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Forecasting Japanese Yen Exchange Rate Behavior with an Intervention Analysis

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1. Introduction

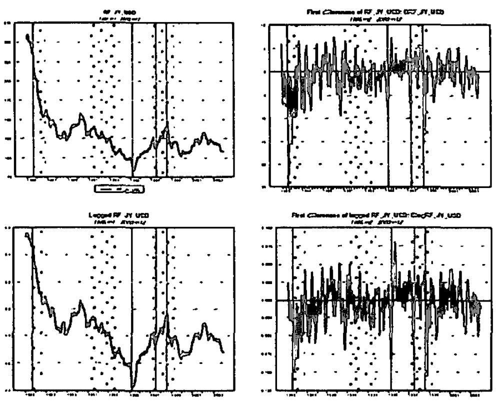
The present paper builds a business time-series forecasting system based on the Box-Jenkins (1976) (B-J) univariate method, and applies the system to the intervention analysis of the monthly Japanese yen per U.S. dollar (yen-dollar) exchange rate behavior. The sample period is a 19-year long 1985:1-2003:12, with the 3-month long out-of-sample (postsample), forecast period being 2004:1-2004:3.

The yen-dollar rate forecasting system comprises the following data file and RATS (Regression Analysis of Time Series) programs: RF_JY_USD.wks; *Stats_er.prg*, hist.src, histscatter.src; RandSample.prg, hist.src; SacfSpacf.prg, bjidentCF.src; *BJidentify_er.prg*, bjident.src; *bjest_er.src*, histnew.src, kolmtest.src; *BJidentify_erAOPS.prg*, bjident.src; *bjest_erAOPS.src*, histnew.src, kolmtest.src; *InterventionModel_er.prg*, *bjest_erIntrvModel.src*; *BJforecast_er.prg*, *bjfore1_er.src*, *bjfore2_er.src*. (All these are available at <http://www.seinan-gu.ac.jp/~kojima/BJTS/>.)

Those intervention events to be studied are additive outlier (AO) and permanent level shift (PS).

2. The Data and Summary Statistics

International Monetary Fund's (IMF's) International Financial Statistics (IFS) Online Service provides both real and financial data in the .xls format. Stats_er.prg is executed to plot the monthly yen-dollar rate as in the figure below. In the figure, the Japanese



yen against the U.S. dollar is readily seen to experience sharp appreciations at several points in time during the sample period, as asterisked in the table below. They are taken to be intervention events (AO or PS):

* 1985:10: Plaza Accord was signed in Sept. 1985.

* 1995:4: 79 yen per dollar, post-war record high, was reached in the same month.

* 1998:9, 1998:10: The Russian economic/financial crisis (a significant depreciation of the currency Louvre) occurred on 8/17/1998. Asian currency crisis started in July, 1997 → Russia → Latin America → Industrial nations. Note also Ito (2004): "The yen depreciation from 1995 to 1997 is often identified as one of the few imoportant factors that led Asian countries into a currency cirsis."

1985:08 237.2100	1995:02 98.2430	1998:07 140.7340
1985:09 236.9500	1995:03 90.7886	1998:08 144.6550
1985:10 214.7300*	1995:04 83.6675*	1998:09 134.5940*
1985:11 203.7200	1995:05 85.0970	1998:10 121.2980*
1985:12 202.8200	1995:06 84.5295	1998:11 120.5820

3. Identification, Estimation, and the Intervention Analysis of Yen-dollar Exchange Rate

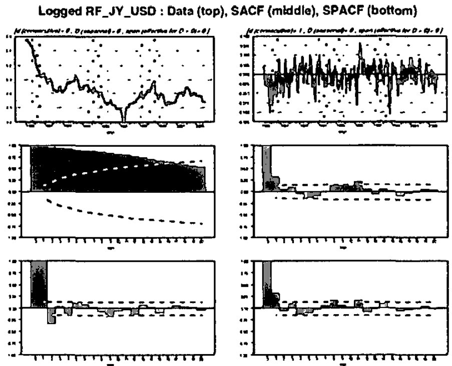
Time-series models for the raw yen-dollar rate data X_t to be considered in this phase are multiplicative SARIMA$(p,d,q;P,D,s,Q)$ models. Letting $X_t^\ell = \log X_t$ and based on the figure below:

$$W_t = (1-B)X_t^\ell \quad (1)$$

$$W_t = c + (1-\theta B)a_t. \quad (2)$$

The non-random walk identification here could be due to the presence of intervention events.

Logged RF_JY_USD : Data (top), SACF (middle), SPACF (bottom)



The diagnostic checking of the estimated MA(1) model (2) leads to the following more adequate model:

$$W_t = (1-\theta_1 B - \theta_{11}B^{11})a_t. \quad (3)$$

The (graph) output for the modified model (3) indicates that the residual normality is still rejected.

An intervention analysis is thus needed in which the presence of AO and PS is adjusted for in the model.

The general form of an intervention model is:

$$X_t^\ell = \sum_{k=1}^{m} \omega_{\mathrm{d}_k} \left\{ \nu_k(B)\xi_t^{(\mathrm{d}_k)} \right\} + \frac{\theta(B)\Theta(B^s)/\phi(B)\Phi(B^s)}{(1-B)^d(1-B^s)^D} a_t. \tag{4}$$

RATS programs are designed and written for the specific attempt to statistically and iteratively detect AO and PS. The table below summarizes all the search results. AOs and PSs that have been detected do correspond to the "spikes" of the past yen against dollar rate behavior. (In the table, OL = outer loop; IL = inner loop; C = critical value.)

OL	IL	C	Time	Type	Initial Impact	$\hat{\sigma}_a^2$	Jarque-Bera (Signif Level (JB=0))
1						7.43272e-04	11.97820 (0.00250592)
	1	4.0					No statistically significant AO or PS detected; C is set at 3.25
	2	3.25	1985 : 10 (34)	PS	−0.08401	7.05886e-04	4.70462 (0.09514889)
	3	3.25					No statistically significant AO or PS detected; C is set at 3.0
2						7.04939e-04	4.78205 (0.09153586)
	1	3.0	1998 : 10 (190)	PS	−0.07362	6.75540e-04	2.12742 (0.34517207)
	2	3.0					No statistically significant AO or PS detected; C is again set at 3.0.
3						6.74839e-04	2.08821 (0.35200682)
	1	2.7	1991 : 02 (98)	AO	−0.03985	6.68801e-04	2.47077 (0.29072265)
	2	2.7					No statistically significant AO or PS detected
4						6.50423e-04	2.92645 (0.23148845)
	1	2.7	1995 : 04 (148)	PS	−0.06103	6.29161e-04	3.03022 (0.21978406)
	2	2.7	1997 : 04 (172)	AO	0.03709	6.24954e-04	3.10711 (0.21149513)
	3	2.7					No statistically significant AO or PS detected
5						6.07039e-04	1.58774 (0.45209161)
	1	2.7					No statistically significant AO or PS detected

After completing the detection procedure, one moves on to specifying and estimating an intervention model, which is eventually specified as:

$$X_t^\ell = \sum_{k=1,2,4} \omega_{\mathrm{d}_k} \left\{ \frac{1}{1-B}\xi_t^{(\mathrm{d}_k)} \right\} + \sum_{k=3,5} \omega_{\mathrm{d}_k} \left\{ 1\xi_t^{(\mathrm{d}_k)} \right\} + \frac{1-\theta_1 B - \theta_{11}B^{11}}{1-B} a_t. \tag{5}$$

4. Forecasting and Forecast Performance: The Model (3) vs. Intervention Model (5)

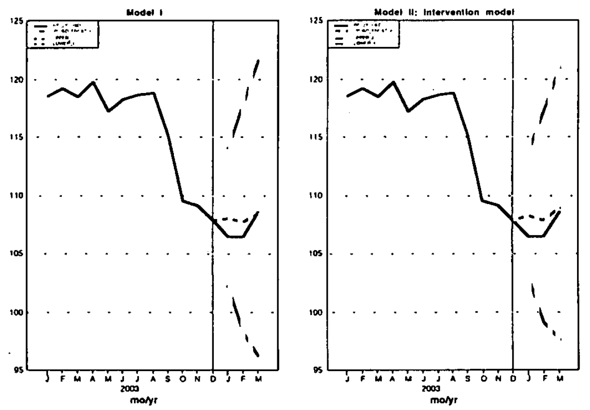
The l-month-ahead forecast will be computed based on the intervention model (5) as follows:

$$\begin{aligned} \hat{X}_T^\ell(l) &\equiv \mathrm{E}\left[X_{T+l}^\ell \middle| I_T\right] \\ &= (1-B)\left[\sum_{k=1,2,4} \omega_{\mathrm{d}_k} \frac{1}{1-B}\xi_{T+l}^{(\mathrm{d}_k)} + \sum_{k=3,5} \omega_{\mathrm{d}_k}\xi_{T+l}^{(\mathrm{d}_k)} \right] \\ &\quad + \left[X_{T+l-1}^\ell\right] - \theta_1\left[a_{T+l-1}\right] - \theta_{11}\left[a_{T+l-11}\right]. \end{aligned} \tag{6}$$

The RATS output and the figure below drawn for *raw* series lead to three types of forecast performance contrast. (In the figure, Models I, II = Models (3), (5).)

As anticipated, the intervention model (5) performs better with regard to forecast accuracy than the model (3): Detecting AO and PS and adjusting for their presence in a model is seen to help improve the model's forecast performance.

Out-of-Sample Forecasts of Raw (Unlogged) Data (RF_JY_USD): 2004:m1 to 2004:m3
Model I (left) vs. Model II (right)



It should be noted that "The effect of the identified disturbances on point forecasts is negligible provided that the forecast origin is not too close to the disturbances" (Tsay 1998). One immediate implication of this is that intervention events observed *near* the forecast origin should *not* be ignored if the forecast accuracy is a major concern. This is indeed confirmed in the present intervention modeling analysis: PS in October 1998 is close enough to the forecast origin, December 2003, *and* important enough, to *favorably* affect forecast performance as well as point forecasts of the *intervention model.* (Notice from the previous table that the PS is second most significant intervention event.)

5. Concluding Remarks

One may naturally ponder why univariate, why not multivariate. The other, more sophisticated, structural method of forecasting is the vector autoregressive (VAR) type. The simplest structural modeling of foreign exchange rate determination is said to be PPP (purchasing power parity).

It is my future research work to investigate, in a VAR-cointegration-EC framework, the forecast-performance probelm, in conjunction with Chowdhry, Roll and Xia's (2004) strong, supportive evidence for PPP.

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