – 2023m03, it is found that ARIMA (2,1,3) is the best model where AIC and SC are minimum, and R^2 is maximum which is estimated below.

$$Dlog(neer)=0.00124-0.00945log(neer)_{t-2}+\varepsilon_t+0.0066\varepsilon_{t-3}+0.000169\sigma^2_t+\grave{e}_t$$

(1.74) (-0.19) (0.128) (15.09)*

R2=0.0001, F=0.0115, SC=-5.77, AIC=-5.82, DW=1.41, n=350,AR roots=-0.00±0.10i,MA roots=0.09±0.16i and -0.19,*=significant at 5% level.

Since, the AR and MA roots are less than one, so the model is converging but it is insignificant because t values of coefficients are insignificant. Its volatility is minimum because t value of the coefficient of σ^2 is significant. Although it is insignificant model but it is the best model where all criteria have been fulfilled. In Figure 6, the actual and fitted lines of the ARIMA(2,1,3) model of NEER of euro are shown where it is clear that the fitted lines is passing through the equilibrium point and passing around it which proves the convergence conditions and turned into stationary (Figure 6).

In spite of fluctuations, its autocorrelations and partial autocorrelations moved around ±5% significant level in all 36 lags except in lag 1 where Q stats are significant at 5% level. But, the fluctuations did not vanish since the values of AC and PAC changed from positive to negative values through the lags. In Figure 7, it is shown vividly (Figure 7).

If the ARIMA (2, 1, 3) of NEER of Euro is being forecasted for 2027m05 then it is found that the forecast line has been converging around the equilibrium showing cyclical manner which implied that volatility is not

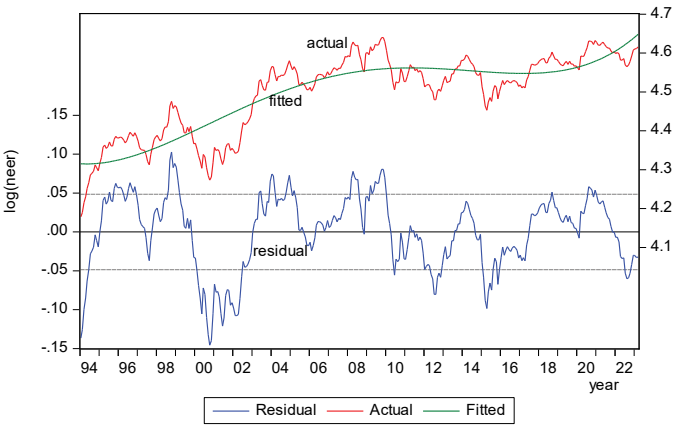

Figure 3. Trend line of NEER of Euro.

Table 1. Unit root test (Tabulated ADF= -2.86 at 5% level).

Series	ADF	Probability	H0=series has unit root	Result
Log(neer)	-2.855237	0.0518	accepted	Non stationary
Dlog(neer)	-13.86899	0.0000	rejected	stationary
Log(reer)	-2.313724	0.1682	accepted	Non stationary
Dlog(reer)	-15.05251	0.0000	rejected	stationary

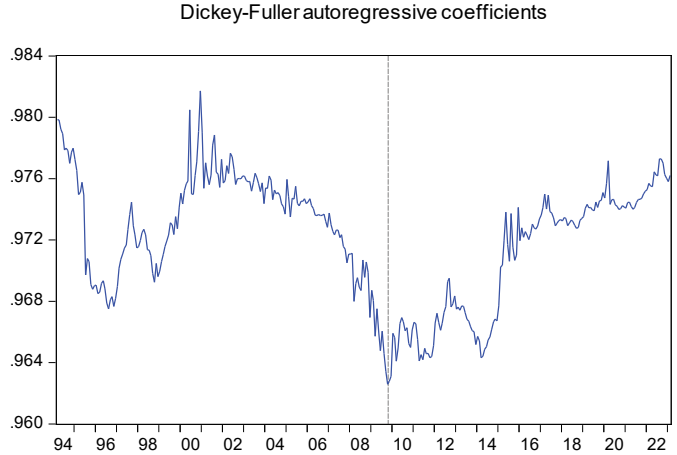

Figure 4. Break unit root test of REER.

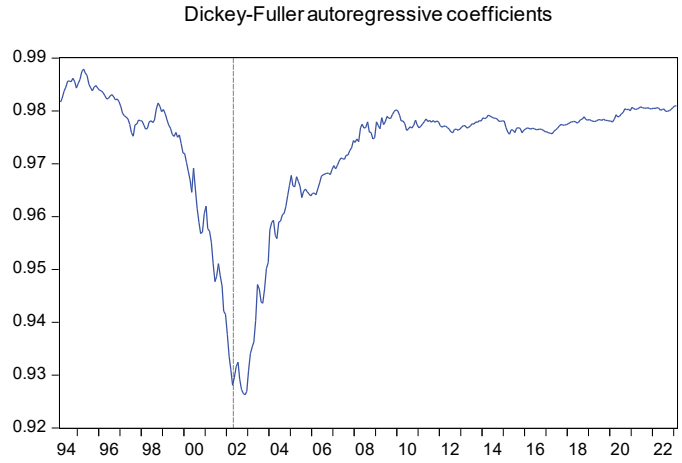

Figure 5. Break unit root test of NEER.

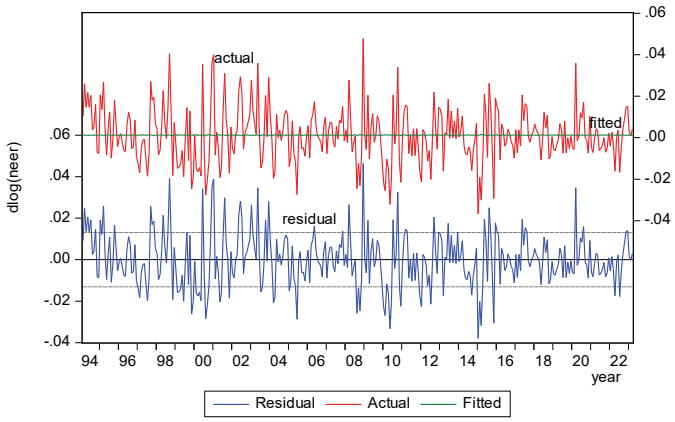

Figure 6. The fitted ARIMA (2, 1, 3).

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.290	0.290	29.704	
		2	0.000	-0.092	29.704	
		3	0.000	0.029	29.704	0.000
		4	0.012	0.004	29.758	0.000
		5	-0.006	-0.012	29.770	0.000
		6	0.008	0.016	29.791	0.000
		7	0.027	0.022	30.062	0.000
		8	0.095	0.089	33.320	0.000
		9	0.071	0.020	35.150	0.000
		10	0.019	-0.000	35.287	0.000
		11	-0.062	-0.070	36.664	0.000
		12	-0.056	-0.020	37.804	0.000
		13	-0.096	-0.088	41.194	0.000
		14	-0.092	-0.047	44.278	0.000
		15	-0.059	-0.031	45.562	0.000
		16	0.005	0.018	45.573	0.000
		17	0.027	0.014	45.840	0.000
		18	0.048	0.042	46.695	0.000
		19	-0.012	-0.026	46.747	0.000
		20	-0.070	-0.048	48.597	0.000
		21	-0.056	-0.005	49.784	0.000
		22	0.034	0.068	50.224	0.000
		23	-0.014	-0.039	50.296	0.000
		24	-0.002	0.013	50.299	0.001
		25	-0.053	-0.084	51.376	0.001
		26	-0.008	0.009	51.398	0.001
		27	0.012	-0.005	51.449	0.001
		28	-0.021	-0.025	51.613	0.002
		29	-0.084	-0.063	54.323	0.001
		30	-0.051	-0.015	55.329	0.002
		31	-0.009	0.008	55.362	0.002
		32	-0.016	-0.020	55.459	0.003
		33	-0.059	-0.043	56.813	0.003
		34	-0.044	-0.029	57.572	0.004
		35	0.039	0.065	58.162	0.004
		36	0.006	-0.031	58.179	0.006

Figure 7. AC and PAC of ARIMA (2, 1, 3) of NEER.

completely disappeared due to problem of autocorrelation and non-stationary. During forthcoming 50 month, the NEER of Euro will not show any nonvolatility (Figure 8).

In the similar fashion, the automatic ARIMA (3, 1, 4) of REER of euro has been selected by using ARMA maximum likelihood method from 1994m02 to 2023m03 and its estimation is given below.

$$Dlog(log(reer))=-5.76e^{-05}-0.00126log(reer)_{t-3}+\varepsilon_t-0.028\varepsilon_{t-4}+8.65e^{-06}\sigma^2_t+\grave{e}_t$$

(-0.35) (-0.024) (-0.543) (16.02)*

R^2=0.0009, F=0.105, SC=-8.75, AIC=-8.79, DW=1.57, n=350, AR roots=0.05±0.09i, and -0.11,MA roots=0.00±0.41i and ±0.41,*=significant at 5% level

Since, the AR and MA roots are less than one, then the model is convergent but it is insignificant because t values of coefficients are insignificant. Its volatility is minimum because t value of the coefficient of σ^2 is significant. Although it is insignificant model but it is the best model where all criteria have been fulfilled. In Figure 9, the actual and fitted lines of the ARIMA (3,1,4) model of REER of euro are shown where it is clear that the fitted lines is passing through the equilibrium point and passing around it which proves the convergence conditions and turned into stationary (Figure 9).

This ARIMA (3, 1, 4) of REER of euro during 1994m02 – 2023m03 has been showing strong autocorrelation and partial autocorrelation for which volatility did not disappear completely and even in lags 1, 2, 13, and 25 its AC and PAC values crossed ±5% significant level but fluctuations continued because AC and PAC values moved from positive to negative randomly although Q stats are significant. It is shown in Figure 10 (Figure 10).

Thus, when the ARIMA (3, 1, 4) of REER of euro during 1994m02-

Figure 8. Forecast of ARIMA (2, 1, 3) of NEER of Euro.

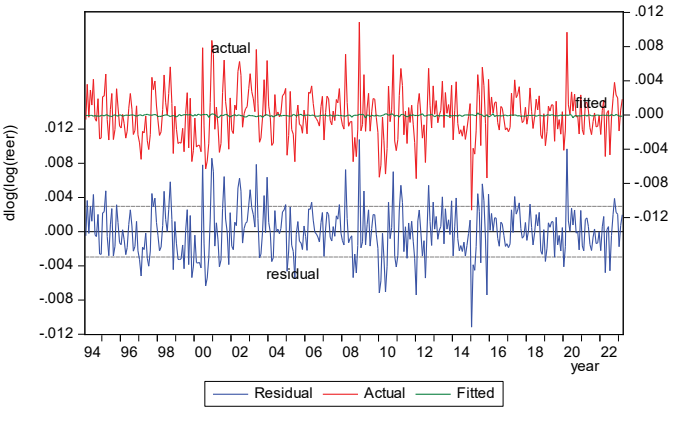

Figure 9. Fitted ARIMA (3, 1, 4) of REER of Euro.

2023m03 has been predicted for 2027m05, its forecast line is being seasonally fluctuated during the course of equilibrium path in a converging manner under ±5% significant level which is shown in Figure 11 (Figure 11).

Hamilton regression filter model is estimated below for NEER of euro from 1996m04 to 2023m03.

$Log(neer)_t=1.571+0.723log(neer)_{t-24}-0.245log(neer)_{t-25}+0.0409log(neer)_{t-26}+0.135log(neer)_{t-27}+v_t$

Where $R^2=0.511$, F=83.41*, DW=0.064, AIC=-2.67, SC=-2.61, n=324[t value of 0.723 is significant]

Thus,

$v_t=log(neer)t-[1.571+0.723log(neer)_{t-24}-0.245log(neer)_{t-25}+0.0409log(neer)_{t-26}+0.135log(neer)_{t-27}]$

This residual v_t of Hamilton model for NEER of euro has been decomposed by using STL method from which we get the cycles, cyclical trend, seasonal fluctuations of the REER of euro during the specified period which is depicted in Figure 12. In panel 1, the cycles are shown which have many peaks and troughs in both upward and downward fashions. In panel 2, the cyclical trend is drawn where 7 troughs and 8 peaks have been found. As a whole the cyclical trend is marginally downward fashion. In panel 3, the seasonal variation is plotted where the W type seasonality was found which are shrinking but after 2013 they are again growing (Figure 12).

If the residual of Hamilton filter model of NEER of euro from 1994m01 to 2023m03 passes through the automatically selected ARIMA (p, d, q) model then volatility due to AR and MA may reduce and quickens to converge towards equilibrium. In NEER of euro, the ARIMA (1,0,1) model has been selected where AIC, SC are minimum, variance(σ^2) is minimum, R^2 is maximum and AR and MA roots are less than one for convergence criterion. The estimated ARIMA (1, 0, 1) of NEER of euro is given below.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.210	0.210	15.513	
		2	-0.060	-0.108	16.777	
		3	0.000	0.039	16.777	0.000
		4	-0.002	-0.018	16.778	0.000
		5	-0.005	0.002	16.788	0.001
		6	0.060	0.063	18.061	0.001
		7	0.009	-0.021	18.092	0.003
		8	0.062	0.080	19.465	0.003
		9	0.072	0.040	21.360	0.003
		10	-0.011	-0.026	21.401	0.006
		11	-0.078	-0.064	23.618	0.005
		12	0.068	0.099	25.321	0.005
		13	-0.117	-0.180	30.340	0.001
		14	-0.097	-0.018	33.809	0.001
		15	-0.039	-0.051	34.377	0.001
		16	-0.040	-0.034	34.956	0.001
		17	0.030	0.052	35.295	0.002
		18	0.093	0.056	38.492	0.001
		19	-0.029	-0.030	38.795	0.002
		20	-0.091	-0.067	41.917	0.001
		21	-0.034	0.006	42.344	0.002
		22	0.012	0.029	42.397	0.002
		23	-0.015	-0.004	42.485	0.004
		24	0.102	0.086	46.381	0.002
		25	-0.095	-0.141	49.792	0.001
		26	-0.014	0.049	49.869	0.001
		27	0.024	-0.033	50.081	0.002
		28	-0.065	-0.056	51.681	0.002
		29	-0.073	-0.043	53.709	0.002
		30	0.013	-0.002	53.771	0.002
		31	-0.004	0.012	53.776	0.003
		32	-0.037	-0.039	54.310	0.004
		33	-0.034	-0.020	54.758	0.005
		34	-0.057	-0.063	56.004	0.005
		35	0.018	0.071	56.124	0.007
		36	0.092	0.021	59.474	0.004

Figure 10. AC and PAC of ARIMA (3, 1, 4) of REER of Euro.

Figure 11. Prediction for 2027m03 of ARIMA (3, 1, 4) of REER of Euro.

$V_t=0.00328+0.948v_{t-1}+\epsilon_t+0.281\epsilon_{t-1}+0.000234\ \sigma^2_t$

(0.149) (55.52)* (5.11)* (14.96)*

$R^2=0.94$, F=1682.06*, AIC=-5.48, SC=-5.44, DW=2.03, n=324, AR root=0.95, MA root=-0.28,*=significant at 5% level.

Since, AR and MA root are less than one then the model is convergent. The t values of coefficients of AR and MA are less than one and significant then the model converges to equilibrium in a significant manner. The t value of variance is significant then its volatility is minimum. Here AIC is minimum. This fitted ARIMA (1, 0, 1) is shown in Figure 13 where actual and fitted ARIMA of NEER crossed many times and approached toward equilibrium (Figure 13).

All the autocorrelations and partial autocorrelations of the fitted ARIMA (1, 0, 1) of NEER of euro passed through ±5% significant level except in lag 3 in residual test but Qstats are significant except in lag 3. Thus why its seasonality is not fully vanished. It is shown in Figure 14 (Figure 14).

If the ARIMA (1, 0, 1) of NEER of euro under Hamilton decomposition residual conditions has been predicted for 2027m05, then the model distinctly converges towards equilibrium significantly without fluctuations which are clearly depicted in Figure 15 below (Figure 15).

Hamilton regression filter model is estimated below for REER of euro from 1996m04 to 2023m03.

$Log(reer)_t=3.056+0.729log(reer)_{t-24}-0.266log(reer)_{t-25}+0.126log(reer)_{t-26}-0.249log(reer)_{t-27}+v_{t1}$

Where $R^2=0.153$, F=14.48*, DW=0.072, AIC=-2.75, SC=-2.69, n=324[t value of 0.729 is significant]

Thus,

$v_{t1}=log(reer)t-[3.056+0.729log(reer)_{t-24}-0.266log(reer)_{t-25}+0.126log(reer)_{t-26}-0.249log(reer)_{t-27}]$

This residual v_{t1} of Hamilton model for REER of euro has been decomposed by using STL method from which we get the cycles, cyclical trend, seasonal fluctuations of the REER of euro during the specified period which is depicted in Figure 16. In panel 1, the cycles are shown which have many peaks and troughs in both upward and downward fashions. In panel 2, the cyclical trend is drawn where 7 troughs and 7 peaks have been found. As a whole the cyclical trend is marginally downward fashion. In panel 3, the seasonal variation is plotted where the W type seasonality was found which are shrinking (Figure 16).

If the residual of Hamilton filter model of REER of euro from 1996m04 to 2023m03 passes through the automatically selected ARIMA (p, d, q) model then volatility due to AR and MA may reduce and quickens to converge towards equilibrium. In REER of euro, the ARIMA (3,0,3) model has been selected

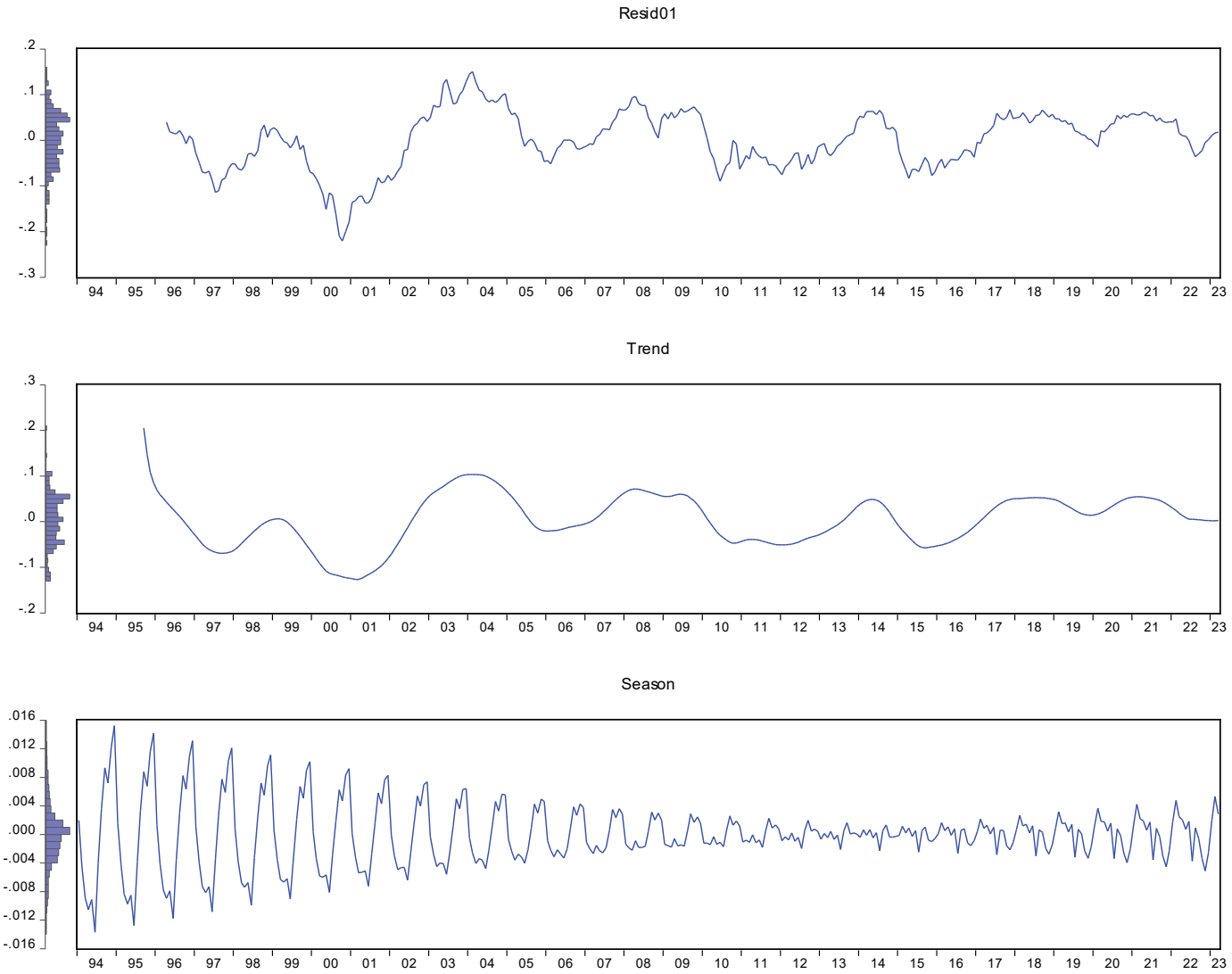

Figure 12. Decomposition of NEER of Euro.

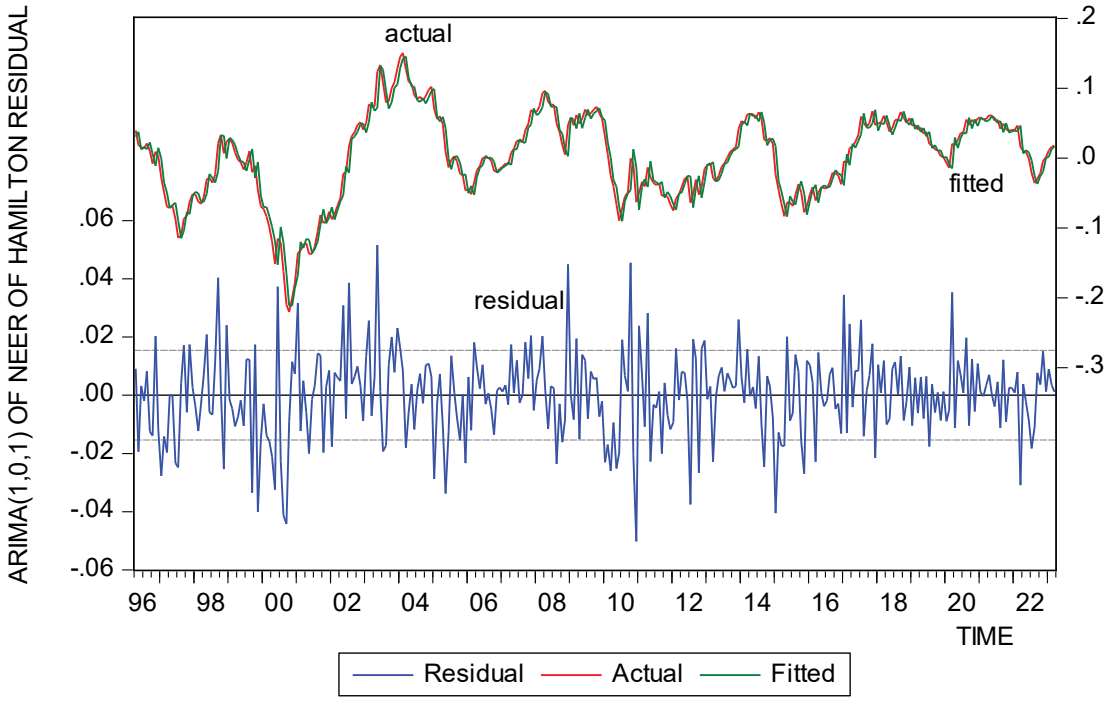

Figure 13. Fitted ARIMA of NEER under Hamilton model.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.018	-0.018	0.1022	
		2	-0.031	-0.031	0.4095	
		3	0.110	0.109	4.3713	0.037
		4	0.048	0.051	5.1172	0.077
		5	0.031	0.040	5.4370	0.142
		6	0.022	0.015	5.6003	0.231
		7	0.023	0.015	5.7718	0.329
		8	0.074	0.067	7.5845	0.270
		9	0.061	0.059	8.8413	0.264
		10	0.079	0.082	10.954	0.204
		11	-0.053	-0.064	11.889	0.220
		12	-0.032	-0.052	12.228	0.270
		13	0.018	-0.017	12.340	0.339
		14	-0.057	-0.063	13.447	0.337
		15	-0.062	-0.063	14.759	0.323
		16	-0.045	-0.060	15.466	0.347
		17	0.037	0.035	15.941	0.386
		18	0.077	0.087	18.006	0.324
		19	-0.019	0.012	18.131	0.381
		20	-0.031	-0.015	18.461	0.426
		21	-0.040	-0.043	19.008	0.456
		22	0.097	0.107	22.275	0.326
		23	-0.083	-0.068	24.691	0.261

Figure 14. AC and PAC of ARIMA (1, 0, 1) of Euro under Hamilton.

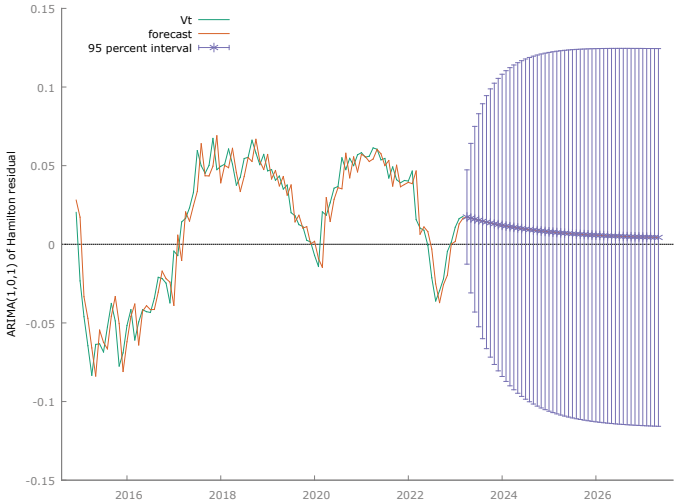

Figure 15. Prediction for 2027m05 of NEER under Hamilton model.

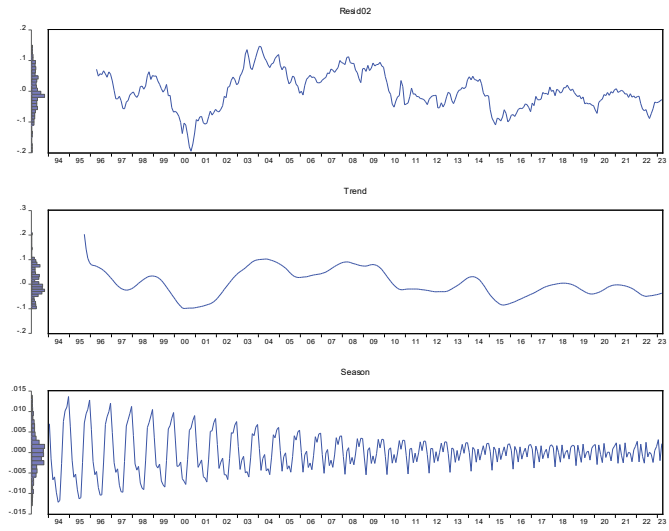

Figure 16. Hamilton decomposition of REER.

where AIC, SC are minimum, variance (σ^2) is minimum,R^2 is maximum and AR and MA roots are less than one for convergence criterion. The estimated ARIMA (1, 0, 1) of REER of euro is given below.

$$V_{t1}=0.0014+0.861v_{t-3}+\epsilon_t+0.0172\epsilon_{t-3}+0.000891\sigma^2_t$$

(0.121) (28.61)* (0.281) (13.78)*

R^2=0.75, F=327.36*, AIC=-4.14, SC=-4.10, DW=0.56, n=324, AR root=0.95,-0.48±0.82i, MA root=–0.26, 0.13±0.22i and *=significant at 5% level.

Since, AR and MA root are less than one then the model is convergent. The coefficients of AR and MA are less than one. The t value of coefficient of AR is significant but MA is not. So, the model converges to equilibrium in an insignificant manner. The t value of variance is significant then its volatility is minimum. Here AIC is minimum. This fitted ARIMA (1, 0, 1) is shown in Figure 17 where actual and fitted ARIMA of REER crossed many times and approached toward equilibrium (Figure 17).

Most of the autocorrelations and partial autocorrelations of the fitted ARIMA (3, 0, 3) of REER of euro did not pass through ±5% significant level specially in lag 1,2,4,7,10,11,12,22,23,24 in residual test but Q-stats are not significant. Thus why its seasonality continues. It is shown in Figure 18 (Figure 18).

If the ARIMA (3, 0, 3) of REER of euro under Hamilton decomposition residual conditions has been predicted for 2027m05, then the model distinctly converges towards equilibrium insignificantly with fluctuations which is clearly depicted in Figure 19 below (Figure 19).

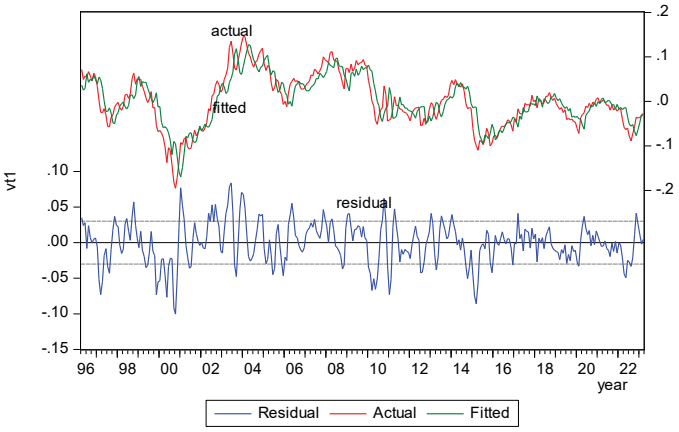

Figure 17. Fitted ARIMA of REER under Hamilton residual.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.713	0.713	166.36	
		2	0.319	-0.387	199.68	
		3	0.002	-0.090	199.68	0.000
		4	-0.003	0.373	199.68	0.000
		5	0.036	-0.236	200.11	0.000
		6	0.081	0.053	202.30	0.000
		7	0.117	0.279	206.86	0.000
		8	0.177	-0.071	217.39	0.000
		9	0.174	-0.094	227.50	0.000
		10	0.125	0.177	232.78	0.000
		11	0.025	-0.154	233.00	0.000
		12	-0.050	-0.124	233.84	0.000
		13	-0.127	0.023	239.33	0.000
		14	-0.178	-0.151	250.18	0.000
		15	-0.164	0.052	259.33	0.000
		16	-0.064	0.132	260.75	0.000
		17	0.060	-0.051	262.00	0.000
		18	0.109	-0.014	266.06	0.000
		19	0.071	0.090	267.80	0.000
		20	0.025	0.030	268.02	0.000
		21	-0.024	-0.138	268.22	0.000
		22	-0.132	-0.215	274.32	0.000
		23	-0.269	-0.011	299.74	0.000
		24	-0.325	-0.024	336.90	0.000

Figure 18. AC, PAC of ARIMA of REER of Euro under Hamilton.

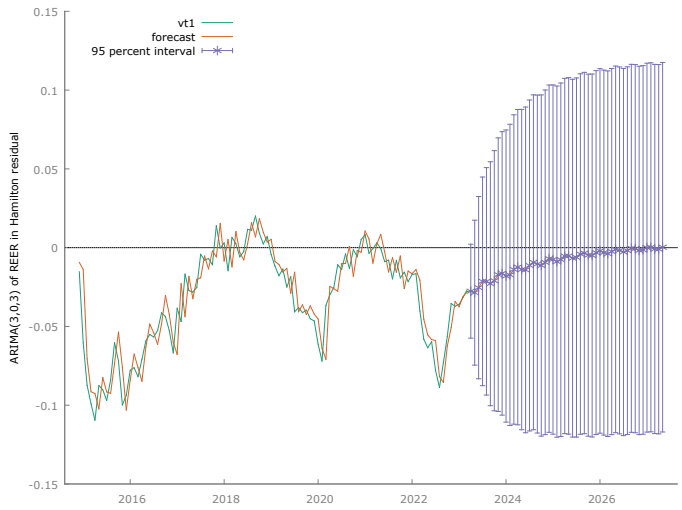

Figure 19. Predicted ARIMA (3, 0, 3) of REER of Euro under Hamilton.

Limitations and future research

The paper excludes the determinants of NEER and REER of euro during 1994m01-2023m03 in analysing the behaviour patterns. The ARCH and GARCH models can be easily incorporated for scrutinising volatility. Even, the diagnostic test of residual in the trends' analysis is avoided for simplicity. The paper has enough scope to apply cointegration and VECM in quarterly or yearly data of NEER and REER of euro in Euro Area.

Policy considerations

In the periods of Euro crises, in recession for financial crises and in covid-19 the erratic behaviour of NEER and REER were observed where strict monetary and fiscal policies, good employment provision targets, debt recovery subsidies, and anti-cyclical-inflationary with government expenditures increasing policies should be effective in stabilising exchange rates.

Conclusion

The paper concludes that both the NEER and REER of euro in Euro Area during 1994m01-2023m05 are non-stationary and four phases nonlinear trends which are significant but the gap between them is gradually diminishing. REER has a break unit root at 2009m10 and NEER has break unit root at 2002m04. The NEER showed automatic ARIMA (2, 1, 3) model whose t values of the coefficients of AR and MA are not significant yet other conditions for convergences are satisfied. Its AC and PAC values passed through ±5% significant level except in lag 1. It is forecasted for 2027m05 and found that the forecast lines have been converging around the equilibrium showing cyclical manner. On the other hand, ARIMA (3, 1, 4) of REER has been selected but it is insignificant although convergence conditions have been satisfied and the fitted lines is passing through the equilibrium point. Its AC and PAC values moved from positive to negative randomly because of non-vanishing volatility. Its forecast line for 2027m05 is being seasonally fluctuated during the course of equilibrium path in a converging manner under ±5% significant level. The decomposed NEER of euro showed many peaks and troughs in cycles, 7 troughs and 8 peaks in cyclical trend and having w shaped seasonal variations. If decomposition model passed through ARIMA, then ARIMA (1, 0, 1) model has been selected for NEER which is significant and convergent towards equilibrium. If it is forecasted for 2027m05, then the model distinctly converges towards equilibrium significantly without fluctuations. Similarly, the decomposed REER of euro showed many peaks and troughs in cycles, 7 troughs and 7 peaks in cyclical trend and having w shaped seasonal variations. If decomposition model passed through ARIMA, then ARIMA (3, 0, 3) model has been selected for REER which is significant and convergent towards equilibrium without insignificant t value of MA and showing insignificant AC and PAC in several lags. If ARIMA (3, 0, 3) of REER of euro is predicted for 2027m05, then the model distinctly converges towards equilibrium insignificantly with fluctuations.

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Conflict of Interest

None.

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