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THE OVERSHOOTING MODEL OF EXCHANGE RATE DETERMINATION

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Abstract

The purpose of this work is to test the exchange rate dynamics by looking at the speed of adjustment of prices with the use firstly, of a long-run monetary path and a short-run overshooting model and secondly, an Autoregressive Distributed Lag (ARDL) model. In these overshooting models, we assume price stickiness (gradual adjustment). If the prices are adjusted instantaneously, we will have the monetarist view; otherwise, the short-run overshooting one, due to slow adjustment of prices and consequently, it affects all the other variables and slowly the exchange rate. Thus, we outline, here, an approach of testing the dynamic models of exchange rate determination and expending the monetary model by using the ARDL process. This approach is based upon the view that it is difficult to measure directly the process by which market participants revise their expectations about current and future money supplies; except lately, where the Fed has made the forward guidance (zero interest rate) explicit. Further, it is possible to make indirect inferences about these expectations through a time series analysis of related financial and real prices. In addition, unit root and cointegration tests are taking place for testing the stationarity of the variables. Empirical tests of the above exchange rate dynamics are used for four different exchange rates ($/€, $/£, C$/$, and ¥/$). Theoretical discussion and empirical evidence have emphasized the impact of gradual adjustment and "overshooting" that it is taking place for some less market oriented countries, as Canada, the C$/$ and partially Japan, the ¥/$. For the $/€ and the $/£ exchange rates the monetarist model is correct; no overshooting.

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

I. Introduction

The exchange rate dynamics (overshooting) model was set forth by Dornbusch (1976), who assumed that asset markets adjust instantaneously, where prices in goods markets and wages adjust slowly (gradually). An important modification was the monetarist model, Bilson (1978), which assumes instantaneous adjustment in all markets. The resulting exchange rate dynamics model retains all the long run equilibrium or steady state properties of the monetary approach, but in the short run, the real exchange rate and the interest rate can diverge from their long run levels. Then, the monetary policy can have effects on real variables (production) in the system. Thus, exchange rate dynamics or "overshooting" can occur in any model, in which some markets do not adjust instantaneously.

This sticky price version is a Keynesian model of the monetary approach. Purchasing power parity ($p_t = s_t\ p_t^*$) may be a good approximation in the long run, but it does not hold in the short run. There are long term contracts, imperfect information, high cost of acquiring information, high cost of changing prices, inertia in consumer habits, price control in some countries, the uncertainty about the future economy that the effective lower bound federal funds rate (i_{FF}^{eff}) has created,[1] and other restrictions, which do not allow prices to change instantaneously, but adjust gradually. This gives us a model of exchange rate determination, in which changes in the nominal money supply (M^s) are also changes in the real money supply ($\frac{M^s \uparrow}{\overline{P}} = \frac{M^s}{P} \uparrow$) because prices are sticky, so the effect is real, as follows:

$$\frac{M^s \uparrow}{\overline{P}} \Rightarrow \frac{M^s}{P} \uparrow \Rightarrow D_{Bonds} \uparrow \Rightarrow P_{Bonds} \uparrow \Rightarrow i \downarrow \Rightarrow K_{outflow} \Rightarrow S_{S-R} \uparrow\uparrow\uparrow \Rightarrow (\$ \downarrow) \Rightarrow X \uparrow \text{ and } M \downarrow$$

In the short run, because prices are sticky ($\overline{P}$), a nominal monetary expansion ($M^s \uparrow$) has an increase in real money (purchasing power, $\frac{M^s}{P} \uparrow$), which increases the demand for bonds ($D_{Bonds} \uparrow$) and the prices of bonds are increasing ($P_{Bonds} \uparrow$) that has a liquidity effect. Thus, the interest rate falls ($i \downarrow$), generating an incipient capital outflow ($K_{outflow}$), which causes the currency to depreciate instantaneously ($S_{S-R} \uparrow\uparrow\uparrow$) more than it will do in the long run, which stimulate exports ($X \uparrow$) and discourages imports ($M \downarrow$), as shown in Figure 1.

In the long run prices are going up ($P \uparrow$) and the effects are:

[1] The federal funds rate (i_{FF}) was between 0% and 0.25% for seven years, from December 16, 2008 to December 15, 2015 and again from March 15, 2020 to present, by the Fed, and the effective (i_{FF}^{eff}) closed to zero. Consumers and firms reduced demand and supply of products because the Fed policy had increased their uncertainty for the future outcomes of the economy. This policy had no effect on output and employment, but it has affected prices, due to enormous liquidity and has generated a new bubble in the financial market. The DJIA from 6,547.05 (3/9/2009) reached 26,616.71 (1/26/2018), a growth of 306.55% in 8.83 years (34.72% p.a.). See, Plante, Richter, and Throckmorton (2017). Also, official inflation rate ($\overline{\pi}$ = 1.6% p.a.) and from independent studies, the SGS one ($\overline{\pi}$ = 6%). See, http://www.usinflationcalculator.com/inflation/current-inflation-rates/. And http://www.shadowstats.com/alternate_data/inflation-charts . From 2015 to 2018, the target federal funds rate was between 0.25% and 2.50%. But on March 15, 2020, it fell again to 0.00% - 0.25%, due to the suspicious and destructive coronavirus (Wuhan virus) pandemic. (*Sic*). This enormous liquidity from ($M2 = \$7{,}504.8$ billion, in January 2008) and reached ($M2 = \$20{,}256.0$, in May 2021), a growth by \$12,751.2 billion or 169.91% (13.07% p.a.). [(https://fred.stlouisfed.org/series/WM2NS]. Thus, the latest enormous money supply has increased the bubble in financial market ($DJIA = 34{,}479.60$) on June 11, 2021. A growth by 426.64% or 34.83% p.a. The official inflation in March 2021 was 2.6% and the SGS inflation was 11%. In May 2021 it was 5% the official and the 13% the SGS inflation rate. Then, the equation of exchange ($M\,\overline{V} = \overline{Q}\,P$) is right!..

$$P\uparrow \Rightarrow \frac{M^{s}}{P}\downarrow \Rightarrow D_{Bonds}\downarrow \Rightarrow P_{Bonds}\downarrow \Rightarrow i\uparrow \Rightarrow K_{\inf low} \Rightarrow S_{L-R}\downarrow \Rightarrow (\$\uparrow) \Rightarrow X\downarrow and\ M\uparrow$$

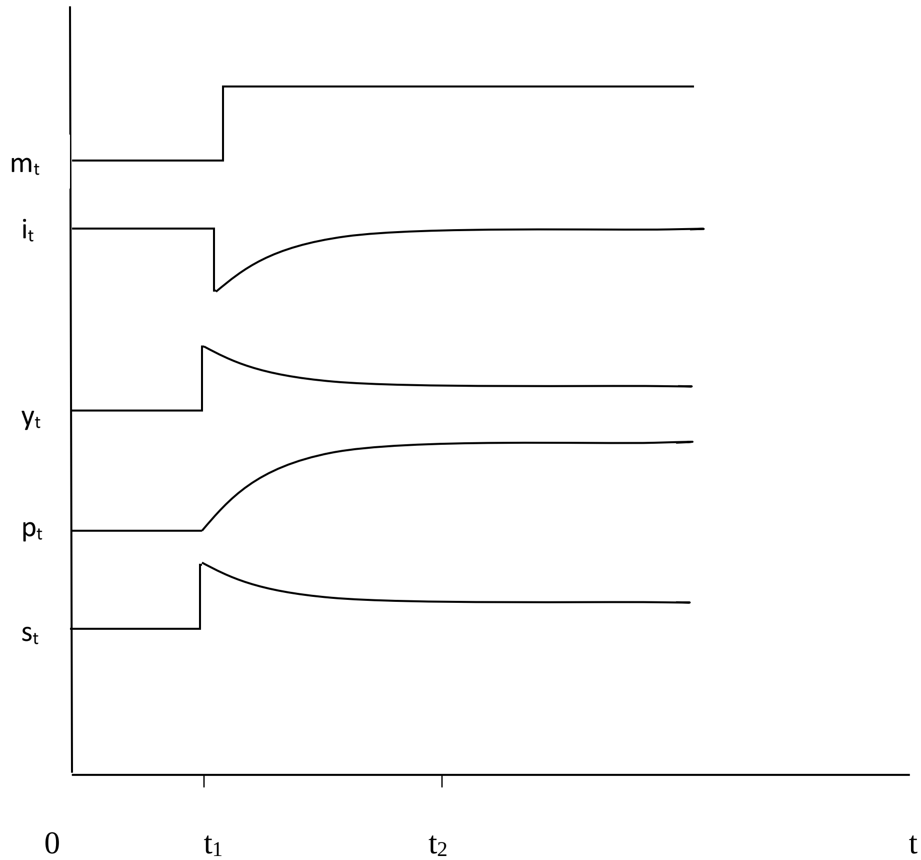
The currency depreciates just enough (S-R), so that the rationally expected rate of future appreciation (L-R) precisely cancels out the interest differential. This is known as "overshooting" of the spot exchange rate.

The overshooting results are consistent with perfect foresight. The assumptions of the model are that goods' prices are sticky (price inertia in the short run), prices of currencies are flexible, arbitrage in asset markets holds [uncovered interest parity (UIP)], and expectations of exchange rate changes are rational. Initial shocks are unanticipated, but when they occur, overshooting clears the way for a time path of the domestic interest rate and the exchange rate that is consistent with perfect foresight on the part of market participants. Given that an unanticipated increase in the domestic money supply in period t_1 would temporarily lower the domestic interest rate (liquidity effect), expectations of currency appreciation are necessary in order to induce individuals to continue to hold domestic securities and money.

When a monetary shock occurs in period t_1 (unanticipated increase in the money supply); the market will adjust to a new equilibrium, which will be between prices and quantities. Due to price stickiness in the goods market, the short run equilibrium will be achieved through shifts in financial market prices. As prices of goods increase gradually toward the new equilibrium in period t_2, the foreign exchange continuous re-pricing approaching its long term equilibrium level. Then, a new long run equilibrium will be attained in the domestic money, currency exchange, and goods markets. As a result, the exchange rate will initially overreact (overshoot), due to a monetary shock. Over time, goods prices will respond, allowing the foreign exchange rate to restrain its overreaction and the economy will reach its new long run equilibrium in all markets in period t_2, Figure 1.[2]

[2] See, Kallianiotis (2013a and 2019).

Figure 1 The Overshooting Model (Exchange Rate Dynamics)



Note: m_t = money supply, i_t = interest rate, y_t = real output (production), p_t = price level, and s_t = spot exchange rate. $M^s \uparrow \Rightarrow (\bar{P}) \Rightarrow \frac{M^s}{P} \uparrow \Rightarrow D_{Bonds} \uparrow \Rightarrow P_{Bonds} \uparrow \Rightarrow i \downarrow \Rightarrow$ capital outflows $\Rightarrow$ currency depreciates instantaneously more than it will be in the long-term. Then, $P \uparrow \Rightarrow \frac{M^s}{P} \downarrow \Rightarrow$ $D_{Bonds} \downarrow \Rightarrow P_{Bonds} \downarrow \Rightarrow i \uparrow \Rightarrow capital\,\inf lows \Rightarrow D_{\$} \uparrow \Rightarrow \$ \uparrow (S \downarrow)$ dollar is appreciated in the long-run.

II. The Theoretical Models

The overshooting models can be presented with the following equations. First, the domestic money demand function,

$$m_t = \bar{p}_t + \alpha + \beta\, y_t - \gamma\, i_t + \varepsilon_t \tag{1}$$

Then, the foreign money demand, assuming the same elasticities in both countries, it is,

$$m_t^* = \bar{p}_t^* + \alpha + \beta\, y_t^* - \gamma\, i_t^* + \varepsilon_t^* \tag{2}$$

where, m_t = demand for money, $\bar{p}_t$ = the (sticky) price level, α = the constant term, β = the income elasticity of the demand for money, y_t = the real income, γ = the interest rate semi-elasticity of the demand for money, i_t = the short-term interest rate, and an asterisk (*) denotes foreign variables; variables are in natural logarithms ($m_t = \ln M^d = \ln M^s = \ln M$).

The uncovered interest parity (UIP),[3]

$$i_t - i_t^* = \Delta s_t^e = s_{t+1}^e - s_t \tag{3}$$

where, i_t = the domestic short-term interest rate, i_t^* = the foreign short-term interest rate, Δs_t^e = expected change of the spot exchange rate, s_{t+1}^e = expected spot rate next period, and s_t = current actual spot rate.

The long-run PPP,

$$\bar{s}_t = \bar{p}_t - \bar{p}_t^* \tag{4}$$

The bars (i.e., $\bar{p}$) over the variables mean that the relationship holds in the long run.

The long run monetarist exchange rate equation,

$$\bar{s}_t = (\bar{m}_t - \bar{m}_t^*) - \beta(\bar{y}_t - \bar{y}_t^*) + \gamma(\bar{i}_t - \bar{i}_t^*) + \varepsilon_t \tag{5}$$

or by decomposing the nominal interest rate ($\bar{i}_t = \bar{r}_t + \Delta\bar{p}_t^e$), we have,

$$\bar{s}_t = (\bar{m}_t - \bar{m}_t^*) - \beta(\bar{y}_t - \bar{y}_t^*) + \gamma[(\bar{r}_t + \Delta\bar{p}_t^e) - (\bar{r}_t^* + \Delta\bar{p}_t^{*e})] + \varepsilon_t \tag{6}$$

We assume that expectations are rational and the system is stable. Income growth is exogenous [random with $E(g_y) = 0$] and monetary growth follows a random walk. Also, we assume, the $\bar{r}_t \cong \bar{r}_t^*$. Then, the relative money supply and in the long run, the relative price level and exchange rate, are all rationally expected to follow paths that increase at the current rate of relative money growth. Thus, in the long-run, we have,

$$g_{m_t} - g_{m_t^*} = \dot{m}_t - \dot{m}_t^* \cong \pi_t^e - \pi_t^{*e} \cong \Delta s_t^e \tag{7}$$

Consequently, equation (6) can be written as,

[3] Thus, we can apply UIP to forecast s_{t+1}^e : From eq. (3), we have, $s_{t+1}^e = i_t - i_t^* + s_t$. See, Figures A1e, A2e, A3e, and A4e in the Appendix.

$$\bar{s}_t = (m_t - m_t^*) - \beta(y_t - y_t^*) + \gamma(g_{m_t} - g_{m_t^*}) + \varepsilon_t \tag{8}$$

which is the L-R equilibrium, or

$$\bar{s}_t = (m_t - m_t^*) - \beta(y_t - y_t^*) + \gamma(\pi_t^e - \pi_t^{*e}) + \varepsilon_t \tag{9}$$

In the short run, when the exchange rate deviates from its equilibrium path, it is expected to close that gap with a speed of adjustment of Θ (theta). In the long run, when the exchange rate lies on its equilibrium path, it is expected to increase at ($g_{m_t} - g_{m_t^*}$).

$$\Delta s_t^e = -\Theta(s_t - \bar{s}_t) + g_{m_t} - g_{m_t^*} \tag{10}$$

By combining (10) with (3), we obtain,

$$i_t - i_t^* = \Delta s_t^e = -\Theta(s_t - \bar{s}_t) + g_{m_t} - g_{m_t^*} \tag{11}$$

and putting the growth of money equal to the expected inflation, eq. (7),[4] equation (11) becomes,

$$-\Theta(s_t - \bar{s}_t) = i_t - g_{m_t} - i_t^* + g_{m_t^*} \Rightarrow -\Theta(s_t - \bar{s}_t) = i_t - \pi_t^e - i_t^* + \pi_t^{*e} \Rightarrow -\Theta(s_t - \bar{s}_t) = [(i_t - \pi_t^e) - (i_t^* - \pi_t^{*e})]$$

and solving for ($s_t - \bar{s}_t$), we have,

$$s_t - \bar{s}_t = -\frac{1}{\Theta}[(i_t - \pi_t^e) - (i_t^* - \pi_t^{*e})] \tag{12}$$

which is the S-R overshooting path.

Eq. (12) shows that the gap between the exchange rate and its equilibrium value is proportional to the real interest rate differential ($r_t - r_t^*$). When a tight domestic monetary policy causes the interest differential to rise above its equilibrium level, an incipient capital inflow causes the value of the domestic currency to rise (spot rate falls) proportionately above its equilibrium level.

Then, by combining eq. (8), which represents the long run monetary equilibrium path, with eq. (12), representing the short run overshooting effect, we can obtain a general monetary equation of exchange rate determination,

$$s_t = \bar{s}_t - \frac{1}{\Theta}[(i_t - \pi_t^e) - (i_t^* - \pi_t^{*e})] + \varepsilon_t \tag{13}$$

and

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[4] We have from eq. (10) $\Rightarrow$ $\Delta s_t^e = -\Theta(s_t - \bar{s}_t) + g_{m_t} - g_{m_t^*}$ $\Rightarrow -\Theta(s_t - \bar{s}_t) = \Delta s_t^e - (g_{m_t} - g_{m_t^*})$

$\Rightarrow s_t - \bar{s}_t = -\frac{1}{\Theta}[\Delta s_t^e - (g_{m_t} - g_{m_t^*})]$ $\Rightarrow s_t - \bar{s}_t = -\frac{1}{\Theta}[(i_t - i_t^*) - (g_{m_t} - g_{m_t^*})]$, which is another form of eq. (12).

$$s_t = (m_t - m_t^*) - \beta(y_t - y_t^*) + \gamma(g_{m_t} - g_{m_t^*}) - \frac{1}{\Theta}[(i_t - \pi_t^e) - (i_t^* - \pi_t^{*e})] + \varepsilon_t \tag{14}$$

Eq. (14) is an expansion of the monetarist equation with the addition of the fourth variable, the real interest differential ($r_t - r_t^*$) between the two countries. If the monetarist model is correct, the last variable must have a coefficient of zero ($\frac{1}{\Theta} = 0$), which means that the speed of adjustment ($\Theta \to \infty$) is infinite; instantaneous adjustment. By considering that the level of the money supply, rather than the change in the money supply, is a random walk; the expected long run inflation differential is zero ($\pi_t^e - \pi_t^{*e} = 0 = g_{m_t} - g_{m_t^*}$).

Thus, eq. (14) becomes,

$$s_t = (m_t - m_t^*) - \beta(y_t - y_t^*) - \frac{1}{\Theta}(i_t - i_t^*) + \varepsilon_t \tag{15}$$

The above eq. (15) is the Dornbusch equation, which can be tested econometrically by estimating eq. (14). A question remains, here; whether or not the domestic and foreign bonds are perfect substitutes. The violation of this assumption means that the interest differential will differ from the expected rate of currency depreciation. This difference may arise due to transaction costs, expectation errors or a risk premium, as most financial analysts consider being the case.

Assuming that the real rate of interest is the same in the two countries ($r_t = r_t^*$), eq. (15) becomes,

$$s_t = (m_t - m_t^*) - \beta(y_t - y_t^*) + \frac{1}{\Theta}(\pi_t^e - \pi_t^{*e}) + \varepsilon_t \tag{16}$$

Eq. (16) is an equation that can also be tested by using eq. (17), an expansion of the monetarist equation, to determine the speed of adjustment of prices (Θ), which will prove to us what model is correct, the monetarist ($\Theta \cong \infty$) or the overshooting ($\Theta \neq \infty$).

$$s_t = (m_t - m_t^*) - \beta(y_t - y_t^*) + \gamma(g_{m_t} - g_{m_t^*}) + \frac{1}{\Theta}(\pi_t^e - \pi_t^{*e}) + \varepsilon_t \tag{17}$$

Eq. (17) is an expansion of the monetarist equation with the addition of the fourth variable, the expected inflation differential between the two countries.

Now, we use a second model, the Autoregressive Distributed Lag (ARDL) approach, which is relating to the following formula that is a version of eq. (6):

$$s_t = \alpha_0 + \alpha_1(m_t - m_t^*) + \alpha_2(y_t - y_t^*) + \alpha_3(r_t - r_t^*) + \alpha_4(\pi_t^e - \pi_t^{*e}) + \varepsilon_t \tag{18}$$

where, $\alpha_1 > 0, \alpha_2 < 0, \alpha_3 > 0,\ \alpha_4 > 0$ and.

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and it is expanding to the following ARDL form in eq. (19) below,

$$\Delta s_t = \alpha_0 + \sum_{j=1}^{n}\alpha_1 \Delta s_{t-j} + \sum_{j=0}^{n}\alpha_2 \Delta(m_{t-j} - m^*_{t-j}) + \sum_{j=0}^{n}\alpha_3 \Delta(y_{t-j} - y^*_{t-j}) + \sum_{j=0}^{n}\alpha_4 \Delta(r_{t-j} - r^*_{t-j})$$
$$+ \sum_{j=0}^{n}\alpha_5 \Delta(\pi^e_{t-j} - \pi^{*e}_{t-j}) + \beta_1 s_{t-1} + \beta_2(m_{t-1} - m^*_{t-1}) + \beta_3(y_{t-1} - y^*_{t-1}) + \beta_4(r_{t-1} - r^*_{t-1}) + \beta_5(\pi^e_{t-1} - \pi^{*e}_{t-1}) + \varepsilon_t \tag{19}$$

The ARDL approach, eq. (19), will be used to test for the existence of a long-run relationship between these variables. The null hypothesis of the ARDL model is, $H_0 : \beta_i = 0$ for all i ($i = 1, 2, 3, 4, and\ 5$) and the alternative hypothesis is, H_1: at least one β_i is not equal to zero ($\beta_i \neq 0$). If the β_i's are statistically insignificant ($\beta_i \cong 0$), it is an indication that there is no long-run equilibrium relationship between exchange rates and macro fundamentals. This implies that the fluctuations of the exchange rate do not depend on changes of the macro fundamentals, but influenced by trade, capital flows, and speculations.

III. Data, Tests, and 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 2020:12 and for the other four currencies ($, £, C$, and ¥) from 1973:03 to 2020:12. Other data, beyond the four exchange rates ($/€, $/£, C$/$, and ¥/$) used, here, are T-Bill rates, money supplies, incomes, and price levels (CPIs). An empirical test of the overshooting and monetarist model is taking place, which will give the dynamics of exchange rates. Recent tests for the $/€ exchange rate conducted by Kallianiotis (2013a) show that the evidence are supporting the overshooting model.[5] The implication of these empirical findings is that the market oriented economies have an instantaneous price adjustment ($\Theta \cong \infty$) and some less market oriented ones have a gradual adjustment of their prices ($\Theta \neq \infty$), as it was expected; thus, prices are not a monetary phenomenon everywhere, but a cost-push (speculation, profit maximization, lack of competition) process (supply side inflation).

In addition, the study uses the second approach, the ARDL model to test if there is overshooting in the short-run, due to a non-anticipated increase in money supply. Concurrently, we can examine the existence of a long-run equilibrium relationship between the exchange rates and the macro fundamentals of the two countries. The general monetary model is represented in eq. (18).[6] Then, we use eq. (19) for our short-run and long-run ARDL model estimation.

We use also unit root tests to test the stationarity of our variables and co-integration tests for our models. The ARDL approach allows variables of different integration orders [$I(0)$ or $I(1)$] to be applied in the same model. Two unit root tests are used, here, a Dickey-Fuller[7] and a Phillips-

[5] See, Kallianiotis (2013a, p. 121).

[6] See also, Kallianiotis (2019, pp. 134-135) for its different versions.
[7] See, Dickey and Fuller (1979).

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Perron[8] one, to analyze the stationarity of each variable. The results of the unit root tests are shown in the Appendix, Table A1. Some variables are $I(0)$ (i.e., UKS, JS, USCPI, USM2, etc.), but there are many as $I(1)$ (i.e., EUS, CS EUHICP, UKM2, etc.). The results from the co-integration tests are in Tables A2.2 and A3.2. We start forecasting $\hat{\pi}_t^e$ for the five economies and the results are presented in Table 1.

Table 1 Forecasting Inflation Rates $\hat{\pi}_t^e$ with an ARMA (p, q) Process

$\hat{\pi}_t^e$ (U.S.)	$\hat{\pi}_t^{*e}$ (EMU)	$\hat{\pi}_t^{*e}$ (U.K.)	$\hat{\pi}_t^{*e}$ (Canada)	$\hat{\pi}_t^{*e}$ (Japan)	
c	4.426***	0.901	6.814	3.537	0.282
	(1.501)	(2.507)	(10.763)	(4.949)	(0.254)
π_{t-1}	1.255***	-0.977***	0.997***	-	0.998***
	(0.101)	(0.058)	(0.007)		(0.004)
π_{t-2}	-0.261***	-	-	-	-0.999***
(0.099)				(0.002)	
π_{t-3}	-	-	-	0.988***	-
(0.045)					
ε_{t-1}	-0.771***	0.999	0.139***	-	-0.977***
(0.101)	(63.423)	(0.023)		(0.019)	
ε_{t-2}	-0.151*	-	-0.949***	-	0.980***
(0.084)		(0.027)		(0.019)	
ε_{t-3}	-	-	-0.106***	-0.950***	-
(0.034)	(0.072)				
R^2	0.420	0.012	0.188	0.038	0.172
SER	3.329	12.924	9.779	13.122	4.344
F	82.773	1.049	26.422	7.474	15.212
$D-W$	1.990	1.977	2.002	1.959	1.875
N	577	267	576	576	373
$RMSE$	3.323	12.852	9.748	13.080	4.341

Note: R^2 = R-squared, SER = S.E. of 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*.

[8] See, Phillips and Perron (1988).

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Then, we estimate eq. (14) to determine the speed of adjustment (Θ) and it is shown in Table 2a. For the \$/€ exchange rate, the $\frac{1}{\Theta} = -0.011^{**}$ (statistically significant at the 5% level); so, $\Theta = 90.909$ there is overshooting, the monetarist model is not correct. The \$/£ exchange rate has $\frac{1}{\Theta} = -0.007^{***}$ (statistically significant at the 1% level), which gives a $\Theta = 142.857$; there is overshooting, here, too (the monetarist model is not correct). Then, the C\$/\$ exchange rate gives $\frac{1}{\Theta} = 0.006^{***}$ (significant at the 1% level) and $\Theta = 166.667$, which shows overshooting of exchange rate. Lastly, the ¥/\$ exchange rate has a $\frac{1}{\Theta} = -0.019^{***}$ (statistically significant at the 1% level) and its $\Theta = 52.632$; thus, the monetarist model is not correct, overshooting takes place.

Table 2a Estimation of the Overshooting Model, Eq. (14)

$$s_t = \alpha(m_t - m_t^*) - \beta(y_t - y_t^*) + \gamma(g_{m_t} - g_{m_t^*}) - \frac{1}{\Theta}[(i_t - \pi_t^e) - (i_t^* - \pi_t^{*e})] + \varepsilon_t$$

	α	β	γ	$\frac{1}{\Theta}$	R^2	SSR	F	$D-W$	N
\$/€	-0.220*** (0.079)	0.093*** (0.008)	0.001* (0.001)	-0.011** (0.001)	0.085	5.570	-	0.075	262
\$/£	0.380*** (0.035)	0.101*** (0.022)	-0.001 (0.001)	-0.007*** (0.002)	0.262	3.893	-	0.120	371
C\$/\$	0.217*** (0.014)	-0.123*** (0.014)	0.001 (0.001)	0.006*** (0.002)	0.312	4.891	-	0.064	478
¥/\$	0.432** (0.171)	-1.877*** (0.224)	0.003 (0.002)	-0.019*** (0.004)	0.199	11.568	-	0.098	282

Note: See, Table 1.
Source: See, Table 1.

Now, we run eq. (14) by correcting the serial correlation of the error term and the results are given in Table 2b. For the \$/€ exchange rate $\frac{1}{\Theta} = -0.001 \cong 0$ (statistically insignificant); thus, $\Theta \cong \infty$ and we have instantaneous adjustment of prices (no overshooting, but monetarist model is

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Table 2b Estimation of the Overshooting Model, Eq. (14), with Correction of Serial Correlation

$$s_t = \alpha(m_t - m_t^*) - \beta(y_t - y_t^*) + \gamma(g_{m_t} - g_{m_t^*}) - \frac{1}{\Theta}[(i_t - \pi_t^e) - (i_t^* - \pi_t^{*e})] + \varepsilon_t$$

	\$/€	\$/£	C\$/\$	¥/\$
α	-0.001	0.340***	0.168***	-0.611***
	(0.047)	(0.047)	(0.009)	(0.115)
β	0.085***	0.073**	-0.074***	-0.513***
	(0.008)	(0.029)	(0.009)	(0.151)
γ	0.001	-0.001**	-0.001***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
$\frac{1}{\Theta}$	-0.001	0.001	-0.001***	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
ε_{t-1}	1.575***	1.441***	1.557***	1.785***
	(0.050)	(0.052)	(0.030)	(0.055)
ε_{t-2}	1.805***	1.468***	1.869***	2.148***
	(0.091)	(0.081)	(0.055)	(0.093)
ε_{t-3}	1.500***	1.412***	1.593***	1.959***
	(0.107)	(0.091)	(0.068)	(0.108)
ε_{t-4}	0.885***	1.216***	1.023***	1.291***
	(0.096)	(0.092)	(0.059)	(0.099)
ε_{t-5}	0.280***	0.792***	0.457***	0.486***
	(0.058)	(0.081)	(0.034)	(0.060)
ε_{t-6}	-	0.313***	-	-
		(0.051)		
R^2	0.942	0.958	0.967	0.915
SSR	0.297	0.223	0.233	0.448
F	-	-	-	-
$D-W$	1.739	1.805	1.697	1.657
N	262	371	478	282

Note: See, Table 1.
Source: See, Table 1.

correct). For the \$/£, the $\frac{1}{\Theta} = 0.001 \cong 0$ (statistically insignificant) and $\Theta \cong \infty$, the monetarist model is correct, there is no overshooting, here. The C\$/\$ exchange rate gives $\frac{1}{\Theta} = -0.001^{***}$ (significant at the 1% level) and $\Theta = 1{,}000$, which shows a relatively high speed of adjustment, but not instantaneous (overshooting still holds). Finally, the ¥/$ exchange rate shows $\frac{1}{\Theta} = -0.001 \cong 0$ (statistically insignificant), which gives a $\Theta \cong 0$ and the monetarist model is not correct, there is no overshooting.

Further, we estimate eq. (17) to test if there is price inertia and the results are presented in Table 3a. Starting with $/€ exchange rate, $\frac{1}{\Theta} = 0.007 \cong 0$ (statistically insignificant); then, $\Theta \cong \infty$ and no price inertia takes place. The $/£ exchange rate has an $\frac{1}{\Theta} = 0.003 \cong 0$ (insignificant); then, $\Theta \cong \infty$ and the monetarist model is correct. The C$/$ gives $\frac{1}{\Theta} = -0.006^{***}$ (statistically significant at the 1% level); so, $\Theta = 166.667$ which shows that there is overshooting. Lastly, the ¥/$ exchange rate has $\frac{1}{\Theta} = -0.006 \cong 0$ (statistically insignificant); then $\Theta \cong \infty$, instantaneous price adjustment.

Table 3a Estimation of the Overshooting Model, Eq. (17)

$$s_t = \alpha(m_t - m_t^*) - \beta(y_t - y_t^*) + \gamma(g_{m_t} - g_{m_t^*}) + \frac{1}{\Theta}(\pi_t^e - \pi_t^{*e}) + \varepsilon_t$$

	α	β	γ	$\frac{1}{\Theta}$	R^2	SSR	F	$D-W$	N
$/€	-0.228*** (0.080)	0.097*** (0.008)	0.001* (0.001)	0.007 (0.005)	0.103	5.664	-	0.063	262
$/£	0.409*** (0.038)	0.116*** (0.023)	-0.001 (0.001)	0.003 (0.002)	0.232	4.052	-	0.057	371
C$/$	0.228*** (0.015)	-0.137*** (0.015)	0.001 (0.001)	-0.006*** (0.002)	0.309	4.909	-	0.068	478
¥/$	-0.288** (0.14)	-0.930*** (0.192)	0.002 (0.002)	-0.006 (0.005)	0.365	16.516	-	0.035	333

Note: See, Table 1.
Source: See, Table 1.

Furthermore, we correct eq. (17) for the serial correlation of the error term and the results are shown in Table 3b. The $\frac{1}{\Theta} = 0.001 \cong 0$ (statistically insignificant) for the $/€, $/£, and ¥/$ exchange rates; thus, $\Theta \cong \infty$ which shows that the speed of adjustment of prices is infinite. For

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C$/$ exchange rate, $\frac{1}{\Theta} = 0.001^{**} \neq 0$ (statistically significant at 5% level; then $\Theta = 1{,}000$, which means overshooting (a small price inertia exists).

Table 3b Estimation of the Overshooting Model, Eq. (17), with Correction of Serial Correlation

$$s_t = \alpha(m_t - m_t^*) - \beta(y_t - y_t^*) + \gamma(g_{m_t} - g_{m_t^*}) + \frac{1}{\Theta}(\pi_t^e - \pi_t^{*e}) + \varepsilon_t$$

	\$/€	\$/£	C\$/\$	¥/\$
α	-0.001	0.339***	0.168***	-0.870***
	(0.047)	(0.047)	(0.009)	(0.075)
β	0.085***	0.072**	-0.074***	-0.167*
	(0.008)	(0.029)	(0.009)	(0.097)
γ	-0.001	-0.001**	-0.001***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
$\frac{1}{\Theta}$	0.001	-0.001	0.001**	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
ε_{t-1}	1.575***	1.442***	1.556***	1.774***
	(0.050)	(0.051)	(0.030)	(0.050)
ε_{t-2}	1.806***	1.468***	1.868***	2.040***
	(0.091)	(0.081)	(0.055)	(0.088)
ε_{t-3}	1.501***	1.412***	1.591***	1.841***
	(0.108)	(0.091)	(0.068)	(0.104)
ε_{t-4}	0.885***	1.216***	1.023***	1.268***
	(0.096)	(0.092)	(0.059)	(0.094)
ε_{t-5}	0.279***	0.792***	0.457***	0.478***
	(0.058)	(0.081)	(0.034)	(0.054)
ε_{t-6}	-	0.311***	-	-
		(0.051)		
R^2	0.942	0.958	0.967	0.923
SSR	0.297	0.223	0.233	0.536
F	-	-	-	-
$D-W$	1.739	1.806	1.698	1.571
N	262	371	478	333

Note: See, Table 1.
Source: See, Table 1.

The ARDL empirical tests for depicting the short-run movement of the exchange rates caused by changes in money supply are based on eq. (19). The short-run effects of money supply on the exchange rate are inferred by the coefficient α_2 and the long-run effects by the coefficient β_2 (signs and level of significance). Overshooting is a short-run phenomenon. The study also tests whether there is a long-run equilibrium relationship between the exchange rate and the relevant macroeconomic fundamentals.

The estimation of the ARDL model, eq. (19), gives the fallowing results (Table 4a). The money supply differential has no short-run or long-run effect on $\Delta(EUS)$ and consequently, no overshooting, too. The money supply differential has no significant short-run or long-run effect on $\Delta(UKS)$, which shows overshooting. The money supply differential has a significant short-run (0.448*** and 0.383***) effect on $\Delta(CS)$ and a long-run significant (21.345**) effect on $\Delta(CS)$, overshooting exists, too. The money supply differential has a significant short-run effect (0.487*) on $\Delta(JS)$, which shows overshooting, but no long-run significant effect. The insignificant L-R effects show that there are no L-R equilibrium relationships between the exchange rates and the macro fundamentals; these exchange rates are affected by trade, capital flows, and speculations.

Table 4a Estimation of the ARDL Model, Eq. (19)

$$\Delta s_t = \alpha_0 + \sum_{j=1}^{n}\alpha_1 \Delta s_{t-j} + \sum_{j=0}^{n}\alpha_2 \Delta(m_{t-j} - m^*_{t-j}) + \sum_{j=0}^{n}\alpha_3 \Delta(y_{t-j} - y^*_{t-j}) + \sum_{j=0}^{n}\alpha_4 \Delta(r_{t-j} - r^*_{t-j})$$

$$+ \sum_{j=0}^{n}\alpha_5 \Delta(\pi^e_{t-j} - \pi^{*e}_{t-j}) + \beta_1 s_{t-1} + \beta_2(m_{t-1} - m^*_{t-1}) + \beta_3(y_{t-1} - y^*_{t-1}) + \beta_4(r_{t-1} - r^*_{t-1}) + \beta_5(\pi^e_{t-1} - \pi^{*e}_{t-1}) + \varepsilon_t$$

	Δs_t (\$/€)	Δs_t (\$/£)	Δs_t (C\$/\$)	Δs_t (¥/\$)
α_0	-7.501	99.214	-33.136**	236.515**
	(24.799)	(166.703)	(14.028)	(95.767)
Δs_{t-1}	0.158**	0.230***	-0.098**	0.308***
	(0.064)	(0.053)	(0.041)	(0.061)
Δs_{t-2}	0.053	-0.071	0.026	0.060
	(0.064)	(0.051)	(0.035)	(0.059)
$\Delta(m_t - m^*_t)$	-0.007	0.124	0.448***	-0.288
	(0.011)	(0.091)	(0.028)	(0.278)
$\Delta(m_{t-1} - m^*_{t-1})$	0.014	-0.137	0.383***	0.487*
	(0.010)	(0.091)	(0.032)	(0.274)
$\Delta(y_t - y^*_t)$	0.026	0.130	-0.011	-0.002
	(0.039)	(0.225)	(0.014)	(0.149)
$\Delta(y_{t-1} - y^*_{t-1})$	0.093**	-0.263	0.021	0.088
	(0.042)	(0.223)	(0.014)	(0.154)
$\Delta(r_t - r^*_t)$	15.384	-21.667***	-1.195	31.367***

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	(10.255)	(5.389)	(1.701)	(11.048)
$\Delta(r_{t-1}-r^{*}_{t-1})$	5.491	-19.482***	1.072	-10.414
	(10.240)	(5.521)	(1.706)	(11.125)
$\Delta(\pi^{e}_{t}-\pi^{*e}_{t})$	15.468	-21.485***	-0.677	31.209***
	(10.252)	(5.399)	(1.705)	(11.017)
$\Delta(\pi^{e}_{t-1}-\pi^{*e}_{t-1})$	5.495	-19.403***	0.972	-10.290
	(10.237)	(5.524)	(1.707)	(11.160)
s_{t-1}	-20.762	-39.964**	-31.658***	-38.723***
	(17.120)	(17.106)	(10.637)	(14.884)
$(m_{t-1}-m^{*}_{t-1})$	-26.842	14.258	21.345**	29.353
	(20.661)	(13.516)	(8.824)	(27.785)
$(y_{t-1}-y^{*}_{t-1})$	7.704	33.641	-5.335	-20.539
	(12.297)	(45.968)	(3.284)	(39.545)
$(r_{t-1}-r^{*}_{t-1})$	-0.840	-0.840	-1.044**	3.224**
	(1.936)	(1.453)	(0.529)	(1.631)
$(\pi^{e}_{t-1}-\pi^{*e}_{t-1})$	-0.736	-1.123	0.036	3.337**
	(1.945)	(1.462)	(0.532)	(1.675)
R^2	0.086	0.204	0.483	0.180
SER	28.845	24.749	14.840	29.177
F	1.521	6.040	28.681	3.866
$D-W$	2.014	1.925	2.139	2.040
N	259	370	476	280

Note: See, Table 1.
Source: See, Table 1.

We continue with some Augmented Dickey Fuller (ADF) and Phillips & Peron (PP) tests (Table A1) and cointegration ones. We run a VAR estimation to see the short-run [$\Delta(m_t-m^{*}_t)$] effect, Table A2.1 and the long-run [$(m_t-m^{*}_t)$] effect, Table A3.1, of money supply on the four exchange rate ($/€, $/£, C$/$, and ¥/$) and their cointegration tests, Table A2.2 and Table A3.2. We reject the null hypothesis of no cointegration at the 5% level. Both tables report 4 cointegrating relations. Then, the series are cointegrated.

We try to interpret the VAR estimations. First, the VAR (short-run effects, S-R E), Table A2.1, shows the followings. The $\Delta(EUS)$ is affected by $\Delta(EUS_{t-1})$ (0.141*), by $\Delta(CS_{t-1})$ (-0.153*) and $\Delta(USM2-CM2)$ (-0.204**). The $\Delta(UKS)$ is affected by $\Delta(EUS_{t-1})$ (0.275***), by $\Delta(UKS_{t-2})$ (0.118*), by $\Delta(CS_{t-1})$ (-0.163***), by $\Delta(JS_{t-2})$ (0.105*), by $\Delta(USM2-UKM2)$ (0.125***) (S-R E), $\Delta(USM2-CM2)$ (-0.108***) and by $\Delta(USM2-JM2)$ (-0.319*). The $\Delta(CS)$ is affected by $\Delta(EUS_{t-1})$ (-0.217***) by $\Delta(UKS_{t-1})$ (0.122*), by $\Delta(USM2-EUM2)$ (-0.012**), by $\Delta(USM2-CM2)$ (0.267***) (S-

R E) and by $\Delta(USM2-JM2)$ (0.468***). The $\Delta(JS)$ is affected by $\Delta(CS_{t-1})$ (0.140*) by $\Delta(JS_{t-1})$ (0.225***) by $\Delta(JS_{t-2})$ (0.104*) and by $\Delta(USM2-JM2)$ (-0.564***) (S-R E).

Now, Table A3.1 (the long-run effects, L-R E) gives the following results. The $\Delta(EUS)$ is affected by $\Delta(CS_{t-1})$ (-0.160*). The $\Delta(UKS)$ is affected by $\Delta(EUS_{t-1})$ (0.266***), by $\Delta(CS_{t-1})$ (-0.186***), by $\Delta(USM2-EUM2)$ (25.639***). The $\Delta(CS)$ is affected by $\Delta(EUS_{t-1})$ (-0.185***), by $\Delta(USM2-EUM2)$ (-28.118***), by $\Delta(USM2-CM2)$ (24.824***) (L-R E) and by $\Delta(USM2-JM2)$ (34.820***). The $\Delta(JS)$ is affected by $\Delta(CS_{t-1})$ (0.097*), by $\Delta(JS_{t-1})$ (0.225***) and by $\Delta(USM2-UKM2)$ (32.379*).

In the Appendix, we present different figures that give some good information on the exchange rate determination, too. Figure A1a plots the EUS exchange rate. Figure A1b shows that the L-R trend of EUS ($/€) is positive. The U.S. dollar is depreciated with respect the euro. Figure A1c shows that PPP does not hold in the S-R. The interest differential between U.S. and EMU is very small until 2016; after 2016, the EMU interest rate is negative and the deviation between the two rates is increasing, Figure A1d. Then, we forecast E(EUS) by using the UIP, eq. (3) and we have a perfect forecasting, Figure A1e.

Figure A2a gives the UKS ($/£) exchange rate. Figure A2b shows a negative trend; the dollar is appreciated with respect the pound. Figure A2c shows that PPP does not hold. Figure A2d gives the interest differential between U.S. and U.K. Until 2009, the UKST3M > STT3M; after that date the difference became very small and after 2018, the STT3M exceeds the UKST3M rate. Figure A2e shows the forecasting of E(UKS) by using the UIP and gives very good results.

Figure A3a gives the CS (C$/$) exchange rate, Figure A3b shows a small positive trend; the Canadian dollar is depreciated a little. Figure A3c shows the PPP, which does not hold. Figure A3d gives the interest differential (STT3M-CTB), which shows the CTB > STT3M until 2018; after that date the STT3M > CTB. Figure A3e gives the forecasting of the E(CS) by using the UIP and it is a very good forecasting.

Lastly, Figure A4a presents the JS (¥/$) exchange rate. The yen is appreciated (negative slope) with respect the U.S. dollar, Figure A4b. The PPP does not hold at all between the two countries, Japan and U.S. (different price indexes), Figure A4c. The interest differential is closed to zero, Figure A4d. Then, Figure A4e is forecasting the E(JS) by using the UIP, the results are also good.

IV. Conclusion

The purpose of this research has been to outline two approaches to the testing of dynamic models of exchange rate determination. These approaches are based upon the idea that it is difficult to measure directly the process by which market participants revise their expectations about current and future money supplies. On the other hand, it is possible to make indirect inferences about these expectations through a time series analysis of related financial and real variables. Dornbusch (1976) assumed that asset markets adjust instantaneously, whereas prices and wages in goods and labor markets adjust gradually (slowly). These exchange rate dynamics models retain all the long run equilibrium or steady state properties of the monetary approach, but in the short run the exchange rate and the interest rate can diverge from their long run levels, so monetary policy can have effects on real variables (production) in the system. Lately, since December 2008, uncertainty has increased because the Fed has reduced the federal funds rate to zero, due to the global financial crisis and the global destruction with the Wuhan virus; the economy had not been stabilized yet. Prices were expected to change, due to this enormous liquidity in the U.S. Now, we see a double digit inflation and an enormous bubble in the stock market. Thus, these public policies (mostly monetary and less fiscal) and strange politics are ineffective, inefficient, and very risky.

The empirical results are as follows. Table 2a shows overshooting of the four exchange rates, but there are serial correlations of the error terms. Correcting the serial correlations (Table 2b), we have overshooting only of the CS (C$/$), the other three exchange rates have instantaneous adjustments (the monetarist model is correct); it is price inertia only in Canada. Table 3a shows overshooting only of the CS, but there are serial correlations, too. Then, we correct these serial correlations and the results show again overshooting only of the CS rate; the other three exchange rates are adjusted instantaneously. The results from the ARDL (Table 4a) show a S-R effect of the change of money supply differential [$\Delta(m_t - m_t^*)$ and $\Delta(m_{t-1} - m_{t-1}^*)$] on Δs_t (C$/$) and there is a S-R effect only of the $\Delta(m_{t-1} - m_{t-1}^*)$ on the Δs_t (¥/$); overshooting. Long-run effect exists only on the Δs_t (C$/$). For the other three exchange rates, it shows that there are no L-R equilibrium relationships between the exchange rates and the macro fundamentals. Thus, monetary policy in U.S., U.K., EMU, and Japan have no effects on exchange rates; only speculations, trades, and capita flows affect these three rates.

As a summary, in an empirical test of the process to the Dornbusch model of exchange rate dynamics by using eqs. (14), (17), and the ARDL model, eq. (19), it was shown that the monetarist model is correct for the ($/€), ($/£), and (¥/$) exchange rates ($\Theta \cong \infty$), which means that prices are adjusted instantaneously in the U.S. and Euro-zone, U.K., and Japanese economies. For the Canadian dollar exchange rate (C$/$), the overshooting takes place (gradual adjustment of prices). The speed of adjustment of prices for the C$/$ exchange rate is relatively high ($\Theta = 1{,}000$). It follows by the ¥/$ exchange rate, which shows relatively price stickiness. Thus, the monetarist model does not hold for the CS (C$/$) exchange rate; this exchange rate is overshooting in the short-run. By using eq. (19), the C$/$ and the ¥/$ exchange rates show price inertia (overshooting); the other two exchange rates show instantaneous price adjustment (monetarist model is correct). Consequently, results are mixed, here, so more research is needed to evaluate the two models, monetarist and overshooting. It is obvious that countries with some price controls (socialists-liberals) the overshooting takes place.

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Appendix

Table A1
Augmented Dickey-Fuller and Phillips-Perron Unit Root Tests

Variables In levels [yt]	ADF	I(d)	PP	I(d)	Variables in 1st differences [Δ(yt)]	ADF	I(d)	PP	I(d)
EUS	2.029	I(1)	1.812	I(1)	Δ(EUS)	6.777***	I(1)	13.648***	I(1)
LEUS	1.859	I(1)	1.695	I(1)	Δ(LEUS)	6.884***	I(1)	13.409***	I(1)
GEUS	6.884***	I(0)	13.409***	I(0)	Δ(GEUS)	12.194***	I(1)	33.630***	I(1)
UKS	2.634*	I(0)	2.443	I(1)	Δ(UKS)	10.369***	I(1)	16.786***	I(1)
LUKS	2.585*	I(0)	2.400	I(1)	Δ(LUKS)	10.428***	I(1)	17.259***	I(1)
GUKS	10.428***	I(0)	17.259***	I(0)	Δ(GUKS)	16.894***	I(1)	41.558***	I(1)
CS	2.022	I(1)	1.912	I(1)	Δ(CS)	9.833***	I(1)	19.636***	I(1)
LCS	2.057	I(1)	1.941	I(1)	Δ(LCS)	9.664***	I(1)	20.543***	I(1)
GCS	9.664***	I(0)	20.543***	I(0)	Δ(GCS)	17.747***	I(1)	53.249***	I(1)
JS	2.836*	I(0)	2.835*	I(0)	Δ(JS)	9.669***	I(1)	17.392***	I(1)
LJS	2.140	I(1)	2.104	I(1)	Δ(LJS)	10.913***	I(1)	17.588***	I(1)
GJS	10.913***	I(0)	17.588***	I(0)	Δ(GJS)	16.371***	I(1)	43.202***	I(1)
USCPI	4.249***	I(0)	4.679***	I(0)	Δ(USCPI)	10.867***	I(1)	16.058***	I(1)
LUSCPI	1.184	I(1)	1.581	I(1)	Δ(LUSCPI)	7.662***	I(1)	16.624***	I(1)
USINF	7.662***	I(0)	16.624***	I(0)	Δ(USINF)	20.977***	I(1)	57.910***	I(1)
EUHICP	1.730	I(1)	1.785	I(1)	Δ(EUHICP)	7.864***	I(1)	17.079***	I(1)
LEUHICP	1.832	I(1)	1.906	I(1)	Δ(LEUHICP)	7.842***	I(1)	17.220***	I(1)
EUINF	7.842***	I(0)	17.220***	I(0)	Δ(EUIBF)	14.510***	I(1)	46.656***	I(1)
UKCPI	0.243	I(1)	0.275	I(1)	Δ(UKCPI)	12.271***	I(1)	27.522***	I(1)
LUKCPI	2.867***	I(0)	3.238***	I(0)	Δ(LUKCPI)	8.559***	I(1)	23.374***	I(1)
UKINF	8.559***	I(0)	23.374***	I(0)	Δ(UKINF)	23.757***	I(1)	74.734***	I(1)
CCPI	2.079	I(1)	2.077	I(1)	Δ(CCPI)	10.618***	I(1)	24.324***	I(1)
LCCPI	5.109***	I(0)	5.669***	I(0)	Δ(LCCPI)	9.115***	I(1)	23.285***	I(1)
CINF	9.115***	I(0)	23.285***	I(0)	Δ(CINF)	18.545***	I(1)	64.899***	I(1)
JCPI	4.026***	I(0)	4.456***	I(0)	Δ(JCPI)	8.587***	I(1)	16.296***	I(1)
LJCPI	4.136***	I(0)	4.606***	I(0)	Δ(LJCPI)	8.547***	I(1)	16.275***	I(1)
JINF	8.547***	I(0)	16.275***	I(0)	Δ(JINF)	16.743***	I(1)	43.036***	I(1)
USM2	7.027***	I(0)	10.171***	I(0)	Δ(USM2)	6.369***	I(1)	11.152***	I(1)
LUSM2	0.952	I(1)	0.848	I(1)	Δ(LUSM2)	9.562***	I(1)	23.090***	I(1)
GUSM2	9.562***	I(0)	23.090***	I(0)	Δ(GUSM2)	21.126***	I(1)	61.096***	I(1)
EUM2	4.419***	I(0)	15.139***	I(0)	Δ(EUM2)	14.554***	I(1)	51.373***	I(1)
LEUM2	0.449	I(1)	1.635	I(1)	Δ(LEUM2)	14.544***	I(1)	51.777***	I(1)
GEUM2	14.544***	I(0)	51.777***	I(0)	Δ(GEUM2)	19.012***	I(1)	91.901***	I(1)

UKM2	2.220	I(1)	2.238	I(1)	Δ(UKM2)	7.843***	I(1)	18.595***	I(1)
LUKM2	0.121	I(1)	0.027	I(1)	Δ(LUKM2)	8.424***	I(1)	19.271***	I(1)
GUKM2	8.424***	I(0)	19.271***	I(0)	Δ(GUKM2)	14.885***	I(1)	51.369***	I(1)
CM2	3.691***	I(0)	4.428***	I(0)	Δ(CM2)	9.457***	I(1)	26.192***	I(1)
LCM2	1.074	I(1)	1.223	I(1)	Δ(LCM2)	9.597***	I(1)	25.838***	I(1)
GCM2	9.597***	I(0)	25.838***	I(0)	Δ(GCM2)	18.188***	I(1)	73.117***	I(1)
JM2	3.954***	I(0)	5.017***	I(0)	Δ(JM2)	5.615***	I(1)	10.724***	I(1)
LJM2	2.124	I(1)	1.461	I(1)	Δ(LJM2)	6.431***	I(1)	14.300***	I(1)
GJM2	6.431***	I(0)	14.300***	I(0)	Δ(GJM2)	13.617***	I(1)	41.498***	I(1)
USRGDP	1.958	I(1)	1.824	I(1)	Δ(USRGDP)	15.190***	I(1)	31.032***	I(1)
LUSRGDP	2.655*	I(0)	2.924**	I(0)	Δ(LUSRGDP)	13.206***	I(1)	32.524***	I(1)
GUSRGDP	13.206***	I(0)	32.524***	I(0)	Δ(GUSRGDP)	25.977***	I(1)	89.062***	I(1)
EUGDP	0.970	I(1)	0.944	I(1)	Δ(EUGDP)	8.897***	I(1)	17.249***	I(1)
LEUGDP	1.188	I(1)	1.110	I(1)	Δ(LEUGDP)	8.915***	I(1)	17.277***	I(1)
GEUGDP	8.915***	I(0)	17.277***	I(0)	Δ(GEUGDP)	15.844***	I(1)	41.782***	I(1)
UKGDP	0.382	I(1)	0.275	I(1)	Δ(UKGDP)	9.971***	I(1)	19.738***	I(1)
LUKGDP	0.026	I(1)	0.071	I(1)	Δ(LUKGDP)	9.988***	I(1)	19.914***	I(1)
GUKGDP	9.988***	I(0)	19.914***	I(0)	Δ(GUKGDP)	15.482***	I(1)	52.253***	I(1)
CGDP	0.337	I(1)	0.354	I(1)	Δ(CGDP)	9.687***	I(1)	21.884***	I(1)
LCGDP	0.057	I(1)	0.041	I(1)	Δ(LCGDP)	9.798***	I(1)	22.160***	I(1)
GCGDP	9.798***	I(0)	22.160***	I(0)	Δ(GCGDP)	16.810***	I(1)	59.200***	I(1)
JGDP	3.774***	I(0)	3.404***	I(0)	Δ(JGDP)	8.433***	I(1)	19.049***	I(1)
LJGDP	4.247***	I(0)	3.788***	I(0)	Δ(LJGDP)	8.394***	I(1)	18.941***	I(1)
GJGDP	8.394***	I(0)	18.941***	I(0)	Δ(GJGDP)	14.146***	I(1)	48.640***	I(1)
STT3M	2.118	I(1)	2.113	I(1)	Δ(STT3M)	12.328***	I(1)	19.908***	I(1)
EU3MDL	1.358	I(1)	0.796	I(1)	Δ(EU3MDL)	5.633***	I(1)	10.537***	I(1)
UKST3M	1.316	I(1)	1.388	I(1)	Δ(UKST3M)	9.634***	I(1)	19.565***	I(1)
CTB	1.509	I(1)	1.533	I(1)	Δ(CTB)	10.961***	I(1)	18.964***	I(1)
JST3M	6.481***	I(0)	4.631***	I(0)	Δ(JST3M)	6.520***	I(1)	17.603***	I(1)

Note: * = significant at the 10% level, ** = significant at the 5% level, *** = significant at the 1% level, ADF = Augmented Dickey-Fuller Test Statistic, PP = Phillips-Perron Test Statistic, I(d) = series contains d unit roots and is of integrated order d (if yt contains unit roots is nonstationary), EUS = \$/€ spot exchange rate, UKS = \$/£ exchange rate, CS = C\$/\$ exchange rate, JS = ¥/\$ exchange rate, LEUS = ln of EUS, USCPI = U.S. Consumer Price Index, EUHICP = EU Harmonized Index of Consumer Price, USINF = U.S. inflation rate, USM2 = U.S. money supply (M2), USRGDP = U.S. Real Gross Domestic Product, EUGDP = EU Gross Domestic Product, STT3M = U.S. T-Bill Rate (3-months), EU3MDL = EU 3-months deposit LIBOR, UKST3M = U.K. short-term 3-month rate, CTB = Canadian T-Bill rate, JST3M = Japanese short-term 3-month rate.
Source, *Economagic.com*, *FRED*, *Bloomberg*, *ECB.*

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Table A2.1
Vector Autoregression Estimates: Short-Run Effects

	Δs_t (\$/€)	Δs_t (\$/£)	Δs_t (C\$/\$)	Δs_t (¥/\$)
Δs_{t-1} (\$/€)	0.141*	0.275***	-0.217***	-0.003
	(0.077)	(0.063)	(0.061)	(0.071)
Δs_{t-2} (\$/€)	0.045	-0.065	0.068	0.066
	(0.080)	(0.065)	(0.063)	(0.074)
Δs_{t-1} (\$/£)	-0.023	-0.004	0.122*	0.135
	(0.093)	(0.076)	(0.073)	(0.085)
Δs_{t-2} (\$/£)	-0.055	0.118*	0.001	-0.101
	(0.089)	(0.073)	(0.070)	(0.062)
Δs_{t-1} (C\$/\$)	-0.153*	-0.163***	0.086	0.140*
	(0.081)	(0.067)	(0.064)	(0.075)
Δs_{t-2} (C\$/\$)	0.049	0.048	0.010	-0.044
	(0.081)	(0.066)	(0.064)	(0.075)
Δs_{t-1} (¥/\$)	-0.049	-0.011	0.014	0.225***
	(0.069)	(0.057)	(0.054)	(0.064)
Δs_{t-2} (¥/\$)	-0.047	0.105*	-0.021	0.104*
	(0.069)	(0.056)	(0.054)	(0.063)
α_0	-1.078	0.263	-1.793	1.871
	(1.064)	(1.609)	(1.544)	(1.812)
$\Delta(m_t - m_t^*)$	-0.002	0.012	-0.012**	0.008
(\$/€)	(0.007)	(0.006)	(0.006)	(0.007)
$\Delta(m_t - m_t^*)$	-0.001	0.125***	-0.066	0.091
(\$/£)	(0.063)	(0.052)	(0.050)	(0.058)
$\Delta(m_t - m_t^*)$	-0.204***	-0.108***	0.267***	0.014
(C\$/\$)	(0.049)	(0.040)	(0.038)	(0.045)
$\Delta(m_t - m_t^*)$	0.232	-0.319*	0.468***	-0.564***
(¥/\$)	(0.233)	(0.191)	(0.163)	(0.215)
R^2	0.130	0.233	0.263	0.127
SER	27.942	22.879	21.959	25.777
F	3.079	6.287	7.378	3.003
N	261	261	261	261

Note: See, Tables 1 and A1.
Source: See, Table 1.

Table A2.2
Johansen Cointegration Test

Series: $\Delta(EUS)$, $\Delta(UKS)$, $\Delta(CS)$, $\Delta(JS)$

Exogenous Series: $\Delta(USM2-EUM2)$, $\Delta(USM2-UKM2)$, $\Delta(USM2-CM2)$, $\Delta(USM2-JM2)$

Rank	Eigenvalue	Trace Stat	Crit. Value(0.05)	Max-Eigen Stat	Crit Value(0.05)
$r=0^*$	0.346	322.925	47.856	110.278	27.584
$r\le 1^*$	0.312	211.748	29.797	97.256	21.132
$r\le 2^*$	0.220	114.492	15.495	64.644	14.265
$r\le 3^*$	0.174	49.848	3.841	49.848	3.841

Note: Trace test indicates 4 cointegrating eqs at the 5% level.
* denotes rejection of the hypothesis at the 5% level.
Source: VAR of Table A2.1.

Table A3.1
Vector Autoregression Estimates: Long-Run Effects

	Δs_t (\$/€)	Δs_t (\$/£)	Δs_t (C\$/\$)	Δs_t (¥/\$)
Δs_{t-1} (\$/€)	0.119	0.266***	-0.185***	-0.008
	(0.079)	(0.064)	(0.067)	(0.071)
Δs_{t-2} (\$/€)	0.083	-0.029	0.023	0.063
	(0.082)	(0.066)	(0.068)	(0.073)
Δs_{t-1} (\$/£)	-0.024	-0.024	0.092	0.131
	(0.096)	(0.077)	(0.080)	(0.086)
Δs_{t-2} (\$/£)	-0.089	0.079	0.038	-0.106
	(0.091)	(0.074)	(0.077)	(0.082)
Δs_{t-1} (C\$/\$)	-0.160*	-0.186***	0.096	0.097*
	(0.084)	(0.068)	(0.070)	(0.075)
Δs_{t-2} (C\$/\$)	0.044	0.032	0.003	-0.074
	(0.085)	(0.069)	(0.071)	(0.076)
Δs_{t-1} (¥/\$)	-0.069	-0.023	0.011	0.225***
	(0.072)	(0.057)	(0.060)	(0.064)
Δs_{t-2} (¥/\$)	-0.061	0.080	-0.004	0.084
	(0.071)	(0.058)	(0.060)	(0.064)
α_0	1.210	-32.692	54.552*	2.481
	(41.344)	(33.404)	(34.605)	(37.186)
$(m_t - m_t^*)$	3.271	25.639***	-28.118***	13.600
(\$/€)	(12.219)	(9.872)	(10.227)	(10.990)
$(m_t - m_t^*)$	-2.508	24.346	23.166	32.379*
(\$/£)	(21.883)	(17.681)	(18.316)	(19.682)
$(m_t - m_t^*)$	-0.161	-17.526	24.824**	-2.281

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(C$/$)	(14.574)	(11.775)	(12.198)	(13.108)	
$(m_t - m_t^*)$	-0.890	-4.947		34.820***	14.040
(¥/$)	(15.878)	(12.828)	(13.290)	(14.280)	
R^2	0.068	0.201		0.105	0.112
SER	28.908	23.356	24.196		25.999
F	1.517	5.197	2.433		2.599
N	261	261		261	261

Note: See, Tables 1 and A1.
Source: See, Table 1.

Table A3.2
Johansen Cointegration Test

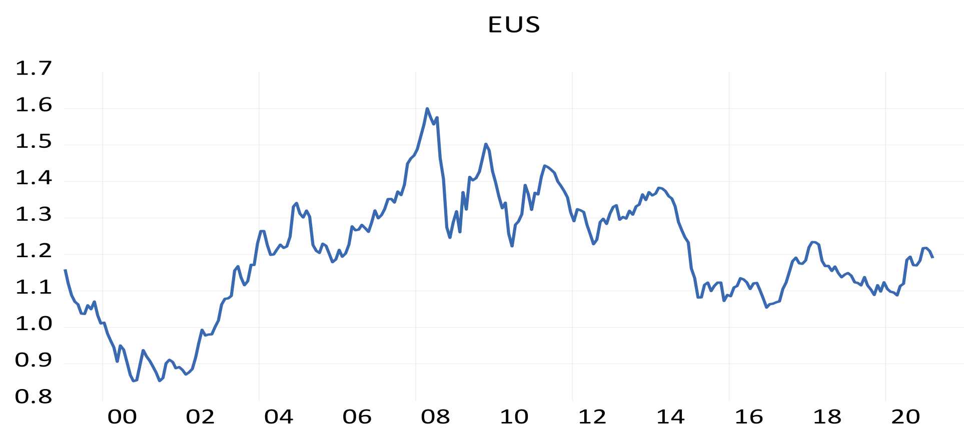
Series: $\Delta(EUS)$, $\Delta(UKS)$, $\Delta(CS)$, $\Delta(JS)$

Exogenous Series: $(LUSM2 - LEUM2)$, $(LUSM2 - LUKM2)$, $(LUSM2 - LCM2)$, $(LUSM2 - LJM2)$

Rank	Eigenvalue	Trace Stat	Crit. Value(0.05)	Max-Eigen Stat	Crit Value(0.05)
$r = 0^*$	0.310	302.911	47.856	96.611	27.584
$r \leq 1^*$	0.287	206.300	29.797	87.776	21.132
$r \leq 2^*$	0.231	118.524	15.495	68.145	14.265
$r \leq 3^*$	0.176	50.379	3.841	50.379	3.841

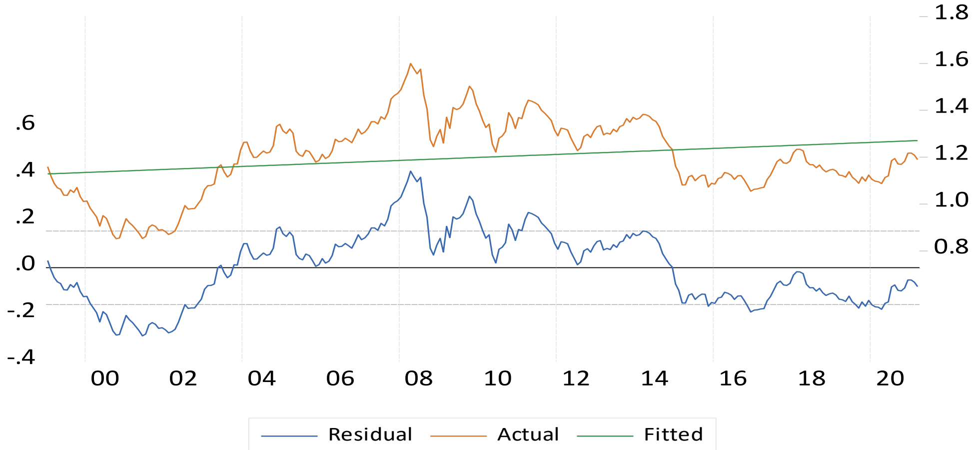
Note: Trace test indicates 4 cointegrating eqs at the 5% level.
* denotes rejection of the hypothesis at the 5% level.
Source: VAR of Table A3.1.

Figure A1a
The Exchange Rate ($/€)



Note: EUS = the dollar/euro exchange rate ($/€).
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

Figure A1b
The Exchange Rate ($/€) and its L-R Trend



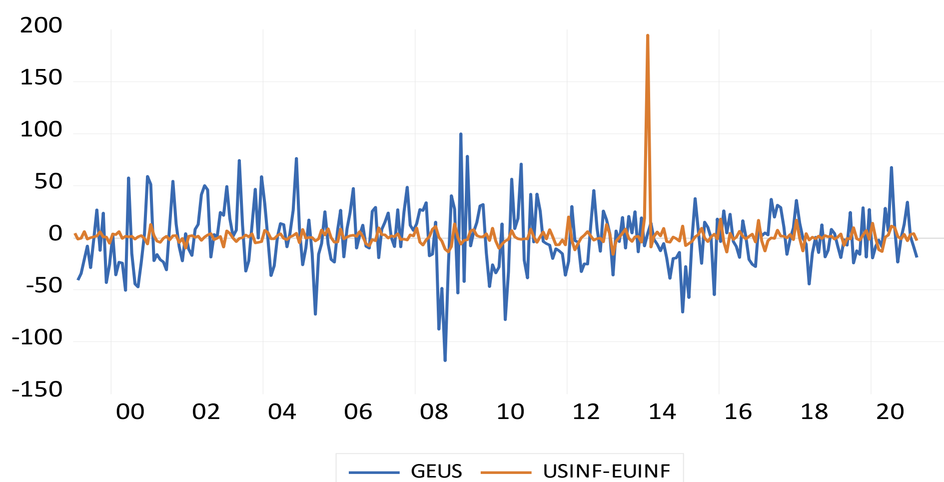
Note: Actual = the EUS = the dollar/euro exchange rate ($/€) and Fitted = the L-R Trend.

$$\underset{}{EUS} = \underset{(0.019)}{1.128^{***}} + \underset{(0.001)}{0.001^{***}}\, t$$

$R^2 = 0.065$, $SER = 0.157$, $F = 18.445$, $D-W = 0.036$, $N = 267$

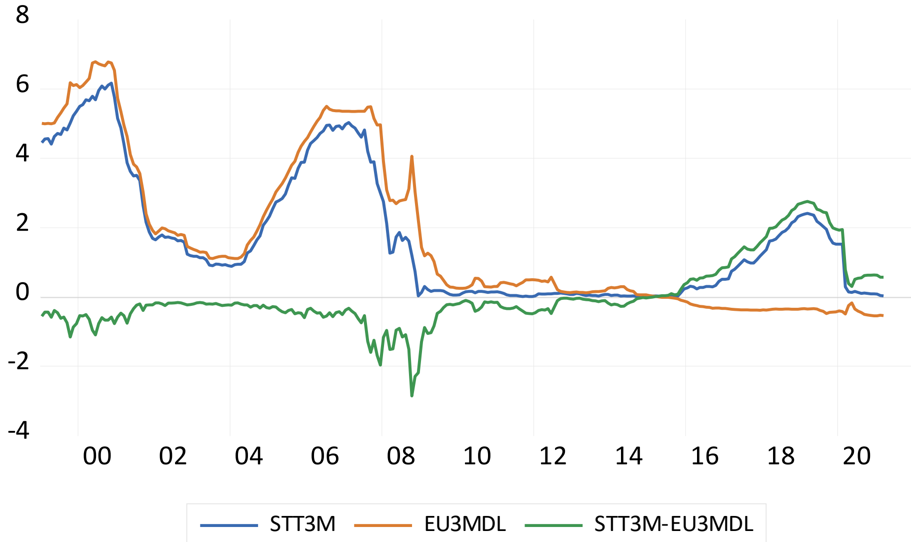
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB.*

Figure A1c
The Change of Exchange Rate ($/€) and the Inflation Differential



Note: GEUS = growth of exchange rate the dollar/euro exchange rate ($/€) and USINF-EUINF = U.S. inflation minus EU inflation.
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB.*

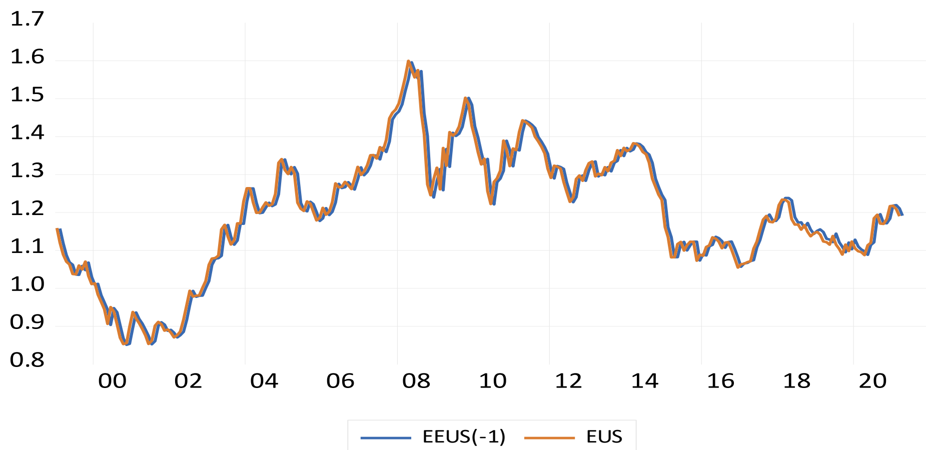
Figure A1d
The Interest Rates and the Interest Rate Differential between U.S. and EU



Note: STT3M = short-term 3-month T-Bill rate, EU3MDL = EU 3-month deposit rate LIBOR, and STT3M-EU3MDL= interest rate deferential.

Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

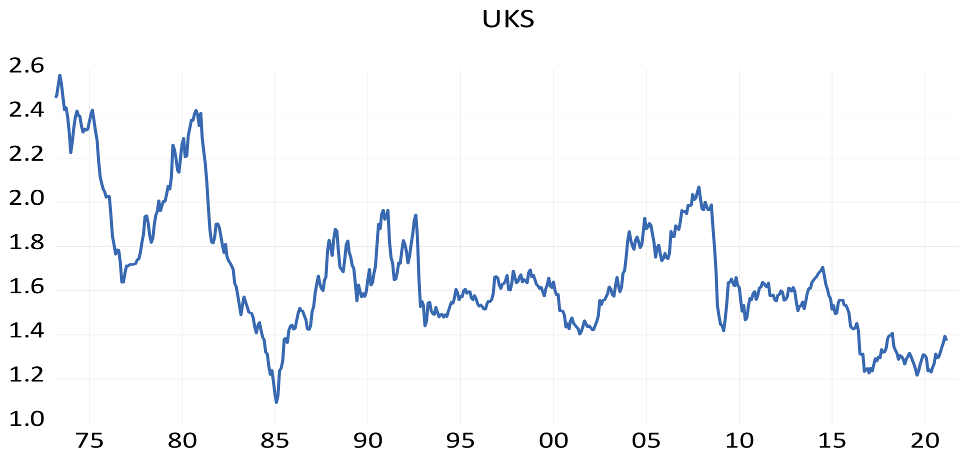
Figure A1e
Forecasting $E(EUS) = s_{t+1}^{e}$



Note: $E(EUS) = s_{t+1}^{e} = i_t - i_t^* + s_t$.
The $E(E\overline{US}_{t-1}) = 1.199869$ (\$/€) and $\sigma_{E(EUS_{t-1})} = \pm 0.161647$; $EU\overline{S} = 1.199973$ and $\sigma_{EUS} = \pm 0.162173$; $\rho_{E(EUS_{t-1}),\, EUS} = +0.982884$

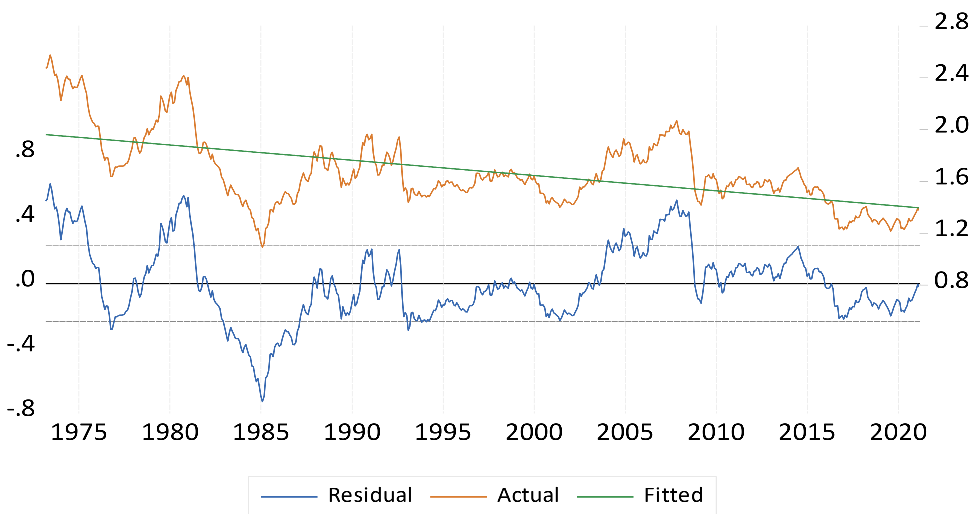
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB.*

Figure A2a
The Exchange Rate ($/£)



Note: UKS = the dollar/pound exchange rate ($/£).
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

Figure A2b
The Exchange Rate ($/£) and its L-R Trend



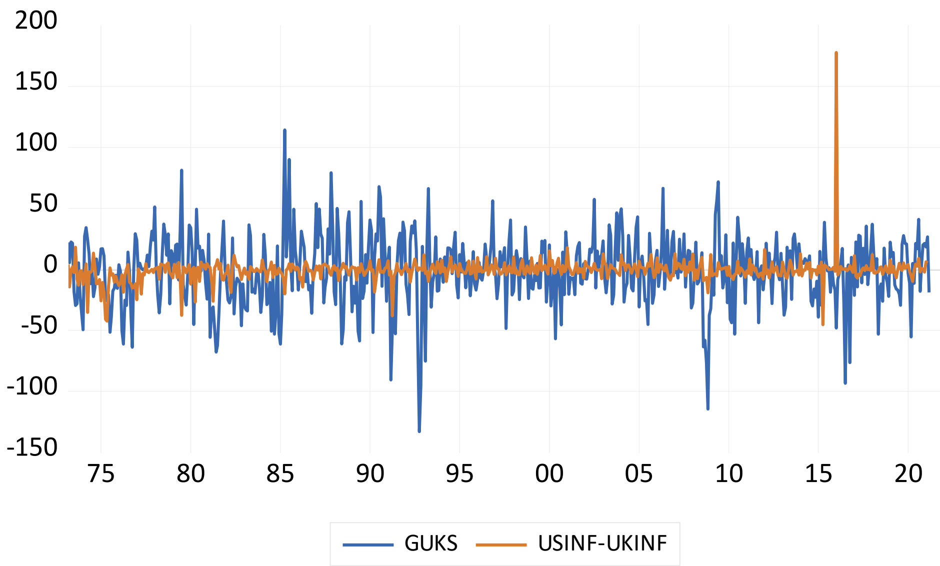
Note: Actual = the UKS = the dollar/pond exchange rate ($/£) and Fitted = the L-R Trend.

$$\underset{(0.020)}{UKS = 1.963^{***}} - \underset{(0.001)}{0.001^{***}}\, t$$

$R^2 = 0.328$, $SER = 0.234$, $F = 281.180$, $D-W = 0.030$, $N = 577$

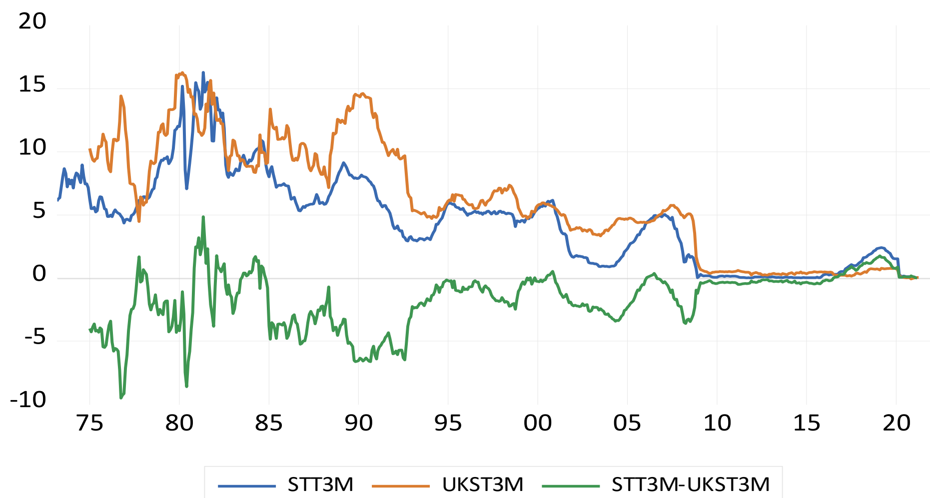
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

Figure A2c
The Change of Exchange Rate ($/£) and the Inflation Differential



Note: GUKS = growth of exchange rate the dollar/pound exchange rate ($/€) and USINF-UKINF = U.S. inflation minus UK inflation.
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

Figure A2d
The Interest Rates and the Interest Rate Differential between U.S. and UK



Note: STT3M = short-term 3-month T-Bill rate, UKST3M = UK short-term 3-month T-Bill rate, and STT3M-UKST3M = interest rate deferential.
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

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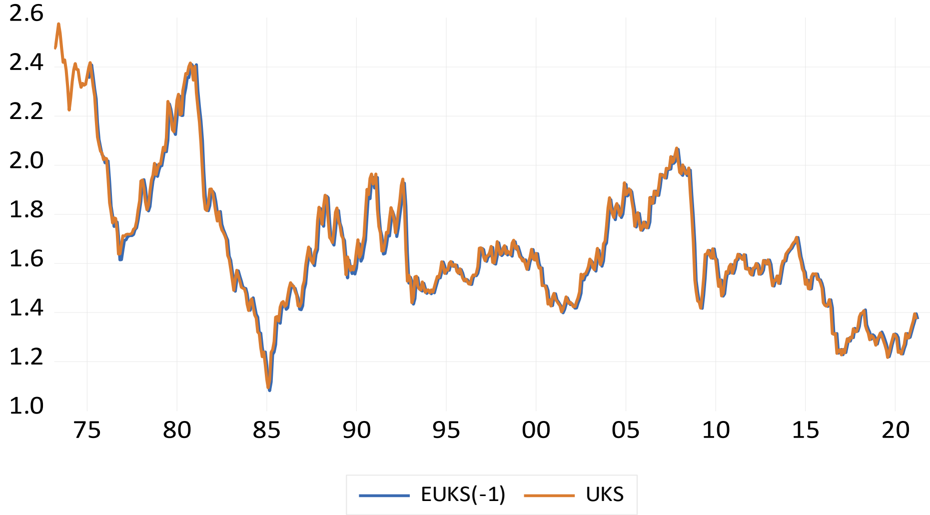
Figure A2e

Forecasting $E(UKS) = s_{t+1}^{e}$



Note: $E(UKS) = s_{t+1}^{e} = i_t - i_t^{*} + s_t$.

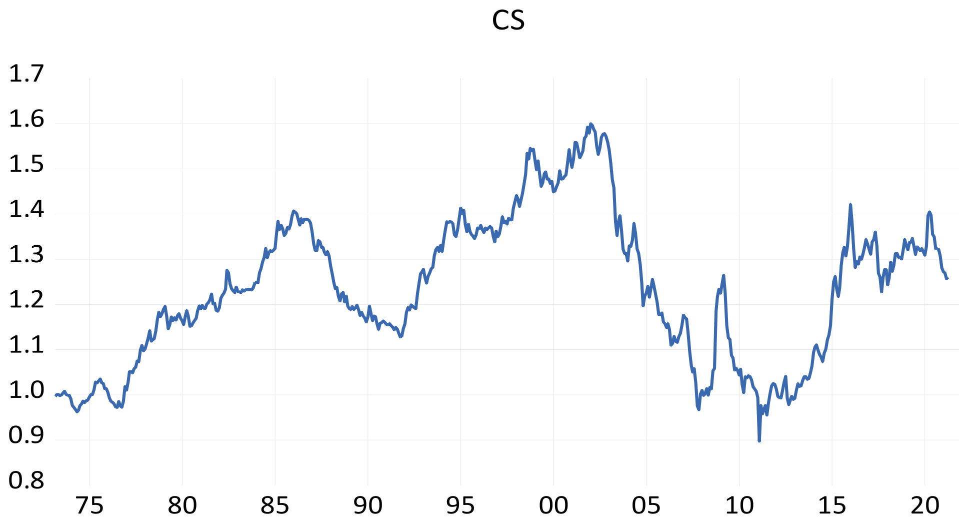
The $E(\overline{UKS_{t-1}}) = 1.647410$ (\$/£) and $\sigma_{E(UKS_{t-1})} = \pm 0.249862$; $\overline{UKS} = 1.649812$ and $\sigma_{UKS} = \pm 0.250179$;

$\rho_{E(UKS_{t-1}), UKS} = +0.986526$

Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

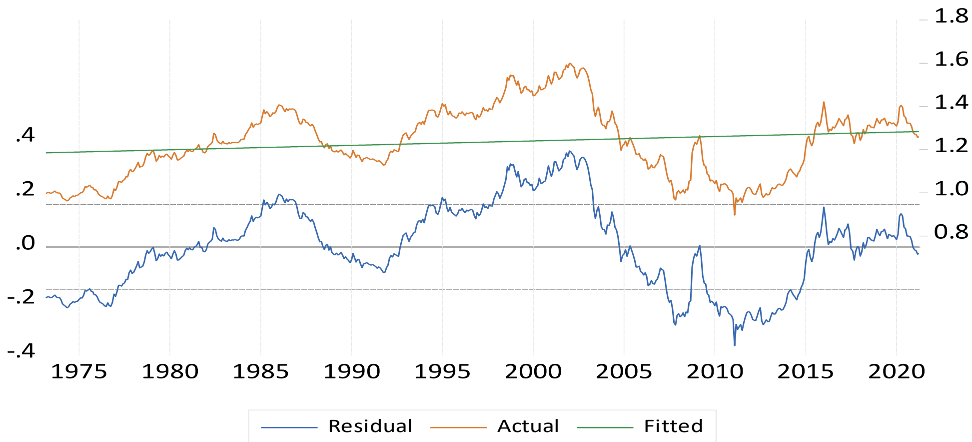
Figure A3a

The Exchange Rate (C\$/\$)



Note: **C**S = the Canadian dollar/dollar exchange rate (C\$/\$).
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

Figure A3b
The Exchange Rate (C$/$) and its L-R Trend



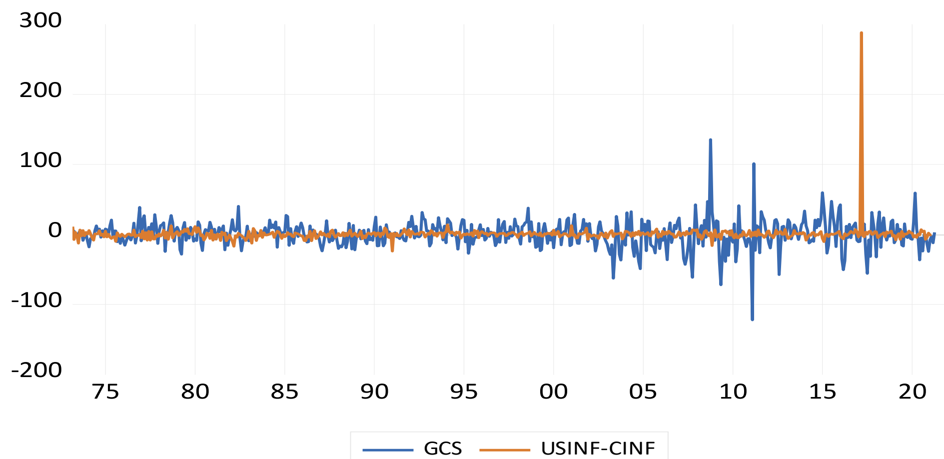
Note: Actual = the CS = the Canadian dollar/U.S. dollar exchange rate (C$/$) and Fitted = the L-R Trend.

$$CS = 1.185^{***} + 0.001^{***} t$$
$$(0.013) \quad (0.001)$$

$$R^2 = 0.032, SER = 0.157, F = 18.899, D-W = 0.015, N = 578$$

Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

Figure A3c
The Change of Exchange Rate (C$/$) and the Inflation Differential



Note: GCS = growth of exchange rate the Canadian dollar/dollar (C$/$) and USINF-CINF = U.S. inflation minus Canadian inflation.
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

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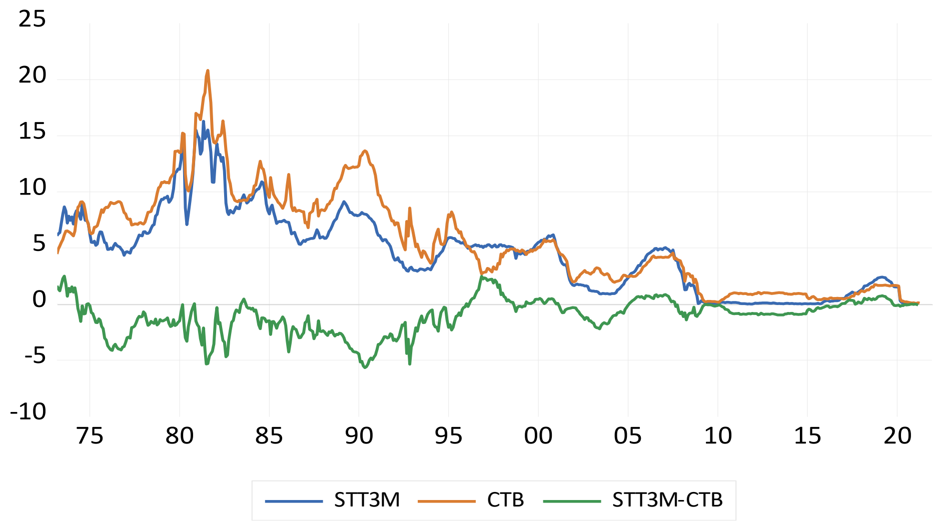
Figure A3d

The Interest Rates and the Interest Rate Differential between U.S. and Canada

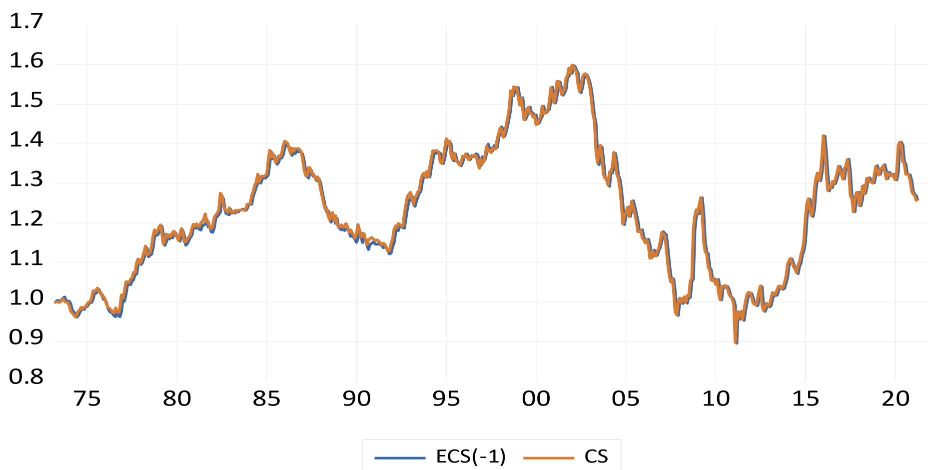


Note: STT3M = short-term 3-month T-Bill rate, CTB = Canadian short-term 3-month T-Bill rate, and STT3M-CTB = interest rate deferential.

Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

Figure A3e

Forecasting $E(CS) = s^{e}_{t+1}$



Note: $E(CS) = s^{e}_{t+1} = i_t - i^{*}_t + s_t$

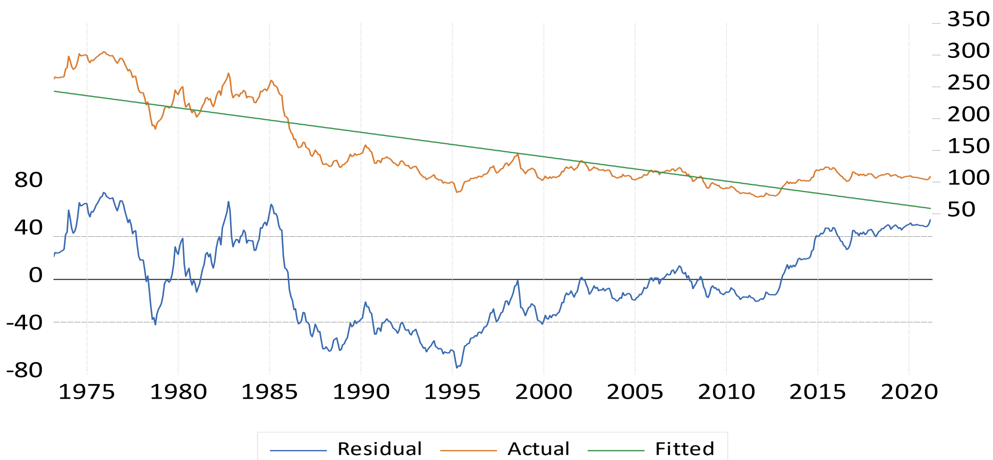
The $E(C\bar{S}_{t-1}) = 1.231746$ (C$/$) and $\sigma_{E(CS_{t-1})} = \pm 0.160698$; $C\bar{S} = 1.234858$

and $\sigma_{CS} = \pm 0.159709$ $\rho_{E(CS_{t-1}),\,CS} = +0.992686$;

Figure A4a
The Exchange Rate (¥/$)

Note: JS = the Japanese yen/U.S. dollar exchange rate (¥/$).
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

Figure A4b
The Exchange Rate (¥/$) and its L-R Trend



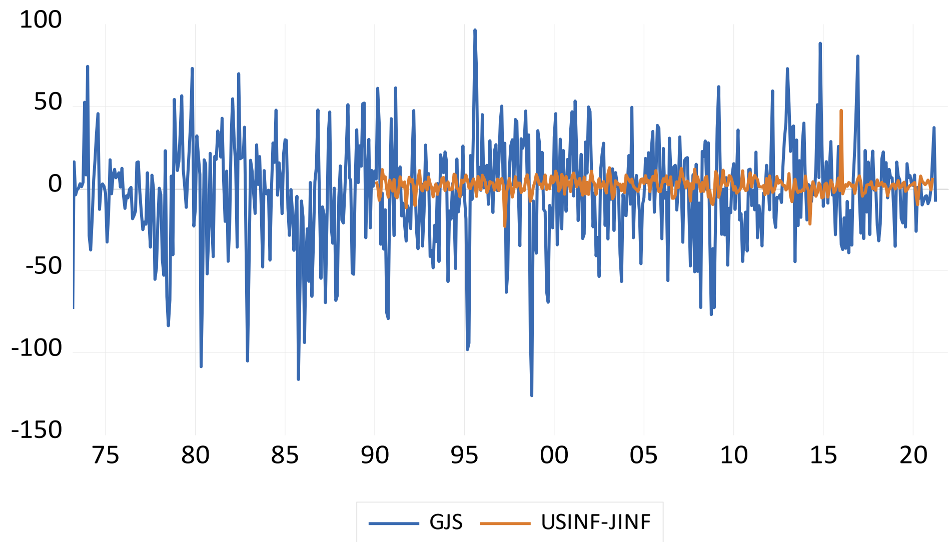
Note: Actual = the JS = the Japanese yen/U.S. dollar exchange rate (¥/$) and Fitted = the L-R Trend.

$$JS = 243.520^{***} - 0.321^{***} t$$
$$\quad (2.997) \qquad (0.009)$$

$$R^2 = 0.689,\ SER = 35.1975,\ F = 1{,}278.876,\ D-W = 0.014,\ N = 578$$

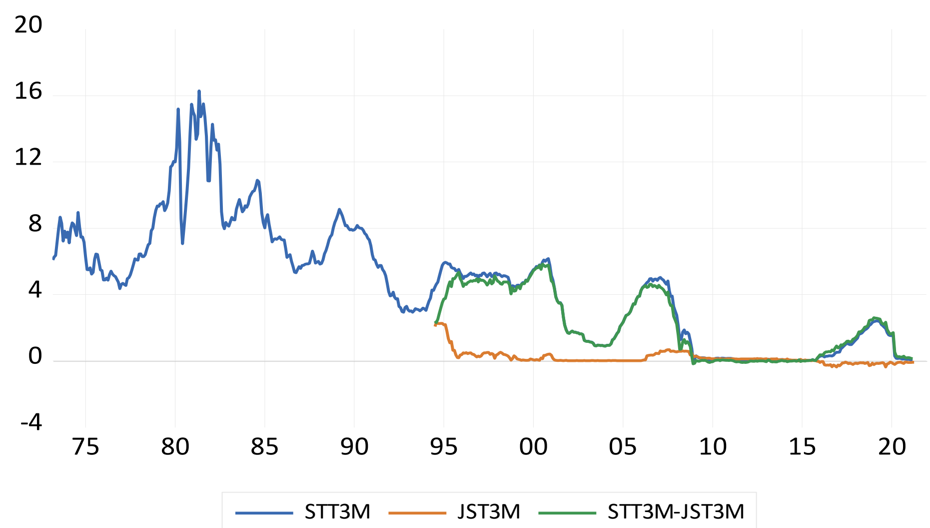
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

Figure A4c
The Change of Exchange Rate (¥/$) and the Inflation Differential



Note: GJS = growth of exchange rate the Japanese yen/dollar (¥/$) and USINF-JINF = U.S. inflation minus Japanese inflation.
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

Figure A4d
The Interest Rates and the Interest Rate Differential between U.S. and Japan



Note: STT3M = short-term 3-month T-Bill rate, JST3M = Japanese short-term 3-month T-Bill rate, and STT3M-JST3M = interest rate deferential.
Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.

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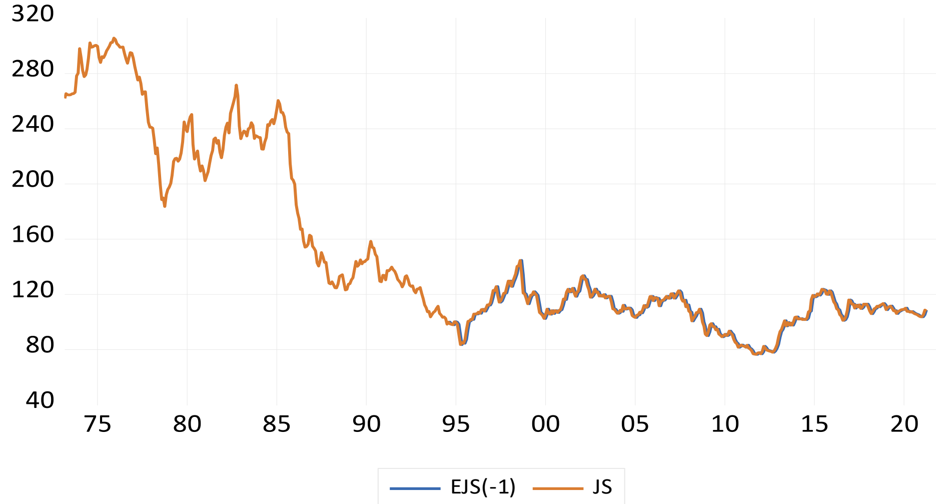
Figure A4e

Forecasting $E(JS) = s_{t+1}^{e}$



Note: $E(JS) = s_{t+1}^{e} = i_t - i_t^{*} + s_t$

The $E(J\overline{S}_{t-1}) = 107.7922$ (¥/\$) and $\sigma_{E(JS_{t-1})} = \pm 13.22693$; $J\overline{S} = 107.8166$ and $\sigma_{JS} = \pm 13.21439$;

$\rho_{E(JS_{t-1}),\, JCS} = +0.978914$

Source: *Economagic.com*, *FRED*, *Bloomberg*, *ECB*.