“Forward and Spot Exchange Rates” by Fama (1984) Revisited

Ulugbek E. Olimov[a] *

[a]Center for Economic Research, Tashkent, Uzbekistan

The main objective of this paper is to review and to replicate the paper ”Forward and Spot Exchange Rates” by Fama (1984). I used non-overlapping monthly data for three major currencies, and divided the sample into two, the ”replication” and the ”extension” periods. The results of this replication paper once more confirmed the conclusions of Fama (1984). After reviewing some post-Fama (1984) empirical studies in this topic, two main conclusions are drawn: (1) there is a general agreement that both components of forward rates vary through time; and (2) there is less agreement that the variance of the premium component is large relative to the variance of the expected depreciation of the spot rate.

1. Introduction

The main objective of this paper is to review and to replicate the paper on forward and spot exchange rates by Eugene Fama (1984) ”Forward and spot exchange rates.” The author considered the regressions of the ex post forward profit and of the one-period-ahead depreciation on the current period forward premium to analyze some properties of the premium.

The results of this replication paper once more confirmed the conclusions of Fama (1984). First, conditional on the hypothesis that the forward market is efficient or rational, there are variation in both the premium and the expected depreciation of the spot rate. Second, most of the variation in forward rates is variation in premiums. Finally, the premium and future spot rate components of forward rates are negatively correlated. The paper consists of three parts: (i) theoretical model; (ii) a brief overview of empirical results and their interpretations (including replication results); and (iii) conclusions.

2. Theoretical approach

This part is entirely based on Fama (1984) and includes detailed derivation of its analytical results. For analytical purposes we adopt the following notation:

$$\Delta s_{t+1} = s_{t+1} - s_t$$

$$\Delta f_t = f_t - s_t$$

$$\Delta f_{t+1} = f_t - s_{t+1}.$$

Define the premium component of the forward rate as

$$p_t = f_t - E_t[s_{t+1}] \tag{1}$$

where f_t: log of forward rate;[2] $E_t[s_{t+1}]$: the rational forecast conditional on information available at time t.

$$\begin{aligned} \Delta f_t &= p_t + E_t[s_{t+1}] - s_t \\ &= p_t + E_t[\Delta s_{t+1}]. \end{aligned} \tag{2}$$

In order to test whether the current forward-spot differential has power to predict the future change in the spot rate, Fama (1984) considered the following two regressions:

$$\Delta f_{t+1} = \alpha_1 + \beta_1 \Delta f_t + \epsilon_{1,t+1} \tag{3}$$

$$\Delta s_{t+1} = \alpha_2 + \beta_2 \Delta f_t + \epsilon_{2,t+1}. \tag{4}$$

Regressions (3) and (4) are complementary, and therefore, contain identical information about the variation of p_t and $E_t[\Delta s_{t+1}]$ components:

$$\begin{aligned} \alpha_1 + \alpha_2 &= 0 \\ \beta_1 + \beta_2 &= 1 \\ \epsilon_{1,t+1} + \epsilon_{2,t+1} &= 0 \end{aligned} \tag{5}$$

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[2]Differences in notation. I used small letters as logs of rates.

Although the above-mentioned regressions have no structural interpretation, they allow "us to estimate moments and functions of moments that characterize the joint distribution of p_t and $E_t[\Delta s_{t+1}]$" (Mark 2001, p. 132.)

In equation (4) $\beta_2 \neq 1$ means that the forward rate observed at time t has information about the spot rate observed at time *t+1*. Similar conclusion can be drawn from equation (3). Thus, $\beta_2 \neq 0$ means that the premium component of Δf_t has variation that shows up in Δs_{t+1}. The regression coefficients are

$$\beta_1 = \frac{\mathtt{cov}(\Delta f_{t+1}, \Delta f_t)}{\mathtt{var}(\Delta f_t)} \quad (6)$$

$$\beta_2 = \frac{\mathtt{cov}(\Delta s_{t+1}, \Delta f_t)}{\mathtt{var}(\Delta f_t)} \quad (7)$$

Using the definition of p_t from equation (1), we have

$$\begin{aligned} \Delta f_t &= p_t + E_t[\Delta s_{t+1}] \\ \Delta f_{t+1} &= p_t + s_{t+1} - E_t[\Delta s_{t+1}] \quad (8) \end{aligned}$$

and their variance and covariance are, respectively,

$$\begin{aligned} \mathtt{var}(\Delta f_t) &= \mathtt{var}(p_t) + \mathtt{var}(E_t[\Delta s_{t+1}]) \\ &\quad + 2\mathtt{cov}(p_t, E_t[\Delta s_{t+1}]) \\ \mathtt{cov}(\Delta f_{t+1}) &= \mathtt{var}(p_t) + \mathtt{cov}(p_t, E_t[\Delta s_{t+1}]) \end{aligned}$$

Substituting the above expressions into equations (6) and (7), and assuming that $\mathtt{cov}(p_t, E_t[\Delta s_{t+1}]) = 0$ i.e. they are uncorrelated, then we will get

$$\begin{aligned} \beta_1 &= \frac{\mathtt{var}(p_t)}{\mathtt{var}(p_t) + \mathtt{var}(E_t[\Delta s_{t+1}])} \\ \beta_2 &= \frac{\mathtt{var}(E_t[\Delta s_{t+1}])}{\mathtt{var}(p_t) + \mathtt{var}(E_t[\Delta s_{t+1}])} \quad (9) \end{aligned}$$

The contribution of covariation is divided between two coefficients. In contrast, if they are correlated then the simple interpretation of the regression coefficients obtained when p_t and $E_t[\Delta s_{t+1}]$ are uncorrelated is lost. For that reason $\mathtt{cov}(p_t, E[\Delta s_{t+1}])$ is a central issue in the empirical analysis.

The author argues that any premium in the forward rate must be explainable in terms of the interest rate differential and discusses the example of open international bond markets. The paper concludes that the difference between the forward and spot exchange rates is directly related to the difference between interest rates on nominal bonds denominated in the two currencies.[3]

3. Empirical Analysis and Results

Fama (1984) used spot exchange rates and thirty-day forward rates for nine currencies, including Belgian Franc (BFR), Canadian Dollar (CAD), French Frank (FFR), Italian Lira (ITL), the Japanese Yen (JPY), Swiss Frank (SFR), British Pound (GBP), Netherlands Guilder (NGL) and German Mark (DEM) (122 observations covering the period the period August 1973 to December 1982).

In this replication paper, I used non-overlapping monthly 192 observations from January 1975 to November 1989 for GBP, DEM and JPY. The data are taken from Professor Fumio Hayashi's website (`www.e.u-tokyo.ac.jp/~hayashi/datasets.htm`). The following three rates, namely, spot rate, thirty-day forward rate and the spot rate on the delivery date on a thirty-day forward contract were used. The important feature of the data is that maturity of the contract covers several sampling intervals; the delivery date is after the Friday of week *t+4* but before the Friday of week *t+5* (Hayashi 2000, p. 418.). All rates are USD per unit of foreign currency. I divided the whole sample into two, the "replication" period (Jan 1975 - Dec 1982) and the "extension" period (Jan 1983 - Nov 1989), with the number of observations 102 and 90, respectively.

Tables 1 and 2 ("R" and "E" mean that a table generated using the replication and the extension period data, respectively) show autocorrelations, means and standard deviations (SDs) of the four-week change in the spot rate, the difference between 30-day forward rate and the spot rate observed four weeks later, and the current forward-spot rate difference. The results documented in both tables are similar to the results of Fama (1984) (see Table 1, Fama 1984, p. 324). Namely, SDs of Δf_{t+1} are larger than the those of Δs_{t+1}. It means that in terms of SD of forecast errors the current spot rate is a better predictor of the future spot rate than the current forward rate. From the graphs we can note that the autocorrelations of changes in spot rates

[3] I do not provide the detailed derivations. For proof, see Fama (1984), pp. 322-23.

and Δf_{t+1} are both close to zero. They indicate that any autocorrelation of the premium (p_t) is not evident in the time series behavior of both Δs_{t+1} and Δf_{t+1}. The case of Δf_t is different. The partial autocorrelations suggest that it is a first-autoregressive process and shows that the premium vary in an autocorrelated way.

I run the regressions (3) and (4), using as mentioned before non-overlapping monthly observations. The OLS estimates are also almost consistent with the Fama (1984) results (see Table 3). A negative sign of β_2 coefficient shows that the premium (p_t) is negatively correlated with the expected depreciation ($E_t[\Delta s_{t+1}]$). At the same time, equation (5) implies that β_1 is positive and, subsequently, the variance of the premium must be large enough to offset the above-mentioned negative covariance. Mark (2001) (p.133) shows that $\texttt{var}(p_t) > var(E_t[\Delta s_{t+1}])$ places a lower bound on the size of the premium (p_t).

The author argues that a negative covariation between the premium and the expected depreciation of the spot rate may due to sampling error. However, individual testing of the slope coefficients of (3) against 1.0 or of (4) against 0.0 does not provide the joint test that all the slope coefficients of (3) are equal to 1.0 or all the slope coefficients of (4) are equal to 0.0. For that reason, Fama (1984) used the 'seemingly unrelated regression' (SUR) technique for joint estimation of Δf_{t+1} [or Δs_{t+1}] for different countries. The replication results of the SUR regressions are summarized in Tables 9 and 12. Comparing them with the original paper, in general, my results confirm Fama's findings.

The properties of forward rates as predictors of future spot rates may be different during the later periods. In order to check this possibility, the results in Tables 1 to 4 are replicated for the two subperiods. I also replicated all tables and documented it in Tables 5, 6, 7 and 8. The summary statistics of Table 5 documents, as in Fama (1984), an increase in the variability of Δs_{t+1} and Δf_{t+1}, and a small increase in the variability of Δf_t for the second subperiod. In contrast, in extension subperiods (Table 6) there is a decrease in the variability of Δs_{t+1}, Δf_{t+1}, and Δf_t. However, at the same time from Tables 1 and 2 we can observe an increase in the variability of Δs_{t+1} and Δf_{t+1}, but a decrease in the variability of Δf_t for the extension period. It reflects, in general, increased uncertainty about the *ex post* change in the spot rate and a decrease in the variability of the *ex ante* premium and the expected depreciation components of Δf_t.

Consistent with Fama (1984)'s results, changes in the mean values of the variables do not suggest improved market forecasts of future spot rates during replication and extension periods as well as during the later subperiods. The OLS results in Tables 7 and 8 are generally similar with Fama (1984), except DEM (the first subperiod of the replication period).

4. Conclusions

The results of this replication paper once more confirmed the conclusions of Fama (1984). Conditional on the hypothesis that the forward market is efficient or rational, (i) there are variation in both the premium and the expected depreciation of the spot rate; (ii) the variance of the premium component of Δf_t is large relative to the variance of the expected depreciation of the spot rate; and (iii) negative covariation between the above mentioned two components of Δf_t dominates the variance of the expected depreciation of the spot rate. Finally, market irrationality in forecasting exchange rates does not change during the later periods despite continued experience with flexible exchange rates.

Although this replication paper demonstrates similar results with Fama (1984), it cannot show all observations/conclusions made by the original paper. For example, in Table 4 we cannot confidently conclude that the correlations of the regressor variable Δf_t across countries are generally lower than the correlations of Δf_{t+1} and Δs_{t+1} across countries. The main reason may be that this replication paper used a small group of currencies (three) whereas Fama (1984) used a large (nine) one.

Since Fama (1984), a lot of studies have been done in this direction. Below I would like to discuss some of them, which I found interesting. Hodrick and Srivastava (1986) also supported Fama (1984) findings and interpreted the bias as evidence that the variance of the risk premium is greater than the variance of expected depreciation. There are some possible explanations of a negative relationship between the premiums and expected future spot rate components of forward rates (in the literature referred to as the forward premium puzzle). In particular, Eichenbaum and Evans (1995) find that a contractionary US monetary policy shock leads to a rise in the US interest rate relative to foreign interest rates. As a result the US dollar appreciates gradually leading to a conditional negative forward premium bias.

Contrary to Fama (1984), Froot and Frankel (1989) conclude that the systematic portion of forward discount prediction errors do not capture a time varying risk premium. They reject (a) the hypothesis that all of the bias in the forward discount is due to the risk premium; and (b) the claim that the variance of the risk premium is greater than the variance of expected depreciation. But, I would like to mention that Froot and Frankel (1989) use the survey data on exchange rate expectations and, therefore, even the authors are also skeptical about the accuracy of the survey data.

Summarizing the above discussions, now we can draw two main conclusions: (1) there is a general agreement that both components of forward rates vary through time; and (2) there is less agreement that the variance of the premium component is large relative to the variance of the expected depreciation of the spot rate.

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Table 1
"R": Autocorrelations, means and standard deviations: 01/75 – 12/82, N=102

	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}	Mean	S.D.
Δs_{t+1}												
GBP	0.3	0.14	-0.01	-0.12	0.14	0.17	0.12	0.02	0.03	0.04	0.37	2.82
DEM	0.23	0.08	0.13	0.00	-0.02	0.04	0.09	0.11	-0.05	-0.01	0.05	2.89
JPY	0.26	-0.03	0.09	0.13	0.21	0.03	-0.05	0.02	0.04	0.04	-0.19	3.27
dff												
GBP	0.33	0.17	0.02	-0.1	0.13	0.17	0.12	0.02	0.01	0.02	-0.19	2.9
DEM	0.25	0.11	0.15	0.02	-0.01	0.05	0.1	0.11	-0.05	-0.0	-0.41	2.92
JPY	0.29	0.02	0.14	0.16	0.23	0.04	-0.03	0.03	0.04	0.04	-0.16	3.36
Δf_t												
GBP	0.87	0.75	0.62	0.55	0.47	0.41	0.32	0.27	0.22	0.18	0.18	0.36
DEM	0.8	0.57	0.41	0.3	0.24	0.26	0.27	0.34	0.42	0.47	-0.36	0.23
JPY	0.86	0.76	0.69	0.62	0.54	0.5	0.43	0.42	0.42	0.38	-0.35	0.4

Table 2
"E": Autocorrelations, means and standard deviations: 01/83 – 11/89, N=90

	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}	Mean	S.D.
Δs_{t+1}												
GBP	0.12	-0.01	-0.06	0.04	0.1	-0.12	-0.03	-0.02	0.09	-0.05	0.35	3.74
DEM	0.03	0.09	0.07	0.12	0.14	0.01	0.08	0.05	0.04	0.06	-0.07	3.85
JPY	0.23	0.01	0.12	0.06	0.1	0.05	0.12	0.12	0.09	-0.03	-0.4	3.41
Δf_{t+1}												
GBP	0.14	0.01	-0.04	0.05	0.1	-0.12	-0.03	-0.01	0.09	-0.04	-0.16	3.81
DEM	0.05	0.1	0.08	0.13	0.15	0.02	0.08	0.06	0.05	0.06	-0.22	3.89
JPY	0.25	0.03	0.14	0.08	0.11	0.07	0.13	0.13	0.1	-0.02	0.13	3.45
Δf_t												
GBP	0.9	0.81	0.73	0.65	0.57	0.49	0.45	0.38	0.33	0.28	0.19	0.18
DEM	0.88	0.75	0.63	0.5	0.39	0.28	0.19	0.12	0.08	0.05	-0.29	0.1
JPY	0.9	0.81	0.72	0.63	0.55	0.45	0.36	0.29	0.23	0.19	-0.27	0.1

Notes: "R" and "E" mean that a table generated using the replication (01/75 - 12/82) and the extension period (01/83 - 11/89) data, respectively. All exchange rates are USD per unit of foreign currency. Δs_{t+1} is the four-week change in the spot exchange rate; Δf_{t+1} is the thirty-day forward rate minus the spot rate observed four weeks later; Δf_t is the forward rate minus the current spot rate. The means and standard deviations of the variables are on a percent per month basis.

Table 3
OLS regressions.

	a_1	b_1	a_2	b_2	s(a)	s(b)	R_1^2	R_2^2	s(E)	p_1	p_2	p_3	p_4
P1 – ”R”													
GBP	-0.01	2.07	0.01	-1.07	0.00	0.77	0.02	0.07	0.03	0.29	0.12	-0.01	-0.11
DEM	0.01	2.61	-0.01	-1.61	0.01	1.26	0.02	0.04	0.03	0.22	0.05	0.10	-0.02
JPY	0.01	2.3	-0.01	-1.3	0.00	0.81	0.02	0.07	0.03	0.25	-0.06	0.06	0.10
P2 – ”E”													
GBP	-0.01	9.95	0.01	-8.95	0.00	2.06	0.18	0.21	0.02	-0.01	0.000	-0.02	0.07
DEM	0.05	8.56	-0.05	-7.56	0.02	3.08	0.06	0.08	0.09	-0.08	0.02	0.07	0.07
JPY	4.53	8.72	-4.53	-7.72	1.47	2.74	0.08	0.10	5.97	0.13	-0.11	0.06	0.01

Notes. OLS regressions: $\Delta f_{t+1} = a_1 + b_1 \Delta f_t + e_{1,t+1}$, $\Delta s_{t+1} = a_2 + b_2 \Delta f_t + e_{2,t+1}$. R_{12} and R_{22} are the coefficients of determination (regression R_2) for the Δf_{t+1} and Δs_{t+1} regressions. The complete complementarity of the Δf_{t+1} and Δs_{t+1} regression for each country means that the standard errors s(a) and s(b) of the estimated regression coefficients, the residual standard error s(E), and the residual autocorrelations, p_t, are the same for the two regressions.

Table 4
Correlations of $s_{t+1} - s_t$, $f_t - s_{t+1}$ and $f_t - s_t$ across countries.

	$s_{t+1} - s_t$			$f_t - s_{t+1}$			$f_t - s_t$		
P1 – ”R”	GBP	DEM	JPY	GBP	DEM	JPY	GBP	DEM	JPY
GBP	1.00			1.00			1.00		
DEM	0.57	1.00		0.57	1.00		0.70	1.00	
JPY	0.46	0.48	1.00	0.47	0.49	1.00	0.79	0.79	1.00
P2 – ”E”	GBP	DEM	JPY	GBP	DEM	JPY	GBP	DEM	JPY
GBP	1.00			1.00			1.00		
DEM	0.75	1.00		0.75	1.00		0.81	1.00	
JPY	0.68	0.79	1.00	0.68	0.79	1.00	0.47	0.57	1.00

Notes: P1: 01/1975 – 12/1982, N=102; P2: 01/83 – 11/89, N=90. ”R” and ”E” mean that a table generated using the replication (01/75 – 12/82) and the extension period (01/83 – 11/89) data, respectively.

Table 5
"R": Autocorrelations, means and standard deviations for 51-month subperiods

	p_1	p_2	p_3	p_4	Mean	S.D.	p_1	p_2	p_3	p_4	Mean	S.D.
			Period 1						Period 2			
			$s_{t+1} - s_t$						$s_{t+1} - s_t$			
GBP	0.49	0.22	-0.08	-0.13	0.31	2.51	0.19	0.07	0.03	-0.09	0.42	3.10
DEM	0.10	0.13	0.06	-0.04	-0.58	2.36	0.25	-0.03	0.06	-0.02	0.68	3.21
JPY	0.22	0.00	0.07	0.06	-1.02	2.54	0.23	-0.17	0.01	0.09	0.64	3.69
			$f_t - s_{t+1}$						$f_t - s_{t+1}$			
GBP	0.46	0.17	-0.14	-0.19	0.06	2.48	0.26	0.15	0.09	-0.04	-0.43	3.24
DEM	0.08	0.12	0.06	-0.05	0.35	2.36	0.26	-0.01	0.07	-0.01	-1.18	3.22
JPY	0.15	-0.07	0.03	-0.01	0.91	2.52	0.25	-0.13	0.05	0.11	-1.23	3.73
			$f_t - s_t$						$f_t - s_t$			
GBP	0.86	0.80	0.69	0.56	0.37	0.28	0.81	0.58	0.37	0.30	-0.01	0.34
DEM	0.79	0.66	0.60	0.52	-0.23	0.14	0.64	0.19	-0.13	-0.30	-0.49	0.22
JPY	0.64	0.65	0.69	0.62	-0.11	0.28	0.83	0.61	0.41	0.23	-0.60	0.34

Notes. Period 1: 01/75 - 12/78; Period 2: 01/79 - 12/82.

Table 6
"E": Autocorrelations, means and standard deviations for 45-month subperiods

	p_1	p_2	p_3	p_4	Mean	S.D.	p_1	p_2	p_3	p_4	Mean	S.D.
			Period 1						Period 2			
			$s_{t+1} - s_t$						$s_{t+1} - s_t$			
GBP	0.02	0.03	0.00	0.14	0.36	4.15	0.26	-0.08	-0.14	-0.13	0.34	3.29
DEM	-0.10	0.13	0.12	0.14	0.09	4.14	0.20	0.06	-0.04	0.09	-0.23	3.53
JPY	0.21	0.10	0.24	0.23	-0.71	3.14	0.20	-0.08	-0.06	-0.11	-0.09	3.63
			$f_t - s_{t+1}$						$f_t - s_{t+1}$			
GBP	0.06	0.05	0.03	0.16	-0.24	4.24	0.27	-0.08	-0.15	-0.14	-0.09	3.32
DEM	-0.09	0.14	0.13	0.15	-0.43	4.17	0.22	0.07	-0.03	0.10	-0.01	3.57
JPY	0.24	0.13	0.26	0.25	0.46	3.19	0.22	-0.07	-0.05	-0.10	-0.2	3.67
			$f_t - s_t$						$f_t - s_t$			
GBP	0.92	0.85	0.77	0.68	0.12	0.20	0.81	0.62	0.45	0.33	0.25	0.12
DEM	0.88	0.69	0.51	0.35	-0.33	0.09	0.81	0.67	0.58	0.44	-0.25	0.08
JPY	0.91	0.79	0.68	0.57	-0.25	0.11	0.86	0.81	0.69	0.60	-0.28	0.09

Notes: Period 1: 01/83 - 06/86; Period 2: 07/86 - 11/89. "R" and "E" mean that a table generated using the replication (01/75 – 12/82) and the extension period (01/83 – 11/89) data, respectively.

Table 7
"R": OLS regressions for 51-month subperiods.

	$a_2(=-a_1)$	$b_2(=1-b_1)$	$s(a)$	$s(b$	R_1^2	R_2^2	$S(E)$	p_1	p_2	p_3	p_4	p_5
	Period 1											
GBP	0.00	1.44	0.01	1.26	0.03	0.00	0.03	0.44	0.15	-0.15	-0.21	-0.06
DEM	0.00	1.17	0.01	2.36	0.01	0.00	0.02	0.08	0.12	0.06	-0.05	-0.07
JPY	0.01	1.28	0.00	1.27	0.02	0.00	0.03	0.14	-0.09	0.02	-0.02	0.07
	Period 2											
GBP	0.00	-3.26	0.00	1.22	0.13	0.20	0.03	0.03	-0.15	-0.15	-0.23	0.16
DEM	0.00	-0.55	0.01	2.06	0.00	0.01	0.03	0.25	-0.04	0.06	-0.02	-0.13
JPY	0.00	-0.95	0.01	1.53	0.01	0.03	0.04	0.21	-0.20	-0.02	0.06	0.08

Notes. Period 1: 01/75 – 12/78; Period 2: 01/79 – 12/82.

Table 8
"E": OLS regressions for 45-month subperiods.

	$a_2(=-a_1)$	$b_2(=1-b_1)$	$s(a)$	$s(b$	R_1^2	R_2^2	$S(E)$	p_1	p_2	p_3	p_4	p_5
	Period 1											
GBP	0.01	-10.67	0.00	2.83	0.25	0.28	0.03	-0.17	-0.03	-0.07	0.08	0.21
DEM	-0.11	-12.69	0.06	6.10	0.09	0.10	0.11	-0.23	-0.04	0.03	-0.02	0.25
JPY	-7.53	-10.58	2.31	3.58	0.17	0.20	6.53	0.00	-0.24	-0.03	0.00	0.07
	Period 2											
GBP	0.01	-5.89	0.01	3.64	0.06	0.08	0.02	0.26	0.00	0.00	-0.02	0.02
DEM	-0.09	-18.50	0.03	6.99	0.14	0.15	0.06	0.02	-0.01	-0.08	-0.01	-0.16
JPY	-4.73	-11.65	2.71	6.75	0.06	0.08	5.08	0.13	-0.13	-0.10	-0.21	-0.13

Notes. OLS regressions: $\Delta f_{t+1} = a_1 + b_1 \Delta f_t + e_{1,t+1}$, $\Delta s_{t+1} = a_2 + b_2 \Delta f_t + e_{2,t+1}$. Period 1: 01/83 – 06/86; Period 2: 07/86 – 11/89. "R" and "E" mean that a table generated using the replication (01/75 - 12/82) and the extension period (01/83 - 11/89) data, respectively. R_1^2 and R_2^2 are the coefficients of determination (regression R_2) for the Δf_{t+1} and Δs_{t+1} regressions. The complete complementarity of the Δf_{t+1} and Δs_{t+1} regression for each country means that the standard errors s(a) and s(b) of the estimated regression coefficients, the residual standard error s(E), and the residual autocorrelations, pt, are the same for the two regressions.

Table 9
"R": SUR regressions.

	$a_2(=-a_1)$			$b_2(=1-b_1)$	S(a)	s(b)
				Part A: Unconstrained		
GBP	0.01			-1.22	0.00	0.77
DEM	-0.01			-2.39	0.01	1.26
JPY	-0.01			-1.48	0.00	0.81
F tests				1. All b2 (or b1) equal	F = 0.64	p-value = 0.53
				2. All a2 (or b1) equal	F = 5.27	p-value = 0.01
				3. All b2 = 0 (or b1=1)	F = 9.44	p-value = 0.00
				Part B: Constrained		
	$\Delta s_{t+1} =$	a_{GBP} +	a_{DEM} +	a_{JPY} + b_2 Δf_t)		
		0.006	-0.005	-0.007 -1.383		
		(0.003)	(0.004)	(0.004) (0.568)		
	All a equal			F = 4.66 p-value = 0.01		

Table 10
"E": SUR regressions.

	$a_2(=-a_1)$			$b_2(=1-b_1)$	S(a)	s(b)
				Part A: Unconstrained		
GBP	0.01			-5.86	0.00	2.06
DEM	-0.06			-9.00	0.02	3.08
JPY	-3.51			-5.61	1.47	2.74
F tests				1. All b2 (or b1) equal	F = 6.34	p-value = 0.00
				2. All a2 (or b1) equal	F = 18.59	p-value = 0.00
				3. All b2 =0 (or b1=1)	F = 20.22	p-value = 0.00
				Part B: Constrained		
	$\Delta s_{t+1} =$	a_{GBP} +	a_{DEM} +	a_{JPY} + b_2 Δf_t		
		0.016	-0.020	-0.021 -6.553		
		(0.005)	(0.006)	(0.005) (1.434)		
	All a equal			F = 13.42 p-value = 0.00		

Notes. Regressions: $\Delta f_{t+1} = a_1 + b_1 \Delta f_t + e_{1,t+1}$, $\Delta s_{t+1} = a_2 + b_2 \Delta f_t + e_{2,t+1}$. "R" and "E" mean that a table generated using the replication (01/75 – 12/82) and the extension period (01/83 – 11/89) data, respectively.

Table 11
"E": SUR regressions for 51-month subperiods.

	$a_2(=-a_1)$	$b_2(=1-b_1)$	S(a)	s(b)
		Period 1: 01/75 - 12/78		
GBP	0.00	0.68	0.01	1.26
DEM	0.00	0.37	0.01	2.36
JPY	-0.01	0.6	0.00	1.27
F tests		1. All b_2 (or b_1) equal	F = 0.01	p-value = 0.99
		2. All a_2 (or b_1) equal	F = 0.67	p-value =0.20
		3. All $b_2 = 0$ (or b_1=1)	F = 0.10	p-value =0.90
		Period 2: 01/79 - 12/82		
GBP	0.00	-3.33	0.00	1.22
DEM	0.00	-2.05	0.01	2.06
JPY	0.00	-1.10	0.01	1.53
F tests		1. All b_2 (or b_1) equal	F = 1.33	p-value = 0.27
		2. All a_2 (or b_1) equal	F = 0.33	p-value =0.72
		3. All b_2 =0 (or b_1=1)	F = 9.30	p-value =0.00

Table 12
"E": SUR regressions for 45-month subperiods.

	$a_2(=-a_1)$	$b_2(=1-b_1)$	S(a)	s(b)
		Period 1: 07/86 - 11/89		
GBP	0.01	-7.39	0.00	2.83
DEM	-0.10	-11.9	0.06	6.10
JPY	-6.04	-8.03	2.31	3.58
F tests		1. All b_2 (or b_1) equal	F = 1.33	p-value = 0.27
		2. All a_2 (or b_1) equal	F = 8.23	p-value = 0.00
		3. All $b_2 = 0$ (or b_1=1)	F = 8.79	p-value = 0.00
		Period 2: 01/83 - 06/86		
GBP	0.01	-2.39	0.01	3.64
DEM	-0.08	-16.15	0.03	6.99
JPY	-2.37	-5.55	2.71	6.75
F tests		1. All b_2 (or b_1) equal	F = 7.69	p-value = 0.00
		2. All a_2 (or b_1) equal	F = 9.54	p-value = 0.00
		3. All b_2 =0 (or b_1=1)	F = 13.68	p-value = 0.00

Notes. Regressions: $\Delta f_{t+1} = a_1 + b_1 \Delta f_t + e_{1,t+1}$, $\Delta s_{t+1} = a_2 + b_2 \Delta f_t + e_{2,t+1}$. "R" and "E" mean that a table generated using the replication (01/75 – 12/82) and the extension period (01/83 – 11/89) data, respectively.