ON THE INTERDEPENDENCE OF EXCHANGE RATES

AND INTEREST RATES

by

Takatoshi Ito

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Center for Economic Research
Department of Economics
University of Minnesota
Minneapolis, Minnesota 55455

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ABSTRACT

This paper considers an interdependence relationship among the U.S. and Japanese interest rates and the spot exchange rate using a vector autoregression model for the period of 1975:8 to 1983:5. First, it is shown that the exchange rate is strongly exogenous to the U.S. and Japanese interest rates. A popular belief that the high U.S. interest rate is causing the strong dollar is refuted. Second, the dynamic response functions for a typical shock to the system are calculated. Dynamic responses (cumulative multipliers) of not only the two interest rates and the spot exchange rate but also the forward exchange rate through the covered interest parity relationship are calculated. This enables us to discuss various effects, including yen depreciation/appreciation with a forward discount/premium, of an unanticipated shock in the system. It will be shown that an unexpected yen depreciation would trigger a lower U.S. interest rate and a higher Japanese interest rate. The U.S. interest rate shock will be followed by an immediate and lasting reaction of the Japanese interest rate, while the Japanese interest rate shock does not cause a response in the U.S. interest rate immediately. The typical shock in the Japanese interest rate would lead to yen appreciation. However, the magnitude of its effect is very small and yen appreciation caused by a typical innovation is less than one-fourth of one standard deviation of the spot rate innovations. Therefore, there is very little the Bank of Japan can do about the exchange rate by manipulating higher domestic interest.

We will closely study yen depreciation in the presence of (dollar) forward discounts in 1981 and 1982. In 1981, the forecast of the spot market from our model would have predicted the future spot rate quite well, while the forward rate overvalued yen. Yen depreciation with forward discounts in 1981 was anticipated depreciation caused by the large innovations in the U.S. interest rate in late 1979 and the beginning of 1980. On the other hand, yen depreciation of 1982 was clearly unanticipated and can be explained only as the result of repeated innovations in the spot exchange rate. Because of yen depreciation, the Japanese authority has not lowered the discount rate in the 22 months since December 1981, although domestic economic conditions might have favored the action. Considering the weak impact of an unexpectedly high (or not-lowered) Japanese interest rate on the U.S. interest rate or the spot exchange rate, lowering the discount rate would not have made a difference in yen movement anyway.

Any correspondence should be sent to: Professor Takatoshi Ito
Department of Economics
1019 Mgmt/Econ
University of Minnesota
Minneapolis, MN 55455
(612)-373-4370
On The Interdependence of Exchange Rates and Interest Rates

Takatoshi Ito

1. Introduction

Recent experiences of high U.S. interest rates and a strong dollar have demonstrated a point in the portfolio balance theory of the exchange rate. The difference in interest rates between the U.S. and other OECD countries is said to be responsible for the strong dollar, because of portfolio selection of asset holders. However, the exchange rate in turn influences domestic variables. It is of great interest to trace the international dynamic effects of an unexpected change in the interest rate or in the exchange rate. We will look at the relationships among the U.S. interest rate, the Japanese interest rate and the exchange rate in order to examine this feedback mechanism. An investigation of this mechanism is relevant for answering questions such as whether the strong dollar was really caused by the high U.S. interest rate rather than by independent shocks to the exchange rate; or whether Japanese monetary policies were conducted in reaction to exchange rate movements. In 1982, for example, the Chairman of the Bank of Japan repeatedly expressed its opinion that the discount rate could not be lowered in the presence of weak yen in spite of the sluggish domestic economy. Moreover, the U.S. domestic interest rate was blamed for causing the strong dollar.

One important relationship has to be taken into account in our dynamic analysis, namely covered interest rate parity. This holds when the difference in nominal interest rates is equal to the forward discount (or premium) so that the net yields of two assets, irrespective of the currency denomination, are the same at any point in time. Therefore unexpected changes in the interest rate in one country could change the interest rate of the other country, the spot exchange rate, or the forward exchange rate, subject to the constraint of covered interest parity. It is important to consider how a
shock in one variable will influence other variables, since the pattern of
dynamic responses sometimes identifies the source of disturbances in a
particular episode.

The purpose of this paper is three-fold. The first purpose is to examine
the relationships among the U.S. interest rate, the Japanese interest rate,
and the spot exchange rate to determine the major cause of fluctuations,
taking into account the dynamic feedbacks among them. This line of
investigation will answer the question of whether the high U.S. interest rate
is responsible for the strong dollar. Section II will show that the exchange
rate is exogenous to the U.S. and Japanese interest rates, and that the
forecast errors of the exchange rate are due to innovations in itself.

The second objective of this paper is to trace how unexpected changes in
interest rates or exchange rates are absorbed by reacted changes in other
interest rates and the spot and forward exchange rates. Using a condition of
covered interest parity, we can calculate the dynamic reaction to the forward
rate in addition to the interest rates and the exchange rate. Section III of
this paper describes the patterns of dynamic reactions to a typical shock
(innovation) to the system.

Third, Section IV of this paper directs our attention to movements of the
spot and forward exchange rates in 1981 and 1982. The spot exchange rate was
constantly depreciating from November 1981 to October 1982, with the exception
of April 1982, in spite of a (dollar) forward discount (i.e., the forward rate
"predicted" yen appreciation.) This apparently contradicts the efficient
market hypothesis without risk aversion. It is of great interest to analyze
degrees and causes of deviations of the forward rate from the expected future
spot rate forecast by our model in 1981-1982. Our examination of innovations
reveals that innovations in the U.S. interest rate after the October 1979
change in Federal Reserve operational procedures explains to some extent yen depreciation in 1981, while the yen depreciation with forward discounts in 1982 was due to repeated depreciations in the spot rate that year.

A few comments are in order to relate this paper to the existing literature. First, models which regress the exchange rate on the interest rates (or their difference) and other financial variables without correcting the simultaneous equations bias will be criticized in light of findings in this paper, because the exchange rate is significant in the U.S. interest rate determination. Second, Frenkel (1981) attempted to decompose the exchange rate into an expected part and a "news" component. He defined "news" as a difference between the actual (contemporaneous) interest rate (domestic-foreign) spread and the expected interest rate spread, "(a)ssuming that asset markets clear fast and that the "news" is immediately reflected in (unexpected) changes in the rate of interest." This assumption implies that "news" is contained in innovations of the interest rate (difference) and not in innovations of the exchange rate. However, it is debatable whether "news" is mainly carried by interest rate innovations rather than by exchange rate innovations. The vector autoregression model employed in this paper yields a straight-forward definition of innovations and a description of which innovations explain most fluctuations of the exchange and interest rates. Third, Cassese and Lothian (1982) considered a two-variable autoregression model for many pairs of financial variables, including the U.S. and Japanese interest rates for periods under the fixed exchange rate regime, 1958:2 to 1971:3. They found that lagged U.S. interest rates did not have a significant effect in the Japanese interest rate equation and pointed out that "the Japanese government exercised substantial direct control over interest rates." Considering the strict capital controls in place for that period, their finding is not surprising. In contrast, the present paper covers a period of
a flexible exchange rate regime with modest to almost completely free capital mobility. Our system is expanded to include the spot exchange rate. Moreover, not only F-tests of coefficients but also the dynamic response functions of the two interest rates and the spot and future exchange rates are examined in this paper.

II. Unanticipated Shocks in a Dynamic Model with Interdependence

The purpose of this section is to construct a model of the U.S. and Japanese financial markets linked through the exchange rate. Many models of "exchange rate determination" have been constructed and tested. A majority of investigators would agree that the "determinants" of the exchange rate include the current account balances, interest rates, and money supplies of the countries involved in the model. However, domestic monetary policies which determine interest rates or money supplies are subject to the exchange rate movements. We consider a feedback model of interest rates in the United States and Japan and the yen/dollar exchange rate. As principal domestic interest rates, we take the three-month commercial (industrial) paper rate in the U.S. and the three-month repurchase agreement (Gensaki) rate in Japan. These are denoted by RUS(t) and RJA(t), respectively. The spot exchange rate, SP(t), and the three-month forward exchange rate, FO(t), are measured in yen per dollar (such as Y240= 1). fn.1

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fn.1 The following data are provided by courtesy of Data Resources Inc. (DRI) and Morgan Guaranty Trust (MG): RUS Industrial paper rate at or near the end of the month as representative domestic short-term interest rate in World Financial Markets; RJA Monthly series by MG, Data Bank. Gensaki rate at or near the end of the month as representative domestic short-term interest rate. The series is provided from the data bank of MG, since the series published in World Financial Markets was changed from Tegata rate to Gensaki rate in the middle of the sample period; SP, FO Monthly series between 75:1 and 76:1 from IMF (ae2C15B and b9C15B), and between 77:1 and 83:5 constructed from DRI daily series by picking the last business day of each month. All the variables are carefully chosen to agree in timing so that covered interest parity holds without capital controls, as shown in Ito (1983) whose appendix contains further notes on the data.
In an environment with no capital controls and minimal transactions costs, covered interest rate parity should hold at every point of time. That is, the net yield after forward discount (or premium) should be the same for the yen-denominated asset as for the dollar-denominated asset:

\[(1 + \frac{\text{RUS}(t)}{400}) \cdot \text{FO}(t) = (1 + \frac{\text{RJA}(t)}{400}) \cdot \text{SP}(t)\]  \hspace{1cm} (2.1)

When the annual interest rate (expressed in percentages) is converted into a three-month rate (divided by 400), it is on the order of .01 to .05. Taking the logarithm of each side and using the approximation formula \(\ln(1+\varepsilon) = \varepsilon\) for small \(\varepsilon\), equation (2.1) is rewritten as

\[\ln\text{FO}(t) = \ln\text{SP}(t) + \frac{(\text{RJA}(t) - \text{RUS}(t))}{400}.\]  \hspace{1cm} (2.2)

This relationship puts an additional restriction on the interdependence between the interest rates and the exchange rates in the U.S. and Japan. Given covered interest parity, one of the four variables is redundant at any point in time. In the rest of this paper, the forward rate is assumed to be determined dependent on the three other variables.

In the following we will focus on a system of vector autoregressions (VAR) consisting of interest rates in the U.S. and Japan and the spot exchange rate. The system can be considered as a reduced form of some simultaneous "structural" equations determining these rates. Estimating a VAR system, of course, does not identify structural parameters. Our system could represent,

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fn.2 See Ito (1983) for a careful study on whether covered interest parity was holding after transactions costs. It was shown there that covered interest parity has been tightly holding since December 1980 when the new Foreign Exchange Law came into effect. There were significant and sustained deviations from parity in 1975 and again in 1978. For the periods in which covered interest parity did not hold, the forward rate used in the rest of this paper is a hypothetical rate which would have held had no capital controls been in place.

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for example, a simultaneous equations system consisting of the exchange rate
equation determined by the current account, the interest rate and the
inflation rate differentials in both countries; the current account equation
which depends on money supplies in each country; and the money supply equation
as a policy reaction to lagged interest and exchange rates. Thus, what we
find in the VAR system is a combination of policy responses and movements of
private sectors. Identifying structural form equations with current accounts,
money supplies, and the price levels, which conforms to the findings in
reduced form equations, will be the topic of a further investigation.
However, it should be emphasized that reduced form equations are sufficient
and desirable for particular tasks. Our system will give a satisfactory
answer to the questions posed in the Introduction without imposing too many
structural assumptions. (See Sims (1982) and comments to his paper for some
aspects of desirability and limitations of a VAR model.)

The following VAR system is estimated using monthly (at the end of the
month) data from January 1975 to May 1983:

\[ X(t) = A(L) X(t) + e(t) \]  \hspace{1cm} (2.3)

where \( X(t) = (\ln SP(t), \text{RUS}(t), \text{RJA}(t))' \), \( e(t) = (e_1(t), e_2(t), e_3(t))' \), and \( A(L) \)
is a matrix of polynomials in lag operators. \( SP(t) \) is in yen per dollar
(ranging from 177 to 305) and \( \text{RUS}(t) \) and \( \text{RJA}(t) \) are in units of percentages
(ranging roughly from 4 to 18). When we appeal to covered interest parity to
calculate the forward interest rate responses, necessary adjustments of the
units for the coefficients will be made. The vector \( e(t) \) denotes
innovations (shocks, surprises) to the three variables. Each equation is
estimated with a trend and a constant term and seven lags for each variable in
the VAR system. The results of the estimation are summarized in Tables 2-1
and 2-2. It should be noted that characteristics of the results presented in Tables 2-1 and 2-2 would not change if we used SP(t), not being log-transformed, instead of lnSP(t).

The F-statistics suggest that the exchange rate is explained by its own lagged rates alone, for coefficients of interest rates are found to be insignificant. The U.S. interest rate is determined both by its lagged values and by the exchange rate, while the Japanese rate is mainly determined by its lagged values and the U.S. interest rate. We have detected a plausible causality relationship from the U.S. interest rate to the Japanese interest rate.

Frenkel (1981) attempted to decompose the exchange rate into an expected part and a "news" component. He defined "news" as a difference between the actual (contemporaneous) interest rate (domestic-foreign) spread and the expected interest rate spread, "(a)ssuming that asset markets clear fast and that the "news" is immediately reflected in (unexpected) changes in the rate of interest." This assumption implies that "news" is contained in innovations of the interest rate (difference) and not in innovations of the exchange rate. Moreover, the forward rate and both domestic and foreign interest rates on the right hand side of his equation may well be functions of the spot exchange rate. Although Frenkel was careful enough to use the instrumental variable method to avoid the simultaneous bias, it is simpler to estimate a dynamic model which describes interdependence explicitly. A vector autoregression model serves this purpose. After our model is presented, Frenkel's equation will be described for comparison.
### TABLE II-1: F-statistics of lagged variables
Estimated with 7 lags over periods from 1975:8 to 1983:5

<table>
<thead>
<tr>
<th>RHS variable</th>
<th>lnSP</th>
<th>RUS</th>
<th>RJA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHS variable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnSP</td>
<td>95.21**</td>
<td>.90</td>
<td>.38</td>
</tr>
<tr>
<td>RUS</td>
<td>2.54*</td>
<td>18.13**</td>
<td>1.98Δ</td>
</tr>
<tr>
<td>RJA</td>
<td>2.04Δ</td>
<td>3.14**</td>
<td>56.51**</td>
</tr>
</tbody>
</table>

** significant at the 1% level
* significant at the 5% level
Δ significant at the 10% level

### TABLE II-2: Matrix of Correlations and Covariances of Innovations
The upper triangle including diagonal elements shows entries of the variance-covariance matrix, while the lower off-diagonal elements are the corresponding correlation coefficients.

<table>
<thead>
<tr>
<th></th>
<th>lnSP</th>
<th>RUS</th>
<th>RJA</th>
</tr>
</thead>
<tbody>
<tr>
<td>lnSP</td>
<td>.001</td>
<td>.007</td>
<td>.001</td>
</tr>
<tr>
<td>RUS</td>
<td>.216</td>
<td>.994</td>
<td>.109</td>
</tr>
<tr>
<td>RJA</td>
<td>.098</td>
<td>.203</td>
<td>.292</td>
</tr>
</tbody>
</table>
Let us elaborate on the comments on Frenkel's model which we made in the Introduction and explain the difference between the two models. Frenkel's model, which uses monthly data with one-month interest and forward exchange rates, is described in our notation as

\[ \ln SP(t) = a + b \ln FO(t-1) + c((RJA(t)-RUS(t)) - E_{t-1}(RJA(t)-RUS(t))) + w(t) \]

\[ \text{-------- (2.4)} \]

where the expected interest rate differential \( E_{t-1}(RJA(t)-RUS(t)) \) is obtained by regressing the interest differential on a constant, on two lagged values of the differential, and on the lagged forward exchange rate in \( \ln FO(t-1) \). We have used three-month interest and forward exchange rates, while Frenkel used one-month rates. Therefore, an unbiased estimator of \( \ln SP \) would be \( \ln FO(t-3) \) instead of \( \ln FO(t-1) \) in equation (2.4). The news component should be expanded to include any information which became available in \( t-1 \) and \( t-2 \). Therefore, the exchange rate equation essentially would depend on \( \ln FO(t-j) \), \( j=1,2,3 \), and \( RJA(t-k), RUS(t-k), k=0,1,2 \). Substituting interest rate parity for \( FO(t-1) \), (equation (2.2), replacing 400 by 1200 because of one-month rates) and the innovations for interest rates (equation (2.3)) into Frenkel's equation (2.4), we have

\[ \ln SP(t) = a + b \ln SP(t-1) + b(RJA(t-1)-RUS(t-1))/1200 + c(e_3(t) - e_2(t)) + w(t) \]

\[ = a + b \ln SP(t-1) + b(RJA(t-1) - RUS(t-1))/1200 + e_1 \]

where \( e_1 = c(e_2 - e_3) + w(t) \). Hence, Frenkel's system is expressed as a special case of our VAR system (2.3). Innovations in the system are ordered in a direction from the two interest rates to the exchange rate, and there are restrictions on coefficients of lagged variables.
Contemporaneous correlations among innovations suggest several implications about how unexpected movements of the interest and exchange rates are related within a period. Whenever there is an unexpected increase in the interest rate in one country, then it is likely there will be an unexpected increase in the interest rate in the other country. This may be caused by a common shock such as an oil price increase. However, it is more likely that the positive correlation is due to the policy reaction of a central bank (most likely the Bank of Japan, as Table 2-1 suggests) to the change in the interest rate of the other country (namely the United States). The positive correlation between innovations of lnSP and RUS suggests that an unexpectedly stronger dollar is likely to be accompanied by an unexpectedly higher interest rate in the United States.\textsuperscript{fn.3} The magnitude of correlation, however, is not too strong so that results in decomposition of variances, which will be presented below, are invariant with respect to the ordering of variables in the orthogonalization of innovations.

The table of F-statistics also supports the popular view that the high U.S. interest rate is causing the high Japanese interest rate but not the other way around. It is a little mysterious that the F-statistic of the exchange rate in the equation of the Japanese interest rate is not very high. It seems that the Japanese interest rate responds to the U.S. interest rate to prevent a possible depreciation of the yen, rather than that the Japanese interest rate reacts only after the yen becomes weak. Since the system consists of reduced form equations, it is possible that the Japanese interest rate does react to the exchange rate while the exchange rate is caused by the

\textsuperscript{fn.3} Branson (1983) studied a table of correlations of innovations in a VAR system with the exchange rate and six domestic variables. Including the money supply and current account balance, among others, made it possible to infer that Japan engaged in a "leaning-against-the-wind" policy and sterilization. This section of the present paper uses the same tool with a different aim, namely determining an interest rate linkage.
U.S. interest rate. However, this explanation seems unlikely because of the low F-statistic of the U.S. interest rate in the exchange rate equation. It is more likely that the exchange rate determines the U.S. interest rate, but the exchange rate is determined by its own lagged values. In order to test the hypothesis that the order of Granger-causal relationship is from the exchange rate to the U.S. interest rate to the Japanese interest rate, the likelihood ratio of the following restricted system is compared to the unrestricted system estimated above. The zero restriction is imposed on all coefficients of the Japanese interest rate in the exchange rate and the U.S. interest rate equations, and also on coefficients of the U.S. interest rate in the exchange rate equation. It is shown that the test statistic, \( \chi^2(21) = 24.58 \), implies that the hypothesis cannot be rejected even at the 10% significance level. A stronger hypothesis that the spot exchange rate is exogenous to the rest of the system is not rejected either (\( \chi^2(14) = 10.28 \)), while the hypothesis that the U.S. interest rate is exogenous to the system is rejected at the 5% level (\( \chi^2(14) = 25.63 \)).

We now investigate what explains fluctuations in terms of variances in forecast errors of the exchange rate and the two interest rates. The decomposition of variances into past innovations proved to be a powerful tool in several works by Sims (1980a) (1980b). The results in the above VAR system are calculated and reported in Table 2-3. In order to check whether contemporaneous correlations are affecting the results by favoring one order of orthogonalization over the other, two opposite orderings are employed: the exchange rate, the U.S. interest rate and the Japanese interest rate, in this order and in reverse order.

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INSERT TABLE 2-3 ABOUT HERE
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### TABLE 2-3: DECOMPOSITION OF VARIANCES OF FORECAST ERRORS

The order of orthogonalization is shown by the arrows.

**Variances of forecast errors of InSP → RUS → RJA**

<table>
<thead>
<tr>
<th>in step</th>
<th>InSP</th>
<th>RUS</th>
<th>RJA</th>
<th>InSP</th>
<th>RUS</th>
<th>RJA</th>
<th>InSP</th>
<th>RUS</th>
<th>RJA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>95</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>96</td>
</tr>
<tr>
<td>3</td>
<td>99</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>94</td>
<td>1</td>
<td>4</td>
<td>32</td>
<td>64</td>
</tr>
<tr>
<td>6</td>
<td>98</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>91</td>
<td>2</td>
<td>11</td>
<td>37</td>
<td>52</td>
</tr>
<tr>
<td>12</td>
<td>95</td>
<td>1</td>
<td>4</td>
<td>33</td>
<td>59</td>
<td>8</td>
<td>18</td>
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<td>43</td>
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<td>24</td>
<td>93</td>
<td>3</td>
<td>5</td>
<td>38</td>
<td>44</td>
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<td>25</td>
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<td>36</td>
<td>87</td>
<td>7</td>
<td>6</td>
<td>46</td>
<td>38</td>
<td>16</td>
<td>33</td>
<td>33</td>
<td>34</td>
</tr>
<tr>
<td>48</td>
<td>86</td>
<td>7</td>
<td>7</td>
<td>47</td>
<td>38</td>
<td>15</td>
<td>34</td>
<td>33</td>
<td>33</td>
</tr>
</tbody>
</table>

**Variances of forecast errors of InSP ← RUS ← RJA**

<table>
<thead>
<tr>
<th>in step</th>
<th>InSP</th>
<th>RUS</th>
<th>RJA</th>
<th>InSP</th>
<th>RUS</th>
<th>RJA</th>
<th>InSP</th>
<th>RUS</th>
<th>RJA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>95</td>
<td>4</td>
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<td>0</td>
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<td>100</td>
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<tr>
<td>3</td>
<td>92</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>94</td>
<td>5</td>
<td>0</td>
<td>22</td>
<td>78</td>
</tr>
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<td>6</td>
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<td>0</td>
<td>4</td>
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<td>3</td>
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<td>92</td>
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<td>2</td>
<td>37</td>
<td>53</td>
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<td>7</td>
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<tr>
<td>48</td>
<td>82</td>
<td>11</td>
<td>7</td>
<td>52</td>
<td>31</td>
<td>17</td>
<td>27</td>
<td>27</td>
<td>46</td>
</tr>
</tbody>
</table>

12
From the table of variance decomposition, we can make several interesting observations. First, the major source, more than 80%, of fluctuations in the exchange rate is past innovations in itself. Second, for the unpredicted variations of the U.S. interest rate, innovations in the exchange rate are as responsible as innovations in the U.S. interest rate in the long run (more than a year). Third, innovations of all three variables are equally powerful in explaining the fluctuations of the Japanese interest rate. These findings partially confirm what is commonly believed to be the causal ordering among the three variables. This is the popular view, particularly in Japan, that the unexpectedly high U.S. interest rate causes a too strong dollar which in turn causes a too high Japanese interest rate. It is very likely that the unexpectedly high U.S. interest rate has caused forecast errors in the Japanese interest rate, and not the other way around. However, the U.S. interest rate is not in general responsible for fluctuations in the exchange rate, contrary to the popular belief. fn.4

There are a few possible explanations reconciling our findings with the popular view. First, it may be the case that "news" about the U.S. economy is reflected in the exchange market faster than in the securities market because of fewer interventions. This is typically the case under monetary policy with an interest-rate target. Second, if a major disturbance in the yen/dollar exchange rate is due to a third party, say the currency preference of oil money investors, then fluctuations in their portfolio decisions appear as innovations in the exchange rate, while lagged policy reactions such as concerted intervention in foreign exchange with imperfect sterilizations cause the domestic interest rate to change.

fn.4 This is analogous to earlier results on the explanatory power of the interest rate in a domestic macroeconomic system. Sims (1980b) showed that the interest rate innovations explain fluctuations in money, prices and production in the United States, while Ito (1982) showed that it was not the case in Japan.
III. Dynamic Effects of Interest and Exchange Rate Shocks

It is easy to understand why a policy measure of one country immediately affects other countries through mobile short-term capital assets. For example, the high interest rate in the United States since 1981 has allegedly attracted short-term capital from other OECD countries, including Japan. The other countries kept their interest rates higher than otherwise in order to prevent depreciation of their currencies. This line of argument is basically confirmed in the preceding section. It is an objective of this section to examine how this effect takes place through a dynamic feedback mechanism. For example, an unanticipated shock in the U.S. interest rate could bring a comparable change in the Japanese interest rate, without changing the spot and forward exchange rates. Alternatively, the same shock could change the spot exchange rate and/or the forward exchange rate without an accompanying change in the Japanese interest rate; this exchange rate spread would keep the same relative attractiveness of the dollar and the Japanese asset. We will trace the dynamic impulse response functions of each variable after a typical shock in a variable. As briefly mentioned in the preceding section, the innovations are orthogonalized so that a typical shock in one variable is accompanied by contemporaneous shocks in lower-ranked variables. In order to calculate the response function of the forward exchange rate, we recall the covered interest rate parity equation (2.2). The response functions are calculated by adding to the exchange rate response the difference in the responses of the two interest rates. The results are summarized in Table 3-1, and plotted in Figure III-1 and III-2.

INSERT TABLES 3-1 to 3-3 ABOUT HERE

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14
TABLE 3-1: Dynamic Responses of Variables to a Typical Shock

Innovations are orthogonalized in the order of lnSP, RD, and RY.

<table>
<thead>
<tr>
<th>Responses in lnSP</th>
<th>Responses in lnFO</th>
<th>Responses in lnSP</th>
<th>Responses in lnFO</th>
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<td>lnFO</td>
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<tr>
<td>48</td>
<td>.0023</td>
<td>-.0563</td>
<td>-.0303</td>
</tr>
</tbody>
</table>
FIGURE III-1: Responses to a shock to RUS, the U.S. interest rate

SYMBOL S: Dynamic responses in the spot rate
SYMBOL F: Dynamic responses in the forward rate

MIN VALUE -.3423E-02 MAX VALUE .7444E-02 SPACING .1045E-03

+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
1 + F S + F S + F S + SF
2 + + + + + +
3 + + + + + +
4 + + + + + +
5 + S F + S F + S F + S F
6 + + + + + +
7 + + + + + +
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44 + + + + + +
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47 + + + + + +
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+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
FIGURE III-2: Responses to the shock in RD, the U.S. interest rate

SYMBOL U: Dynamic responses in the U.S. interest rate
SYMBOL J: Dynamic responses in the Japanese interest rate

MIN VALUE -1.1885 MAX VALUE 1.0498 SPACING .11237E-01

1 + J + U +
2 + J + U +
3 + J + U +
4 + J + U +
5 + U + J +
6 + U + J +
7 + U + J +
8 + U + J +
9 + U + J +
10 + U + J +
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48 + J + U +
First, let us consider a typical innovation in the spot exchange rate. Recalling the matrix of contemporaneous correlations, we immediately know that both interest rates will rise. The above table shows that the U.S. interest rate is only slightly greater than the Japanese interest rate, so the sign of responses of the forward rate is the same as that of innovations in the spot rate. Thus the typical shock in the exchange rate is a combination of a 3% depreciation of the yen in both spot and forward markets, a .2 percentage point increase in the U.S. interest rate (in annual yield), and a slight increase in the Japanese interest rate. Three months after the shock of yen depreciation, the U.S. interest rate starts to decline, followed by an increase in the Japanese interest rate. This must be a mix of policy and private sector reactions to the exchange rate shock. Suppose that investors suddenly find yen unattractive. Then spot and forward exchange rates move by themselves to reinforce a depreciation of the yen. (Remember that only own innovations explain the spot rate movement.) In reaction to unexpected depreciation, the Japanese authority moves to prevent capital outflows by raising its interest rate, although the U.S. interest rate is declining.

The typical U.S. interest rate shock, that is, its one percentage point increase, causes an immediate reaction in the Japanese interest rate. The Japanese interest rate will stay higher than otherwise by .2 to .3 percentage points for more than a year after the shock, although the U.S. interest rate will exhibit a cyclical movement. The difference between the two interest rates must be matched by (dollar) forward discounts in the first few months, followed by several months of forward premia for to keep covered interest parity. The spot and forward rate responses from 12 to 27 months after a shock are characterized by yen depreciation in the presence of forward discounts.
In contrast to the immediate reaction of the Japanese interest rate to a U.S. interest shock, the U.S. interest rate reacts quite slowly to a shock in the Japanese interest rate. It takes one year for the U.S. interest rate to respond to the Japanese interest rate shocks, so that in the meantime the Japanese interest rate is higher than the U.S. interest rate, causing (dollar) forward premia. Moreover, innovations in the Japanese interest rate do lead to actual appreciation of the yen for about one and one-half years. This confirms the conventional wisdom that an increase in the Japanese interest rate causes yen appreciation. However, the magnitude of this yen appreciation caused by a typical innovation (.5 percentage points) is at most .7% of the exchange rate. This is even less than one-fourth of one standard deviation of the spot rate innovations. Therefore, there is very little the Bank of Japan can do about the exchange rate through arranging higher domestic interest.

IV. An Explanation of Spot and Forward Rate Movements in 1981-1982

What has happened in the foreign exchange market in 1981-82 deserves a careful examination. From December 1980 to October 1982, yen depreciated from 203yen/$ to 278yen/$ in a steady long-run slide, with three isolated months of temporary appreciation (August and November 1981, and April 1982). Especially from November 1981 to October 1982, the rate of depreciation in the actual spot rate was very high in spite of heavy (dollar) forward discounts. As a matter of fact, the direction predicted by the (three-month) forward rate turned out to be wrong for nine consecutive months in this period. See FIGURE IV-1 for this anomalous phenomenon, if the market with risk-neutral agents is believed to be "efficient." This experience is in a sharp contrast to the common belief in the 70's that the forward exchange rate is an unbiased predictor of the spot rate. (See, for example, Mussa (1979).) However, it
has recently been documented that the forward rate is not necessarily the unbiased predictor of the future spot rate due to risk aversion. See, among others, Wyplosz (1983) and Cumby and Obstfeld (1982). The latter reported findings similar to ours in four out of five countries including Japan; "the three-month forward premium has on average mispredicted the direction of movement of the subsequently observed spot rate." (p.19)

Since the model produces the expected future spot rate as three-step ahead forecast, we are able to analyze the relationship between the forward rate and the expected future spot rate. The investigation also determine how much the high U.S. interest shock after the operational procedure changes of October 1979 is responsible for changes in the (expected) spot rate path.

Spot and forward rate movements in 1981-82 were either caused by some past shocks which were incorporated in expectations by then or caused by repeated shocks in the spot rate during those period. On the one hand, there were a few but large U.S. interest rate shocks in 1979 and 1980, and the dynamic response functions for U.S. interest rate innovations fit the pattern of yen depreciation in the presence of forward discounts 12 to 24 months after a shock. In this case the yen depreciation of 1981 and 1982 was largely "anticipated" by the VAR model as the three-step ahead forecast. On the other hand, the misprediction of forward rates may be simply because of repeated (unanticipated) shocks in the spot rate in the same direction for consecutive months. If the forecast errors of the spot rate in our three variable system is smaller than the deviations of the forward rate from the actual spot rate, then the latter explanation is more plausible, but if the forecast of the spot rate by our model is closer to the actual rate than the forward rate, then the former explanation is more plausible.
FIGURE IV-1: SPOT AND (LAGGED) FORWARD RATES IN 1981-1982

SYMBOL S: SP, the spot rate observed at t.
SYMBOL F: FLAG = F0(t-3), the 3-month forward rate observed at t-3,

MIN VALUE 211.42  MAX VALUE 277.70  SPACING .63732

A solid line connects actual spot rates.
Arrows show (dollar) forward discounts.
The difference between S and F for any month on the graph shows the deviation between the forward rate observed three months prior to that month.
Figure IV-2 shows three series of data: three-step ahead forecasts by the vector autoregressions lagged for three months, the three-month forward rate lagged three months, and the actual spot rate of the month.

The U.S. interest innovations were very large right after the (in)famous changes in the Federal Reserve operational procedures in October 1979. Between October 1979 and March 1980, actual U.S. interest rates hovered above the expected rates by 2 to 4 percentage points. The sum of the innovations during this period is 10.38 percentage points. Our study of dynamic response functions in the preceding sections gives a rough estimate of the contribution of these innovations. Let us approximate the shocks by a one-time 10 percentage point shock in December 1979. From Table III-1 we see that the resulting yen depreciation would peak at 7% in March 1982, or about 17 yen out of 247. In other words, yen in late 1981 would have been at most 17 yen less depreciated had there been no Volcker shock in the U.S. interest rate at the end of 1979.
FIGURE IV-1: Movements of expected, forward, and spot exchange rates in 1981-1983

SYMBOL R: Expected Spot Rate = $E_{SP(t)}$

SYMBOL F: Lagged Forward Rate = $F(t-3)$

SYMBOL A: Actual Spot Rate = $SP(t)$

MIN VALUE: 198.77  MAX VALUE: 277.70  SPACING: 0.75895

yen appreciation ← → yen depreciation
Next, let us consider innovations in the spot exchange rates. Innovations of the spot rate in 1981 were not significantly positive, while innovations in 1982 were significant and large. The magnitudes of the innovations were about 3 to 5% of the spot exchange rate in every month from February to October 1982 with the exception of April. There were no systematic patterns for innovations of the spot rate in 1981. In fact the sum of innovations in the exchange rate during 1981 was about (-5)%, while the sum during 1982 was about 4.7%.

An investigation of innovations in the U.S. interest rate and in the spot exchange rate between 1979 to 1982 reveals that both of the reasons listed above contributed to the phenomenon. The yen depreciation from December 1980 to July 1981 is well approximated by the expected path of the VAR model. The expected spot rate moves closely with the actual spot rate, rather than the forward rate. Theoretical explanations have to be provided as to why uncovered interest parity did not hold during this period. Discrepancies must be explained by some capital controls and risk premium factors. One capital control which has still been maintained since the 1980 deregulations of foreign exchange in Japan is the prohibition of outright transactions in the forward market. Therefore, even if the Japanese investors knew the

fn.5 Innovations are obtained as the one-step ahead forecast errors with VAR coefficients obtained by regressions using the whole sample. These correspond to surprises experienced by the econometricians who know the true structure but have data up to a period before. Other ways of obtaining measures of shocks to a system include three-step ahead forecast errors using the whole sample (since we are dealing with three month interest and forward rates), and three-step ahead forecasts with coefficients estimated using samples up to the forecasting point. The qualitative nature of our statement above would not change even if we employ any of the alternative measures of innovations. Three-step ahead forecast errors were very close to one-step ahead forecast errors in 1981-82.

fn.6 For a brief description of changes in capital controls and their effect on covered interest parity, see Ito (1983).
forward rate was biased, they could not take short positions in the forward market. This partly explains the violation of uncovered interest parity while covered interest parity was holding in these periods. From November 1981 to October 1982 the expected path is no better than the forward rate path, implying that the deviation was mainly due to repeated spot rate chocks. Therefore, the shock from the U.S. interest rate was primarily responsible for depreciation in 1981 while the repeated shocks in the spot rate were responsible for the 1982 depreciation.

We can now summarize that yen depreciation in 1981 was largely expected, with some evidence of delayed responses in the spot rate from large innovations in the U.S. interest rate at the end of 1979, while yen depreciation in 1982 was due to repeated innovations in the spot rate that year. Although the Japanese monetary policy was tight in the belief that keeping the interest rate high would induce higher exchange rates, the effect was very minimal according to our analysis in the preceding chapter. It would have made little difference had the Bank of Japan decided to lower the interest rate in Japan. fn.7

fn.7 The Bank of Japan lowered the (official) discount rate to 5 percent by 0.5 percentage points on October 22, 1983 after a long deliberation about the timing. This was the first change in one year and ten months. During the same period, the U.S. lowered the discount rate 7 times by a total of 3.5 percentage points. Because of its stagnant economy, both the Japanese authority and economists in Japan have expected a decision of lowering the discount rate since early 1983. However, the Chairman of the Bank of Japan was publicly explained the delay in lowering the interest rate, citing the "temporarily" undervalued yen. The many interest rates including deposit rates and prime lending rates are tied to the discount rate. Although the Gensaki rate is not regulated, it is influenced by the discount rate through traders expectations and arbitrage activities. According to our analysis in the preceding section, "unexpectedly" high (i.e., not lowered) Japanese interest rate does not cause yen appreciation by significant magnitudes. Note that the magnitude of the change in the discount rate on October 22 happens to be very close to one-standard deviation shock in the Gensaki interest rate in Table 3-1.
V. Concluding Remarks

A few comments on the robustness of our analysis are in order. First, one might think that any econometric model of international finance concerning Japan between 1975 and 1983 suffers from changes in capital controls in Japan. Gradual deregulation took place during the 1970's, followed by the new Foreign Exchange Law in December 1980. It is shown in Ito (1983) that covered interest parity held tightly only after 1980. In order to check our model for periods before 1980, the same model was estimated from 75:8 to 80:12. Characteristics of VAR estimations remain mostly unchanged for the shortened observation periods. Compared to results in the preceding sections, correlation of innovations from the early subperiods shows that there was a higher correlation between the exchange rate and the U.S. interest rate, but that the correlation between the U.S. interest rate and the Japanese interest rate was significantly smaller. With capital controls then in place, the Japanese authority probably did not find it necessary to react contemporaneously to unanticipated changes in the U.S. interest rate. Results of decomposition of variances in forecast errors remain very close to ones in the preceding sections, with a weaker explanatory power of the Japanese interest rate innovations. Dynamic response functions show that a typical shock did not have persistent effects, but caused a cyclical behavior on variables involved.

Let us summarize conclusions of this paper and then point out tasks left for further research. First, we have shown that the exchange rate is strongly exogenous to the U.S. and Japanese interest rates. A popular belief that the high U.S. interest rate is causing the strong dollar is refuted. Second, the dynamic response functions for a typical shock to the system are calculated. Dynamic responses (cumulative multipliers) of not only the two interest rates
and the spot exchange rate but also the forward exchange rate through the covered interest parity relationship were calculated. It was shown that an unexpected yen depreciation would trigger a lower U.S. interest rate and a higher Japanese interest rate. The U.S. interest rate shock would be followed by an immediate reaction of the Japanese interest rate. After a year, however, it will cause a yen depreciation with a (dollar) forward discount. The typical shock in the Japanese interest rate would lead to yen appreciation. However, the magnitude of this yen appreciation caused by a typical innovation (0.5 percentage point) is at most 0.7% of the exchange rate. This is less than one-fourth of one standard deviation of the spot rate innovations. Therefore, there is very little the Bank of Japan can do about the exchange rate by raising the domestic interest rate.

We closely studied yen depreciation in the presence of (dollar) forward discounts in 1981 and 1982. In 1981, the forecast of the spot market from our model would have predicted the future spot rate quite well, while the forward rate was consistently wrong in forecasting yen. Therefore, the yen depreciation with forward discounts in 1981 was anticipated depreciation. On the other hand, the yen depreciation of 1982 was clearly unanticipated and can be explained only as the result of repeated innovations in the spot exchange rate. Because of yen depreciation, the Japanese authority had not lowered the discount rate for 22 months till October 1983, although domestic economic conditions might have favored the action. Considering the weak impact of an unexpectedly high (not-lowered) Japanese interest rate on the U.S. interest rate or the spot exchange rate, lowering the discount rate would not have made a difference in yen movement anyway.

Our study of a VAR system of exchange and interest rates is useful for further research on the subject for several reasons. First, it restricts the
class of theoretical models which are worth considering seriously. For example, we may want to consider a "structural" model as opposed to our "reduced" form (VAR) model which has the feature that a shock in the (spot) exchange rate causes a higher Japanese interest rate and a lower U.S. interest rate, and the feedback from the Japanese interest rate the spot exchange rate or to the U.S. interest rate can be ignored without causing a bias. Second, we may want to expand our system to include other relevant variables, such as money supply, prices, production and the level of intervention. It seems unlikely to find money supply causing the exchange rate at the level of monthly frequency, since earlier studies such as Sims (1980b) and Ito (1982) found that money was not at the top of the causality ordering in a domestic VAR model. However, it is still interesting to analyze the impact of the exchange rate on production levels and prices. Third, the lag length in this paper was arbitrarily chosen. However, the length can be determined using the Akaike or Schwartz condition as done in Ito (1982). Fourth, findings in Section IV call for our intensive research on the validity of uncovered interest parity. The long spell of yen depreciation while the forward rate predicted appreciation clearly needs more thorough theoretical investigations.
REFERENCES:


