EFFICIENCY IN THE FORWARD MARKETS FOR FOREIGN EXCHANGE

NO. 246

by

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I. INTRODUCTION

An efficient financial market is one which is efficient in processing information, so that current prices incorporate all relevant data, correctly evaluated.[1/] It has two features which ought to be emphasised. Firstly, as prices are presumed to move immediately to a new equilibrium when 'shocked', they represent the harmonious outcome of utility and profit maximising behaviour. The signals sent by these prices will ensure that any consequent resource allocation is an efficient one. Secondly, since the return on a financial asset consists of a yield and capital gain or loss, expectations of the future play an important role in determing the current price. Asset markets are inherently speculative, but the efficient markets hypothesis suggests that all opportunities for investors to earn unusual profit by exploiting available information will be eliminated. The price of a security at time t will reflect all relevant knowledge about the future which will affect its expected return,[2/] which results in the anticipated return to speculative activity being zero.

If the performance of the hypothesis is to be properly tested, the general statement above must be replaced by a more detailed description of the price formation process. Most empirical work has assumed that a market equilibrium can be expressed in terms of equilibrium expected prices. That is

$$E_t(\tilde{P}_{j,t+1} | \Omega_t) = P_{jt}(1+E_t(\tilde{r}_{j,t+1}|\Omega_t) \qquad (1)$$

where E is the expected value operator; P_j is the price of a security; r is the one-period percentage return, Ω_t is the relevant information set, and the tildes indicate that the variables are random at time t. This implies that whatever factors are presumed to determine expected returns, information on their future developments is fully utilised, and reflected in P_t. Furthermore, if the set Ω_t is efficiently tapped, the possibility that there exist trading systems based on Ω_t which have expected profits in excess of the equilibrium return can be ruled out. If

$$z_{j,t+1} = r_{j,t+1} - E_t(\tilde{r}_{j,t+1}|\Omega_t) \qquad (2)$$

then

$$E_t(\tilde{z}_{j,t+1}|\Omega_t) = 0$$

The precise nature of the information set must also be specified. Three different subsets have been identified, allowing three kinds of tests to be performed. Weak form tests are characterised by the inclusion of past prices only. Semi-strong tests attempt to assess the use of other obviously available information, while strong-form tests investigate the possibility of any group having monopolistic access to relevant knowledge. Weak form tests only are considered in the empirical work in this paper.

The major difficulty in extending empirical work from equity markets, where much of the work has been conducted, to the international financial markets, has been the lack of success in isolating one hypothesis to be tested alone. Tests for market efficiency in fact test a joint hypothesis; one postulates the nature of the equilibrium process, the other the manner in which market participants have used the specified information set to ensure that the equilibrium price is maintained through time. If the result of a test is found to be consistent with the null hypothesis of efficiency when applied to a particular price formation process, should this process in fact be incorrect, the result would be spurious. Similarly, the discovery of market inefficiency may be due to the application of the wrong equilibrium model.

This problem is not too severe in equity market studies because, as Levich (1979) points out, "there is probably a considerable concensus across academics and financial practitioners that the equilibrium return is positive, and perhaps fairly constant". In the foreign exchange markets, there is no comparable agreement on equilibrium pricing or rate of return. It is hard to test whether investors set actual values to equilibrium values, unless there is some confidence in what equilibrium values are.

There is one further difference between the markets for stocks and foreign exchange. The former is often used as the text book example of a perfectly competitive institution. However, in the markets for national currencies and assets, government agencies have a considerable amount of power, and may act in a non-profit maximising fashion. Such behaviour would alter the 'normal' equilibrium relationships. Intervention does not imply inefficiency: if predictable it will be reflected in the market price. Any seemingly random action by the national authorities may reduce the willingness of traders to take positions, but this does not imply inefficiency in the usual sense. However, any model which does not incorporate government activity is likely to be misspecified.

can be interpreted as an observable expectation, tests based upon it can be regarded as direct tests for the rationality of expectation formation. The awkward problem of calculating (arbitrary) expectations series can be avoided.

Many studies based on this reasoning have found little evidence of bias in the forward rate's predictions, or significant mean prediction errors when comparing F_t and S_{t+1}. A degree of concensus, that the forward markets were efficient, was established. Begg (1982) suggested that "few conclude that the model is seriously at odds with the data", while according to Frenkel (1982), in the 1970's "in spite of the extraordinary turbulence in the markets for foreign exchange it seems that, to a large extent, the markets have operated efficiently.

This was unfortunate. Firstly, unbiasedness is only a necessary, not a sufficient condition for efficiency. A stronger test demands that, in addition, the predictions of the forward rate should be superior to those of other series. In this respect, Bilson and Levich (1977) show that it is possible to construct a model which fits the data better than the forward rate, even though its superiority fades when applied to post sample observations. Nevertheless, Giddy and Dufey (1975), Giddy (1977) and Levich (1977) all report that the predictions of Euro-currency interest rates or lagged spot rates are often marginally superior to those of the forward rate.

More serious is the problem that some theories of forward market equilibrium are consistent with a forward rate bias. Any systematic discrepancy between F_t and S_{t+1} may not exceed the transactions costs of buying and selling assets. However, from a theoretical perspective, the problem of risk is more interesting. This was first introduced into the literature by Keynes (1930) who developed the concept of normal backwardation. He suggested that forward market equilibrium would entail an expected spot price in excess of the forward rate by an amount equal to that necessary to entice risk averse speculators to enter the market in place of risk averse hedgers. An individual would only speculate in the forward market if compensated for the possible losses which an uncertain future might bring. Hence the equilibrium would be written as

$$F_t = E_t(S_{t+1}) + \hat{n}_t \qquad (5)$$

where n_t is a measure of the risk premium.

The possibility that profit maximising behaviour might entail some discrepancy between the forward rate and the expected spot rate has been extended by several writers. Two single currency models, Tsiang (1959) and Feldstein (1968) assume that speculators are always risk averse, and require a risk premium. Other more general models, like that of Grauer, Litzenberger and Stehl (1976) conclude that the risk premium can be positive, negative or zero, but that the relationship between exchange risk and return is positive and linear.

Frankel (1979) approaches the problem from a different angle. He suggests that variability in the exchange rate creates risk not only for domestic residents, but also for foreign residents: an unexpected rise in the exchange rate raises the value of domestic residents' assets, and the cost of foreign residents' liabilities. Residents of the two countries can trade risks with each other by agreeing to denominate debt in a weighted average of two currencies, or by domestic creditors selling foreign exchange to foreign debtors on the foreign market, allowing both sides to hedge their exchange rate risks. Risk aversion in agents' utility functions is not a sufficient condition for the presence of a risk premium. It is a factor which must be present, but it must also be accompanied by any one of three others; transactions costs, the existence of outside assets, or a non-zero correlation between the value of a currency and the real value of other forms of wealth. If none of these are relevant, risk can be completely diversified away, and no premium would be present.

While the existence of transactions costs has been noted in some studies, to explain away any small but significant bias, the risk premium is particularly difficult to model. Some series have been suggested to act as proxies for it, but their relevance has not been established. For example, it will be determined by the perceived variance of expectational errors, not the actual variance of spot rates over time. A high value of the latter would be compatible with riskless speculation if the movements of the major determinants of future spots were known, but subject to frequent change.

Difficulties in estimation notwithstanding, given the experience of the last decade, on a priori grounds we could expect risk premia to have played a significant role in forward exchange markets. Until the time that it is possible to be certain that such a variable can be excluded from a specified model, results which omit any consideration of it will be ambiguous. Is the forward rate an unbiased predictor of future spots because the markets are efficient, or despite the exclusion of a risk variable? The conclusions to be drawn from studies which follow this course are sensitive to the truth of an untested assumption.

Moreover, no guidance is given in those cases where there is evidence of significant bias in the forward rate's forecasts. This has been the finding of a number of recent studies of the 1920's and 1970's, by Baillie, Lippens and MacMahon, (1982), Frankel (1980), Hakkio (1981) Hodrick and Hansen (1980), Salemi (1980) and Tryon (1979). However, it is not possible to conclude with any great certainty whether these results were due to the inefficient use of information, the presence of risk, or perhaps other factors. Since the correct specification of the equilibrium is not clear, any testing of efficient markets theory in this area in fact tests a joint hypothesis. The importance of this point is further developed through the use of some empirical work.

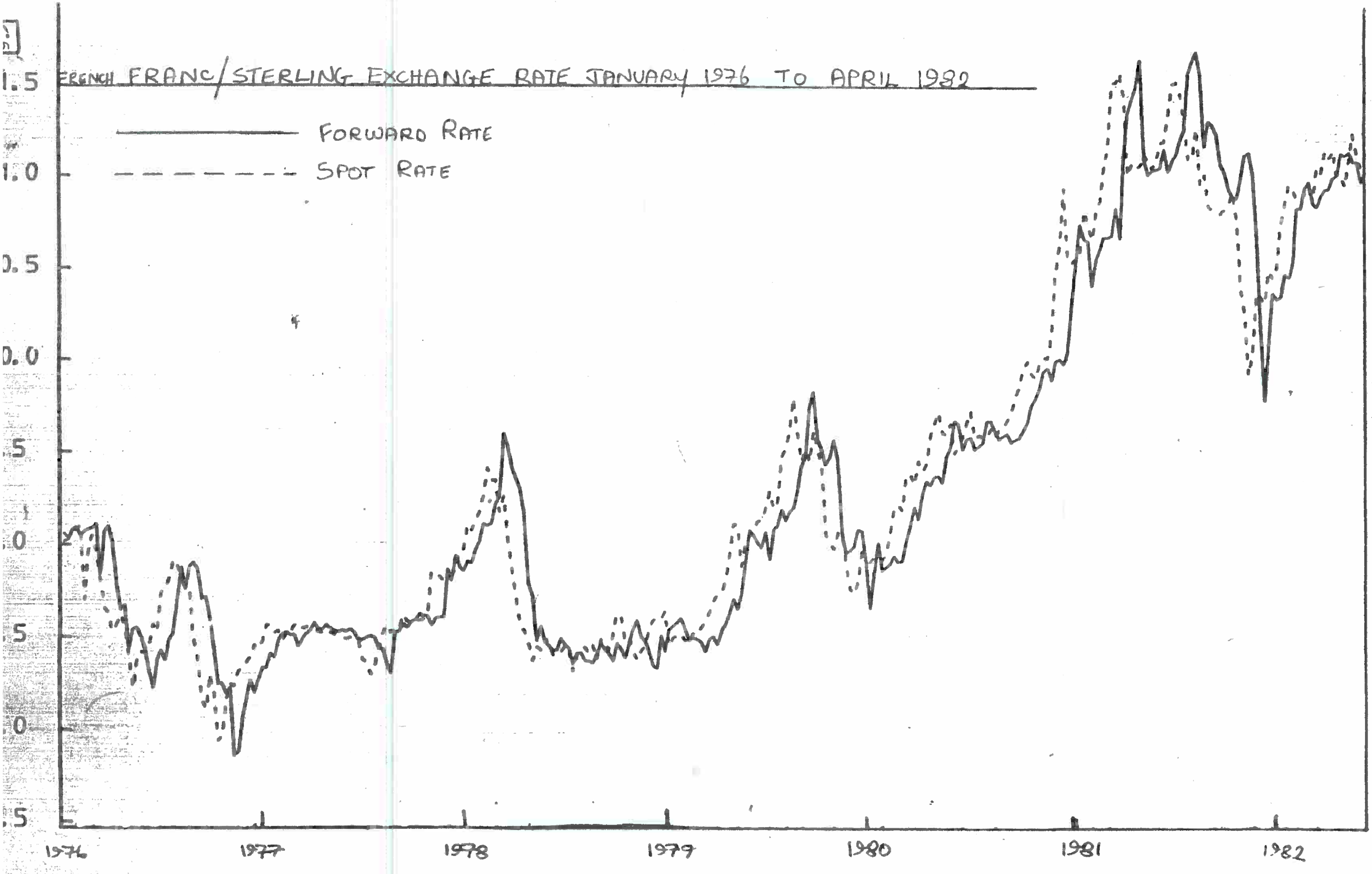
III. TESTING AND INTERPRETING THE DATA

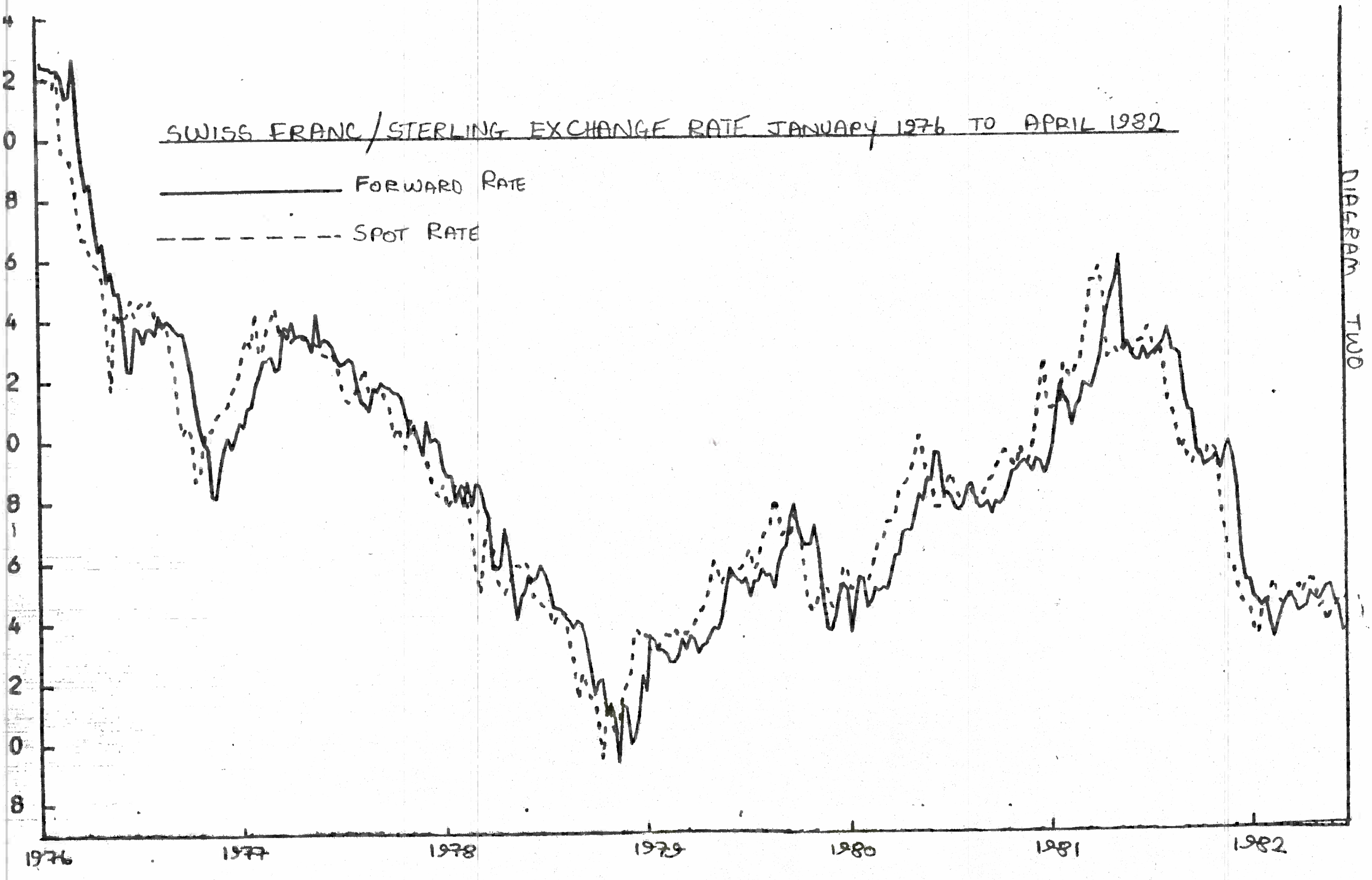
The data to be analysed are spot and 30 day forward rates for four currencies against sterling, the Swiss Franc, the French Franc, the Canadian Dollar and the Deutschemark. The samples run from January 6th 1976 to April 13th 1982, and each contains 328 weekly observations. A preliminary problem is that one figure is used to represent a day's trading. Since exchange rate values fluctuate during the period that a market is open, the profitability of speculative activity will also vary. The assumption made is that the spread between the highest and lowest values of a single day was not consistently wide enough to alter the results fundamentally.

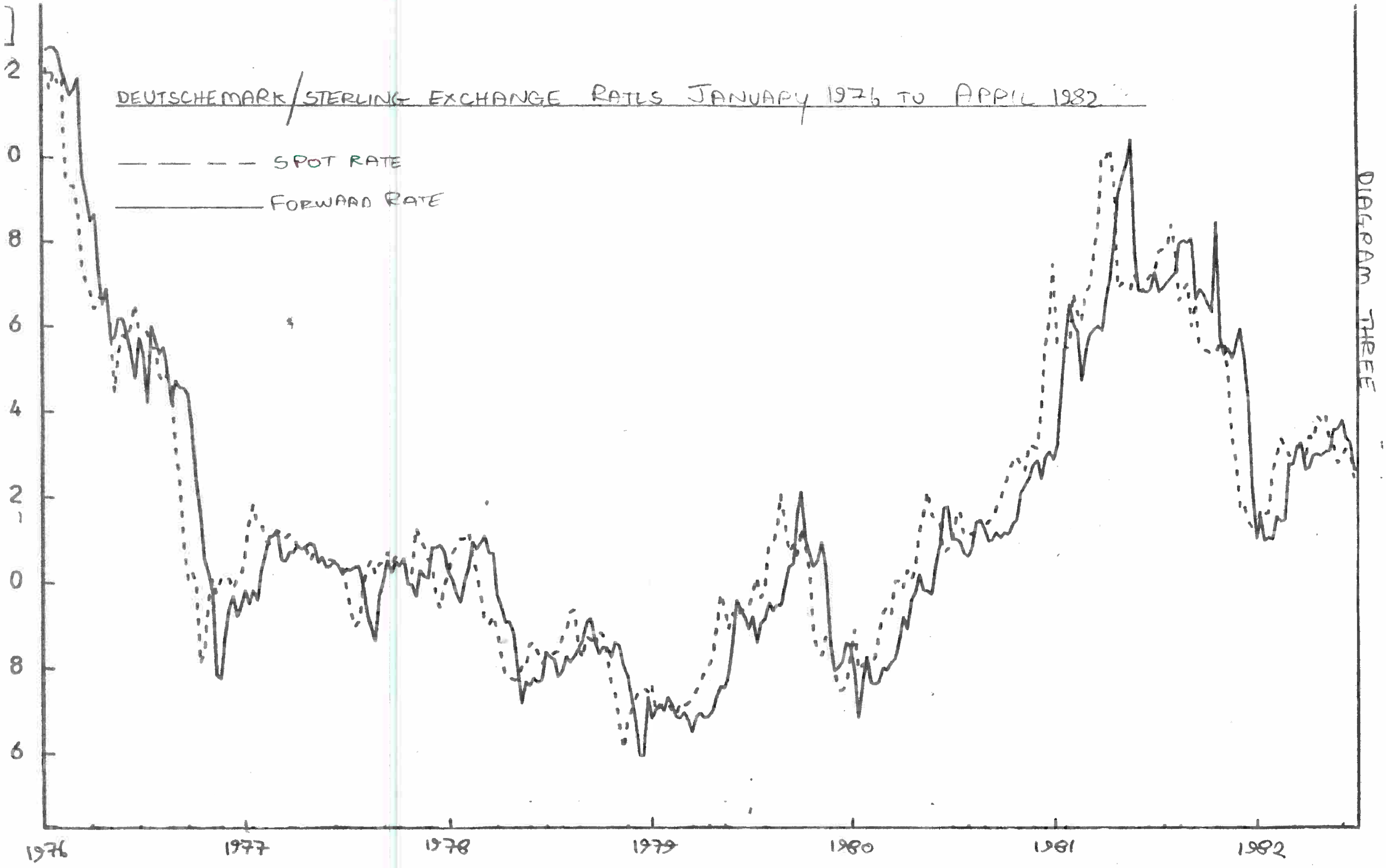
Before any estimation is carried out, one methodological point must be considered. This is the Siegal (1972) paradox. It is based on the fact that, due to Jensen's inequality and the convexity of the inverse function, it is impossible to have simultaneously the forward foreign currency price of domestic currency equal to the expected value of the corresponding anticipated spot rate, and the forward domestic currency price of foreign currency also equal to the expected value. There are two solutions to the problem. One is to ignore it. McCulloch (1975), using data from the 1920's, estimated that it would take 340 years to become empirically relevant. The second and the one employed here is to take logs of the dependent and independent variables. It then makes no difference whether exchange rates are defined from the point of view of the domestic or foreign currency.

Some consideration of the graphs showing the forward rates at time t plotted against the spot rates at t_{+30} is informative. These are shown in diagrams 1-4. It is apparent that the forward rate follows the current spot rate far more closely than the future spot rate; that is the premium or discount at time t is relatively small. The forward rate tends to underestimate the future spot rate when the current spot rate is rising, and overestimate it when the latter falls. The result of this is that the forward rate seems to be a very poor predictor of turning points in the spot rate cycle.

Since efficient use of information depends on what knowledge


FRENCH FRANC/STERLING EXCHANGE RATE JANUARY 1976 TO APRIL 1982
FORWARD RATE
SPOT RATE
1.5
1.0
0.5
0.0
.5
.0
.5
.0
.5
1976
1977
1978
1979
1980
1981
1982


SWISS FRANC/STERLING EXCHANGE RATE JANUARY 1976 TO APRIL 1982
FORWARD RATE
SPOT RATE
DIAGRAM TWO
1976
1977
1978
1979
1980
1981
1982
4
2
0
8
6
4
2
0
8
6
4
2
0
8



DEUTSCHEMARK/STERLING EXCHANGE RATES JANUARY 1976 TO APRIL 1982
SPOT RATE
FORWARD RATE
DIAGRAM THREE
2
0
8
6
4
2
0
8
6
1976
1977
1978
1979
1980
1981
1982

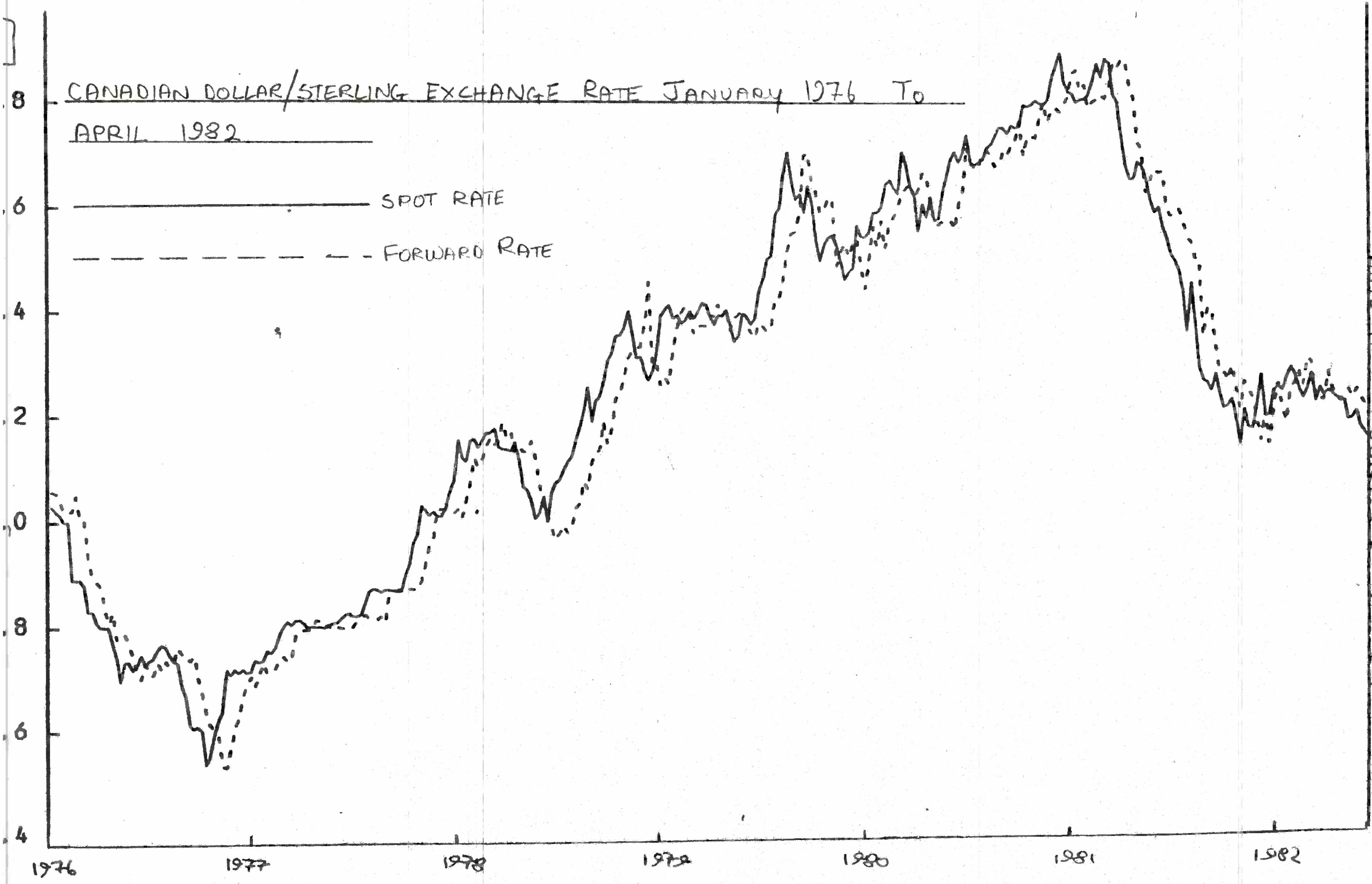


DIAGRAM FOUR

is deemed to be available, a number of different information sets are examined. The performance of the null hypothesis of efficiency is then tested against the data, assuming that no risk premium is relevant.

The first information set consists only of a constant. The criterion of efficiency is that the mean prediction error should not differ significantly from zero, or that $E_t(S_{t+1} - F_t) = 0$. The results, shown in Table 1, are quite consistent, for in no case is this test failed. The mean error never differs from zero, even when the samples were subdivided into two halves. As a standard of comparison, the predictive capability of the lagged spot rate was also examined. There is some evidence to suggest that, in the Canadian sample, the current spot rate is a better forecaster than the current forward rate.

The second test is to include the forward rate in the information set. In an efficient market, it would be the case that $E_t(S_{t+1} - F_t | F_t) = 0$. In a regression of the form

$$S_{t+1} = \alpha + \beta F_t + \varepsilon_t$$

we require α not to differ significantly from 0, nor β from 1, and the errors to be white noise.

One difficulty is that while the observations were taken weekly, the contract length used is one month. Contracts will overlap if the whole time series is included in the sample. Even if the markets were really efficient, the errors would follow a fourth order moving

TABLE 1 : Mean Prediction Errors $S_{t+1}-F_t$; standard errors in brackets

CURRENCY	January 1976 to April 1982	January 1976 to February 1978	January 1979 to April 1982
Swiss Franc	0.0019 (.036)	-0.0044 (.036)	0.0081 (.036)
Canadian Dollar	0.0036 (.033	0.0082 (.039)	-0.0017 (.028)
French Franc	-0.0006 (.041)	-0.0013 (.017)	0.00001 (.014)
Deutschemark	-0.0034 (.016)	-0.0051 (.026)	-0.0017 (0.22)

Mean Prediction Errors $S_{t+1}-S_t$

CURRENCY	January 1976 to April 1982	January 1976 to February 1979	February 1979 to April 1982
Swiss Franc	0.0056 (.036)	0.0120 (.036)	0.0010 (.036)
Canadian Dollar	0.0010 (.013)	0.0038 (.017)	-0.0019 (.018)
French Franc	-0.0010 (.013)	-0.0019 (.017)	-0.0001 (.018)
Deutschemark	-0.0069 (.017)	-0.0104 (.019)	-0.0034 (.024)

average process. This is because new information which would help to determine the spot rate four weeks from now becomes available in weeks one to three. This would be correlated with information bearing on the spot rate in week five that became available between weeks one and four. The presence of autocorrelation would cause the null hypothesis to be rejected. A common procedure in these circumstances would be to establish what the error process was, then transform the original data accordingly. However, as Hodrick and Hansen (1980) point out, the forward rate is not strictly exogenous since its future values would be useful for forecasting S_{t+1}.

The method adopted here to avoid this problem is to include only every fourth observation in the sample, and to estimate four separate sub-samples for each currency. This is not a fully efficient procedure, and an added difficulty is that there is no statistical manoeuvre which would allow the results of each sample to be combined. However, it would be foolish to ignore available data, and it is also possible to check, if in a rather ad hoc fashion, the stability of the whole sample.

The contents of Table 2 show that the results are unambiguous. The null hypothesis is rejected. In the markets for the Swiss and German currencies, the actual parameter values are never equal to those pre-specified. Moreover, all of the Swiss series exhibited auto-correlated error terms, as did the German series A and D. While all of the α and β values for the French and Canadian series are of the correct magnitude, only one has a white noise error term.

TABLE TWO

$S_t = \alpha + \beta F_{t-1} + U_t$

* =SIGNIFICANTLY DIFFERENT FROM HYPOTHESISED VALUE AT 5% LEVEL;
STANDARD ERRORS IN BRACKETS

CURRENCY/SERIES		RESULT: JANUARY 1976 TO APRIL 1982 n=82	R^2	DURBIN-WATSON STATISTIC
SWISS FRANC	A	0.165* + 0.879*F_{t-1} (.053) (.033)	.86	0.965*
	B	0.140* + 0.898*F_{t-1} (.045) (.033)	.90	1.467*
	C	0.116* + 0.916*F_{t-1} (.049) (.037)	.89	1.655*
	D	0.137* + 0.900*F_{t-1} (.045) (.033)	.90	1.625*
CANADIAN DOLLAR	A	0.000 + 1.008F_{t-1} (.018) (.023)	.93	1.466*
	B	0.023 + 0.975F_{t-1} (0.18) (.022)	.96	1.149*
	C	0.003 + 0.967F_{t-1} (.018) (.022)	.96	1.13*
	D	0.028 + 0.969F_{t-1} (.019) (.024)	.95	1.362*
FRENCH FRANC	A	0.061 + 0.974F_{t-1} (.067) (.030)	.93	1.487*
	B	0.067 + 0.971F_{t-1} (.067) (.030)	.93	1.607*
	C	0.091 + 0.961F_{t-1} (.075) (.036)	.91	1.691
	D	0.083 + 0.965F_{t-1} (.069) (.031)	.92	1.565*
DEUTSCHEMARK	A	0.180* + 0.875*F_{t-1} (.053) (.037)	.88	1.538*
	B	0.176* + 0.878*F_{t-1} (.053) (.037)	.88	1.700
	C	0.170* + 0.883*F_{t-1} (.057) (.040)	.86	1.728
	D	0.181* + 0.875*F_{t-1} (.053) (.038)	.87	1.644*

Since it is important to know on what grounds the test for efficiency is failed, the Cochrane-Orcutt iterative technique was used to ensure that the t-tests were valid. Table 3 indicates that this step made little qualitative difference; indeed, in the Canadian case, the results are somewhat less favourable.

One further test, suggested by Frenkel (1982), is to add a one period lag of the forward rate to the set of regressors. In an efficient market, the forward rate at time t would incorporate all relevant information. Since information useful at time t_{-1} would also be available at time t, in the regression

$$S_t = \alpha + \beta F + \gamma F_{t-1} + \varepsilon_t$$

efficiency requires that γ equals zero. Table 4 shows that this is so for all of the French and German series, but only for two of each of the Canadian and Swiss currencies. However, when the Cochrane-Orcutt procedure was used on the series with autocorrelated error terms, the results were more unfavourable to the efficiency hypothesis, except in two of the Canadian cases.

It is possible to look closer at the formation of expectations. Rational expectations require that successive prediction errors be serially uncorrelated, or that $E(S_{t+1} - F_t | S_t - F_{t-1}) = 0$. Consequently the information set in the next test will consist of a constant and the most recent prediction error. The estimating equation then is

$$S_{t+1} - F_t = \alpha(1-\beta) + \beta(S_t - F_{t-1}) + \varepsilon_t$$

In an efficient market, both α and β would not differ significantly from zero.

TABLE 3

$$S_t = \alpha + \beta F_{t-1} + \rho U_{t-1},$$

* SIGNIFICANTLY DIFFERENT FROM HYPOTHESISED VALUE AT 5% LEVEL.

CURRENCY/SERIES		RESULT: JANUARY 1976 TO APRIL 1982	ESTIMATE OF RHO
SWISS FRANC	A	$1.18^{*} + 0.088^{*}F_{t-1}$ (.152) (.114)	.902
	B	$0.194^{*} + 0.858^{*}F_{t-1}$ (.067) (.050)	.306
	C	$0.166^{*} + 0.878^{*}F_{t-1}$ (.067) (.050)	.215
	D	$0.184^{*} + 0.864^{*}F_{t-1}$ (.062) (.046)	.228
CANADIAN DOLLAR	A	$0.010 + 0.995F_{t-1}$ (.038) (.030)	.274
	B	$0.057^{*} + 0.935F_{t-1}$ (.028) (.035)	.446
	C	$0.065^{*} + 0.924^{*}F_{t-1}$ (.031) (.035)	.460
	D	$0.054^{*} + 0.938F_{t-1}$ (.027) (.037)	.340
FRENCH FRANC	A	$0.117 + 0.949F_{t-1}$ (.089) (.039)	.279
	B	$0.119 + 0.948F_{t-1}$ (.082) (.037)	.220
	C		
	D	$0.137 + 0.940F_{t-1}$ (.088) (.040)	.243
DEUTSCHEMARK	A	$0.303^{*} + 0.788^{*}F_{t-1}$ (.079) (.056)	.309
	B		
	C		
	D	$0.231^{*} + 0.840F_{t-1}$ (.074) (.052)	.218

TABLE FOUR

(1) $S_t = \alpha + \beta F_{t-1} + \gamma F_{t-2} + U_t$ (2) $S_t = \alpha + \beta F_{t-1} + \gamma F_{t-2} + U_t - \rho U_{t-1}$

* SIGNIFICANTLY DIFFERENT FROM HYPOTHESISED VALUE AT 5% LEVEL

CURRENCY/SERIES		RESULT (1): JANUARY 1976 TO APRIL 1982 OLS ESTIMATION	DURBIN WATSON STATISTIC	RESULT (2): JANUARY 1976 TO APRIL 1982. COCHRANE-ORCUTT TECHNIQUE
SWISS FRANC	A	$.183 + 1.079F_{t-1} - 0.21F_{t-2}$ (.055) (.152) (.147)	1.248^*	$0.882 + 0.607F_{t-1} + 0.265^*F_{t-2}$ (.186) (.115) (.113)
	B	$.150 + 1.123F_{t-1} - 0.232^*F_{t-2}$ (.040) (.121) (.117)	1.834	
	C	$.150 + 1.123F_{t-1} - 0.232F_{t-2}$ (.046) (.122) (.117)	1.734	
	D	$.146 + 0.959F_{t-1} - 0.066F_{t-2}$ (.048) (.114) (.109)	1.747	
CANADIAN DOLLAR	A	$.001 + 1.142F_{t-1} - 0.136F_{t-2}$ (.018) (.121) (.121)	1.652^*	$0.015 + 0.824F_{t-1} + 0.166F_{t-2}$ (.028) (.123) (.123)
	B	$.023 + 1.290F_{t-1} - 0.318^*F_{t-2}$ (.018) (.118) (.118)	1.639^*	$0.074 + 0.735F_{t-1} + 0.18F_{t-2}$ (.036) (.108) (.108)
	C	$.034 + 1.260F_{t-1} - 0.301^*F_{t-2}$ (.018) (.118) (.119)	1.557^*	$0.082 + 0.741F_{t-1} + 0.163F_{t-2}$ (.030) (.108) (.119)
	D	$.018 + 1.019F_{t-1} - 0.019F_{t-2}$ (.041) (.071) (.057)	1.490^*	$0.089 + 0.581F_{t-1} + 0.314^*F_{t-2}$ (.041) (.109) (.109)
FRENCH FRANC	A	$.079 + 1.140F_{t-1} - .170F_{t-2}$ (.069) (.126) (.129)	1.735	
	B	$.077 + 1.05F_{t-1} - 0.080F_{t-2}$ (.069) (.112) (.114)	1.712	
	C	$.085 + 0.923F_{t-1} + 0.03F_{t-2}$ (.077) (.113) (.115)	1.625^*	$1.05 + 0.788F_{t-1} - 0.278^*F_{t-2}$ (.233) (.149) (.142)
	D	$.092 + 1.056F_{t-1} + 0.096F_{t-2}$ (.071) (.120 (.122)	1.713	
DEUTSCHEMARK	A	$.194 + 0.975F_{t-1} - 0.109F_{t-2}$ (.056) (.114) (.109)	1.726	
	B	$0.182 + 0.961F_{t-1} - 0.086F_{t-2}$ (.055) (.118) (.112)	1.948	
	C	$0.180 + 0.913F_{t-1} - 0.04F_{t-2}$ (.061) (.114) (.109)	1.782	
	D	$0.191 + 0.935F_{t-1} - 0.067F_{t-2}$ (.057) (.115) (.109)	1.743	

The results in table 5 show a degree of diversity in each currency series which is hard to explain. None of the intercept terms are significant, but at least one series for each currency has a significant β value. Only the dollar series seems to be homogeneous.

One last test, which provides further insight into the nature of the foreign exchange market, can be used to examine the ability of the forward rate to predict changes in future spots. This can be done by regressing the rate of depreciation (appreciation) against the forward discount (premium). Subtracting S_t from both sides of equation 6, we obtain

$$S_{t+1} - S_t = \alpha + \beta(F_t - S_t) + \varepsilon_t$$

The null hypothesis is that $\alpha=0$, $\beta=1$ and that ε_t is uncorrelated with its past values. Again, the results, in table 6, exhibit a significant degree of diversity, but in no case does $\beta=1$. In the majority of cases, β is not significantly different from 0. This suggests that the spot rate follows a random walk. However, as Frankel (1982) points out, "the random walk case is not the same as market efficiency: indeed, it would imply that one could make money by betting against the forward rate." The five negative values are also of interest since they imply that a higher forward discount is associated with a more appreciated exchange rate.

It is now time to draw some conclusions from these results. The support for the view that the markets analysed were efficient over the period, and that no risk premium was present, is not strong. Some of the failures may be due to the fact that a battery of tests was applied. Since all

TABLE 5

$$(S_{t+1} - F_t) = E_t \; : \; E_t = \alpha + \beta E_{t-1}$$

* SIGNIFICANTLY DIFFERENT FROM HYPOTHESISED VALUE AT 5% LEVEL

CURRENCY/SERIES		RESULT: JANUARY 1976 TO APRIL 1982
SWISS FRANC	A	0.001 (.004) + 0.515* (.097) E_{t-1}
	B	0.002 (.004) + 0.280* (.108) E_{t-1}
	C	0.002 (.004) + 0.149 (.112) E_{t-1}
	D	0.002 (.004) + 0.182 (.112) E_{t-1}
CANADIAN DOLLAR	A	0.005 (.004) + 0.269* (.109) E_{t-1}
	B	0.002 (.003) + 0.415* (.103) E_{t-1}
	C	0.001 (.003) + 0.427* (.103) E_{t-1}
	D	0.002 (.004) + 0.308* (.105) E_{t-1}
FRENCH FRANC	A	0.002 (.003) + 0.244* (.110) E_{t-1}
	B	0.002 (.003) + 0.180 (.111) E_{t-1}
	C	0.002 (.003) + 0.130 (.111) E_{t-1}
	D	0.003 (.003) + 0.200 (.111) E_{t-1}
DEUTSCHEMARK	A	0.002 (.003) + 0.236* (.109) E_{t-1}
	B	0.003 (.003) + 0.111 (.112) E_{t-1}
	C	0.002 (.003) + 0.115 (.112) E_{t-1}
	D	0.003 (.003) + 0.074 (.111) E_{t-1}

TABLE 6

$$\Delta_1 S_{t+1} = \alpha + \beta(F_t - S_t) + t_t$$

CURRENCY/SERIES		RESULT: JANUARY 1976 TO APRIL 1982
SWISS FRANC	A	$-0.006 - 0.105^{*} (F_{t-1} - S_{t-1})$ (.004) (.150)
	B	$-0.024 - 2.491^{*} (F_{t-1} - S_{t-1})$ (.009) (1.16)
	C	$-0.028 - 2.960^{*} (F_{t-1} - S_{t-1})$ (.010) (1.177)
	D	$-0.005 + 0.071^{*} (F_{t-1} - S_{t-1})$ (.005) (.510)
CANADIAN DOLLARS	A	$0.002 + 0.09^{*} (F_{t-1} - S_{t-1})$ (.004) (.310)
	B	$-0.002 - 1.415^{*} (F_{t-1} - S_{t-1})$ (.005) (.580)
	C	$-0.003 - 1.79^{*} (F_{t-1} - S_{t-1})$ (.006) (.693)
	D	$-0.002 - 1.36^{*} (F_{t-1} - S_{t-1})$ (.003) (.641)
FRENCH FRANC	A	$0.002 - 1.143^{*} (F_{t-1} - S_{t-1})$ (.003) (.740)
	B	$0.002 - 1.070^{*} (F_{t-1} - S_{t-1})$ (.003) (.613)
	C	$0.002 - 0.290^{*} (F_{t-1} - S_{t-1})$ (.003) (.571)
	D	$0.002 - 0.885^{*} (F_{t-1} - S_{t-1})$ (.003) (.644)
DEUTSCHEMARK	A	$-0.007 - 0.916^{*} (F_{t-1} - S_{t-1})$ (.007) (1.186)
	B	$-0.005) - 0.507^{*} (F_{t-1} - S_{t-1})$ (.007) (1.11)
	C	$-0.000 + 0.290^{*} (F_{t-1} - S_{t-1})$ (.005) (.637)
	D	$-0.010 + 1.470^{*} (F_{t-1} - S_{t-1})$ (.007) (1.051)

testing was conducted at the 5% level, we would, on average, record an error five times in every 100 tests. However, it would be perverse to attribute the general failure to statistical mischance. It is also most unlikely that transactions costs can explain all of the results, since some of the most sophisticated of the world's financial markets were studied. It may be instructive to explore in greater detail the role played by the abolition of exchange controls, although that path is not pursued here. Monopolistic speculation can, in principle, explain divergences between the forward rate and the expected spot rate but is unlikely to be relevant here because of the numbers of traders involved

Some writers, such as Frankel (1979), on discovering bias in the forward rate's predictions in the early part of the floating rate period, suggested that the failure could be explained by market participants' lack of experience with the system. However, not only is this interpretation strictly a violation of rational expectations theory, there is little support for it here. For example, the results in tables 7 and 8 showing the sample used in Table 2 subdivided, and where necessary adjusted for autocorrelation, indicate that the forward rate for Swiss, if not French, Francs was more biased in the second half of the period; of course, it is possible that new shocks altered the informational requirements.

It is feasible to argue that the autocorrelation present in Table 2 and the correlation of the prediction errors were the result of the inefficient use of information, or factors other than the expected spot rate determining the forward rate. However, the model of Harris and Purvis

TABLE 7

$$S_t = \alpha + \beta F_{t-1} + U_t$$

CURRENCY/SERIES		JANUARY 1976 TO FEBRUARY 1979	DURBIN-WATSON	FEBRUARY 1979 TO APRIL 1982	DURBIN-WATSON
SWISS FRANC	A	0.115* + 0.914*F$_{t-1}$ (.055) (.040)	1.441*	0.282 + 0.793F$_{t-1}$ (.126) (.095)	0.698*
	B	0.111* + 0.916*F$_{t-1}$ (.054) (.039)	1.313*	0.174 + 0.875F$_{t-1}$ (.091) (.069)	1.637
	C	0.084 + 0.937F$_{t-1}$ (.061) (.044)	1.641	0.170 + 0.877F$_{t-1}$ (.096) (.073)	1.678
	D	0.106* + 0.921*F$_{t-1}$ (.054) (.039)	1.704	0.196 + 0.857F$_{t-1}$ (.090) (.068)	1.540*
CANADIAN DOLLAR	A	−0.017 + 1.036F$_{t-1}$ (.038) (.057)	1.508*	−0.004 + 1.010F$_{t-1}$ (.042) (.045)	1.444*
	B	0.003 + 1.018F$_{t-1}$ (.033) (.047)	1.029*	0.022 + 0.975F$_{t-1}$ (.062) (.067)	1.352*
	C	0.014 + 0.944F$_{t-1}$ (.034) (.051)	1.300*	0.024 + 1.022F$_{t-1}$ (.053) (.058)	1.021*
	D	0.037 + 0.956F$_{t-1}$ (.037) (.054)	1.488*	0.008 + 0.990F$_{t-1}$ (.050) (.055)	1.083*
FRENCH FRANC	A	0.730* + 0.660*F$_{t-1}$ (.208) (.090)	1.255*	0.250* + 0.895*F$_{t-1}$ (.120) (.053)	1.681
	B	0.840* + 0.608*F$_{t-1}$ (.210) (.091)	1.445*	0.243* + 0.897*F$_{t-1}$ (.118) (.051)	1.745
	C	0.850* + 0.606*F$_{t-1}$ (.270 (.102)	1.384*	0.292* + 0.876*F$_{t-1}$ (.143) (.062)	1.822
	D	0.794* + 0.630*F$_{t-1}$ (.224 (.104)	1.359*	0.267* + 0.887*F$_{t-1}$ (.120) (.055)	1.665
DEUTSCHEMARK	A	0.188* + 0.864*F$_{t-1}$ (.065) (.046)	1.744	0.252* + 0.831*F$_{t-1}$ (.091 (.063)	1.553
	B	0.226* + 0.837*F$_{t-1}$ (.065) (.046)	1.811	0.201* + 0.867*F$_{t-1}$ (.018 (.063)	1.952
	C	0.221* + 0.840*F$_{t-1}$ (.079) (.046)	1.812	0.206* + 0.862*F$_{t-1}$ (.096) (.067)	1.715
	D	0.224* + 0.839*F$_{t-1}$ (.075) (.056)	1.771	0.231* + 0.845*F$_{t-1}$ (.061) (.061)	1.625

TABLE 8

$$S_t = \alpha + \beta F_{t-1} + U_t - \rho u_{t-1}$$

CURRENCY/SERIES		JANUARY 1976 TO FEBRUARY 1979	ESTIMATE OF RHO	FEBRUARY 1979 TO APRIL 1982	ESTIMATE OF RHO
SWISS FRANC	A	0.209 + $0.843F_{t-1}$ (.085) (.062)	.328	1.21 + .082 (.239) (.174)	.913
	B	0.166 + $0.875F_{t-1}$	.388	-	
	C	-		-	
	D	-		1.15 + $0.133F_{t-1}$ (.193) (.142)	.900
CANADIAN DOLLAR	A	0.004 + $1.005F_{t-1}$ (.049) (.073)	.269	.020* + $0.985F_{t-1}$ (.055) (.146)	.288
	B	0.049 + $0.947F_{t-1}$ (.044 (.071)	.512	.052* + $0.430F_{t-1}$* (.054) (.147)	.868
	C	0.044 + $0.954F_{t-1}$ (.044) (.069)	.350	.524* + $0.393F_{t-1}$* (.050) (.141)	.952
	D	0.068 + $0.915F_{t-1}$ (.047) (.069)	.286	.578* + $0.327F_{t-1}$* (.049) (.142)	.960
FRENCH FRANC	A	1.31 + $0.39F_{t-1}$* (.280) (.130)	.49	-	
	B	1.25* + $0.418F_{t-1}$* (2.77) (.129)	.439	-	
	C	1.624* + $0.243F_{t-1}$* (.300) (.140)	.556	-	
	D	1.389* + $0.354F_{t-1}$* (.307) (.143)	.458	-	
DEUTSCHEMARK	A	-		-	
	B	-		-	
	C	-		-	
	D	-		-	

(1980) must be considered. They draw a distinction between a temporary and a permanent shock A permanent shock may originally be perceived to be only temporary (the 1973 oil price rise). Over time, the true situation would be realised. However, in the interim period, the forward rate would not be an unbiased predictor of future spots. This may not imply inefficiency in the proper sense, rather the elimination of an initial confusion.

The autocorrelated errors could also be due to drastic events not being independent events. For example, the fact that the dramatic rise of sterling from 1979 was not capped by the authorities in one period may have increased the possibility that it would be in the next. On the other hand, the possibility might have been reduced. The important point is that potential shocks cannot be restricted in their efforts to just one time period. However, the statistical results depend crucially on whether that event actually occurred. All of the confidence intervals were calculated on the assumption that the estimators were normally distributed, or converged quickly to a normal distribution. If the error term includes the possibility of a discontinuously large event the sample size used may be too small, and the distributions significantly non-normal.[3/]

To test the possibility that the errors were normally distributed, the Bowman-Sherton test was performed. Following Kiefer and Salmon (1982) this statistic can be subdivided into two terms, which allows us to determine the cause of deviations from normality. The results are given in Table 9. The first term in each series is the estimated coefficient for skewness, the second for kurtosis. For three out of the

TABLE 9

NORMALITY TESTS

*SIGNIFICANTLY DIFFERENT FROM HYPOTHESISED VALUE AT 5% LEVEL

CURRENCY/SERIES		A	B	C	D
SWISS FRANC	1	3.56	0.058	2.944	2.897*
	2	3.42	1.104	0.617	0.358
CANADIAN DOLLAR	1	0.207	1.369	0.37	2.790
	2	6.259*	0.392	0.348	0.37
FRENCH FRANC	1	0.186	4.03*	6.28*	7.57*
	2	8.37*	3.06	11.88*	3.77
DEUTSCHEMARK	1	3.17	3.7	5.32*	6.201*
	2	18.98*	8.65*	5.16*	6.036*

four Swiss and Canadian series, the normality assumption was found to be valid. This was not so for any of the French or German series. Kurtosis and skewness were found to be responsible for the failures in approximately equal measure.

White's (1980) standard errors were also calculated. These are based on the fact that if a model is functionally misspecified, the parameters estimated average to the parameters of the OLS approximation, not to the true parameters. Some idea of the nature of this approximation may be had by using the covariance matrix estimator $(X'X/n)^{-1}$ $\hat{V}ols\ (X'X/n)^{-1}$, since the usual estimator $s^2 (X'X/n)^{-1}$ is not necessarily consistent. The results in Table 10 show that the estimates yielded by the two formulae do not differ substantially. There is little evidence here of misspecification.

The question of risk merits discussion at greater length, since it is not implausible to argue that the unpredictable nature of exchange rate movements during the period studied would be accompanied by a significant risk factor in the forward market. I shall continue by assessing what, if anything, can be inferred from the data with regard to the risk position of market participants.

The insignificance of the mean prediction errors in Table 1, at the chosen significance level, suggests that no systematic risk premium was present over the period in any currency. Allowing for this, it is possible to interpret the point estimates as estimates of the premia. For example, a negative sign would indicate a greater return on sterling assets than those denominated in other currencies, or that sterling was a relatively unsafe currency and holders of it had to be compensated for greater riskiness.

TABLE 10

WHITES STANDARD ERRORS

CURRENCY/SERIES		A		B		C		D	
		OLS	WHITE	OLS	WHITE	OLS	WHITE	OLS	WHITE
SWISS FRANC	α							0.045	0.039
	β							0.033	0.029
CANADIAN DOLLAR	α	0.018	0.020						
	β	0.022	0.023						
FRENCH FRANC	α	0.066	0.066	0.066	0.066	0.075	0.087	0.069	0.076
	β	0.029	0.030	0.029	0.030	0.034	0.039	0.031	0.034
DEUTSCHEMARK	α	0.053	0.056	0.052	0.046	0.057	0.056	0.054	0.051
	β	0.037	0.039	0.037	0.033	0.042	0.039	0.038	0.037

The problem may be approached in a different way. The estimated model was based on the presumption that

$$S_t = E_{t-1}(S_t) + \eta_t \qquad (10)$$

where η_t is the rational expectations forecasting error. If a risk premium was present this would determine the forward rate along with the expected spot rate, as in

$$F_{t-1} = E_{t-1}S_t + R_t \qquad (11)$$

where R_t is a measure of the risk premium. I shall assume that R_t has a constant value of α. Combining equations 8 and 9 gives

$$S_t = -\alpha + \beta F_{t-1} + \eta_t \qquad (12)$$

Thus, it is possible to interpret the constant terms in Tables 2, 3, 7 and 8 as estimates of the risk premia. This suggests that they were significant for all of the currencies at at least some stage over the period.

This formulation raises a further problem. The forward rate may be a "noisy" predictor of future spots. This would be the case if we were to model the risk premium by

$$R_{t-1} = \alpha+\nu_{t-1} \tag{13}$$

where ν_{t-1} is a serially uncorrelated random variable with zero mean, representing temporary descrepancies between the actual and mean values of the premium. In this case, equation 6 would become

$$S_t = -\alpha+\beta F_{t-1}+(\eta-\nu_{t-1}) \tag{14}$$

Estimating this by OLS would yield inconsistent estimates, because the error term is correlated with the exogenous variable. This is the classic error in variables problem. Consequently, the instrumental variables technique was employed to estimate equation 14. Where there was evidence of autocorrelation, the two-step Cochrane-Orcutt procedure was employed.

A comparison of the results in Tables 2 and 11 show that the OLS and instrumental variable estimates are very similar, and that there is little evidence of misspecification from the source outlined above.

The estimation methods used so far have constrained the parameter estimates to be constant over the entire sample. If the true model was as specified in equation 1, with only the expected future spot rate determining the forward price, this procedure would be justified. Chow tests can be used to test this assumption, but they are quite crude. There is no reason why a structural break should necessarily occur at the specified division, nor why there should be only one per sample. Nevertheless, if a risk premium or any other relevant variable was excluded, the estimated model would be incorrectly specified. However OLS estimation forces a "best" fit on the model, even if it is not an

TABLE 11

CURRENCY/SERIES		RESULT: JANUARY 1976 TO APRIL 1982 INSTRUMENTAL VARIABLES			RESULT: JANUARY 1976 TO APRIL 1982 TWO STEP COCHRANE-ORCUTT	
			R^2	DURBIN-WATSON		ESTIMATE OF RHO
SWISS FRANC	A	$0.194^* + 0.856^*F_{t-1}$ (.058) (.043)	.941	.946*	$0.153 + 0.097^*F_{t-1}$ (.153) (.115)	.515
	B	$0.141^* + 0.897^*F_{t-1}$ (.049) (.037)	.961	1.478*	$0.173 + 0.873^*F_{t-1}$ (.151) (.050)	.964
	C	$0.117^* + 0.915^*F_{t-1}$ (.055) (.041)	.956	1.724	-	
	D	$0.139^* + 0.899^*F_{t-1}$ (.050) (.037)	.962	1.687*	$0.149 + 0.891F_{t-1}$ (.068) (.051)	.124
CANADIAN DOLLAR	A	$0.001 + 1.007F_{t-1}$ (.018) (.023)	.962	1.445*	$0.015 + 0.991F_{t-1}$ (.023) (.029)	.259
	B	$0.028 + 0.972F_{t-1}$ (.018) (.022	.962	1.197*	$0.057^* + 0.937^*F_{t-1}$ (.027) (.033)	.414
	C	$0.034 + 0.963F_{t-1}$ (.018) (.022)	.962	1.160*	$0.065^* + 0.924F_{t-1}$ (.029) (.035)	.449
	D	$0.032 + 0.965F_{t-1}$ (.019) (.024)	.955	1.396*	$0.055^* + 0.938F_{t-1}$ (.027) (.033)	.316
FRENCH FRANC	A	$0.061 + 0.974F_{t-1}$ (.068) (.030)	.929	1.479*	$0.119 + 0.948F_{t-1}$ (.089) (.037)	.280
	B	$0.071 + 0.970F_{t-1}$ (.067) (.030)	.932	1.607*	$0.119 + 0.948F_{t-1}$ (.089) (.040)	.220
	C	$0.092 + 0.960F_{t-1}$ (.076) (.034)	.912	1.676	-	
	D	$0.081 + 0.963F_{t-1}$ (.070) (.032)	.924	1.529*	$0.140 + 0.939^*F_{t-1}$ (.086) (.029)	.236
DEUTSCHEMARK	A	$0.210^* + 0.854^*F_{t-1}$ (.058) (.041)	.85	1.470	$0.265 + 0.815^*F_{t-1}$ (.081) (.057)	.323
	B	$0.166^* + 0.886^*F_{t-1}$ (.058) (.040)	.858	1.815	-	
	C	$0.167 + 0.885F_{t-1}$ (.064) (.045)	.835	1.730	-	
	D	$0.176^* + 0.878^*F_{t-1}$ (.060) (.042)	.851	1.678	-	

accurate representation of the true data generation process.

Consequently, equation 6 was re-estimated using a variable parameter technique on the PSTAB package. The estimation procedure is based on recursive least squares; estimates at time t are based on information available at time t only. The data is allowed to "breathe", to decide at each point in time the value that a parameter should take. Hence it is possible to see how the estimates evolve as more information is added. If these remain fairly constant, this indicates that the model is well specified. If there is much variation, the liklihood is that important regressors have been excluded.

The PSTAB estimates are given in diagrams 5 to 8. Only one series for each currency is included because the visual impression did not vary substantially when the other three were studied. The diagrams are useful not only as a guide to the stability of the regression equation, but also, since the parameters will vary according to the stimuli of important but omitted economic factors, it is possible to associate the start of a change of the route of a path with real world events. In view of this the French Franc series, in diagrams 5 and 6, is the most interesting. It is possible to perceive several minor shocks and one major one which radically alters the paths' courses. This coincides

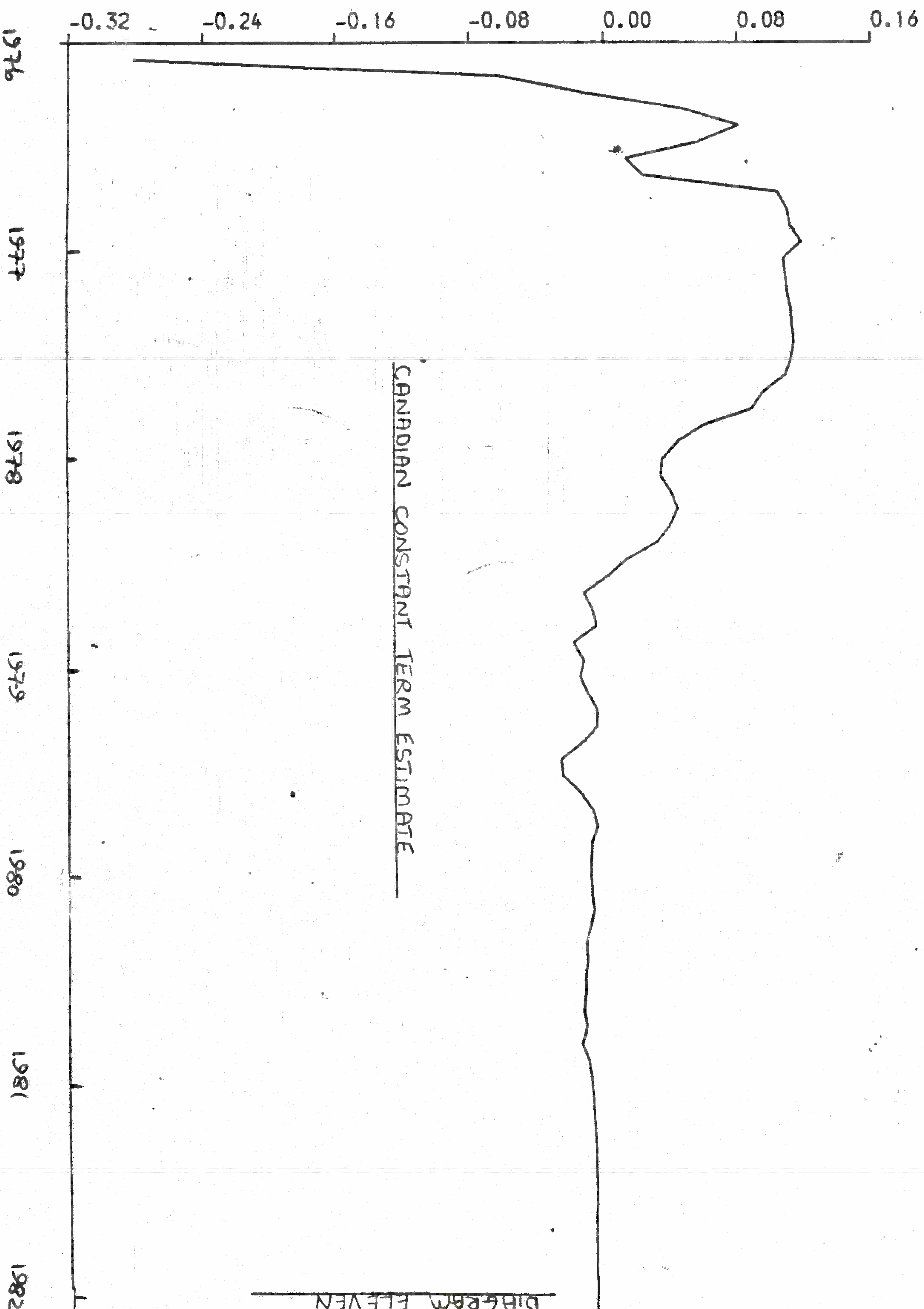


DIAGRAM ELEVEN

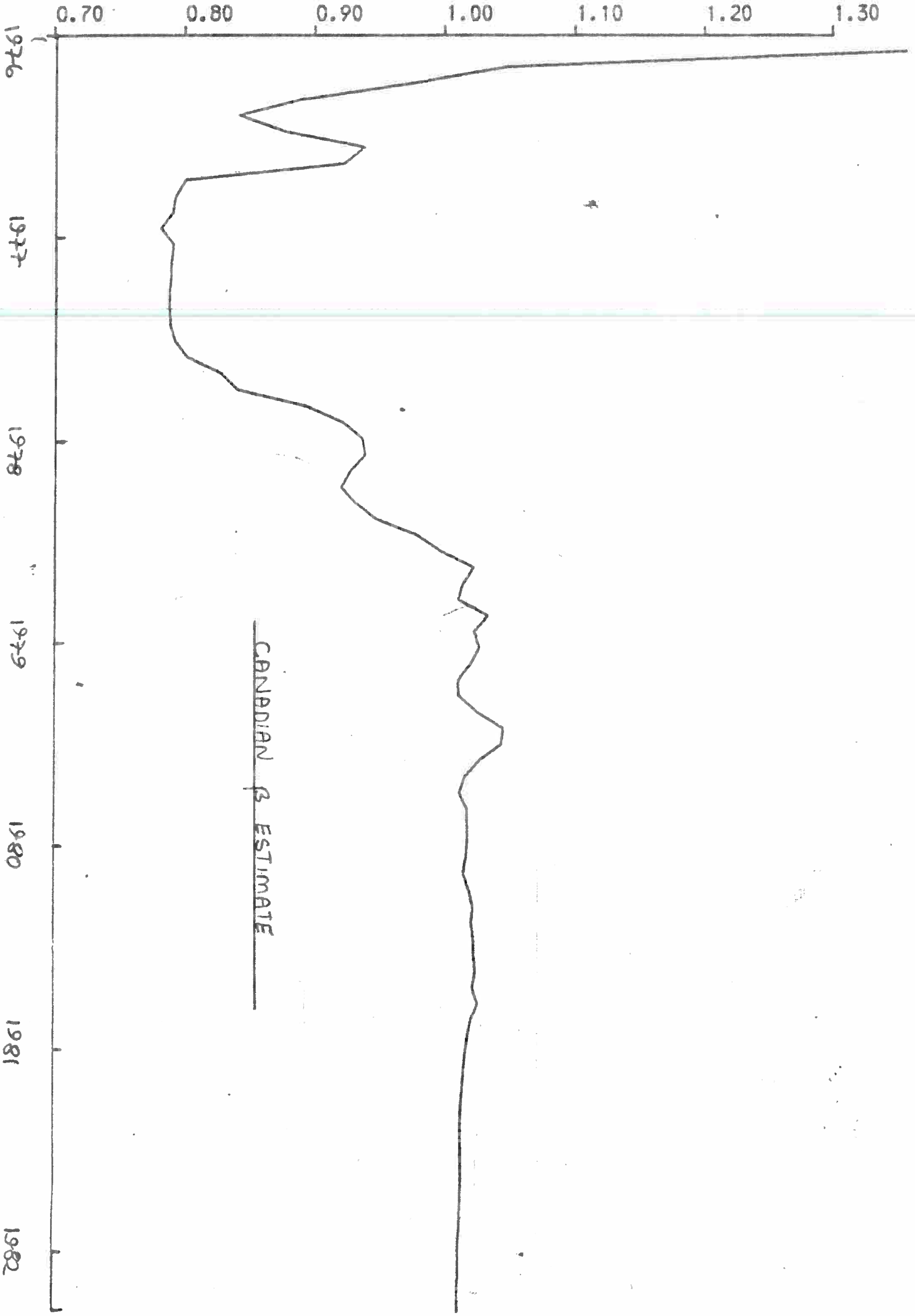


DIAGRAM TWELVE

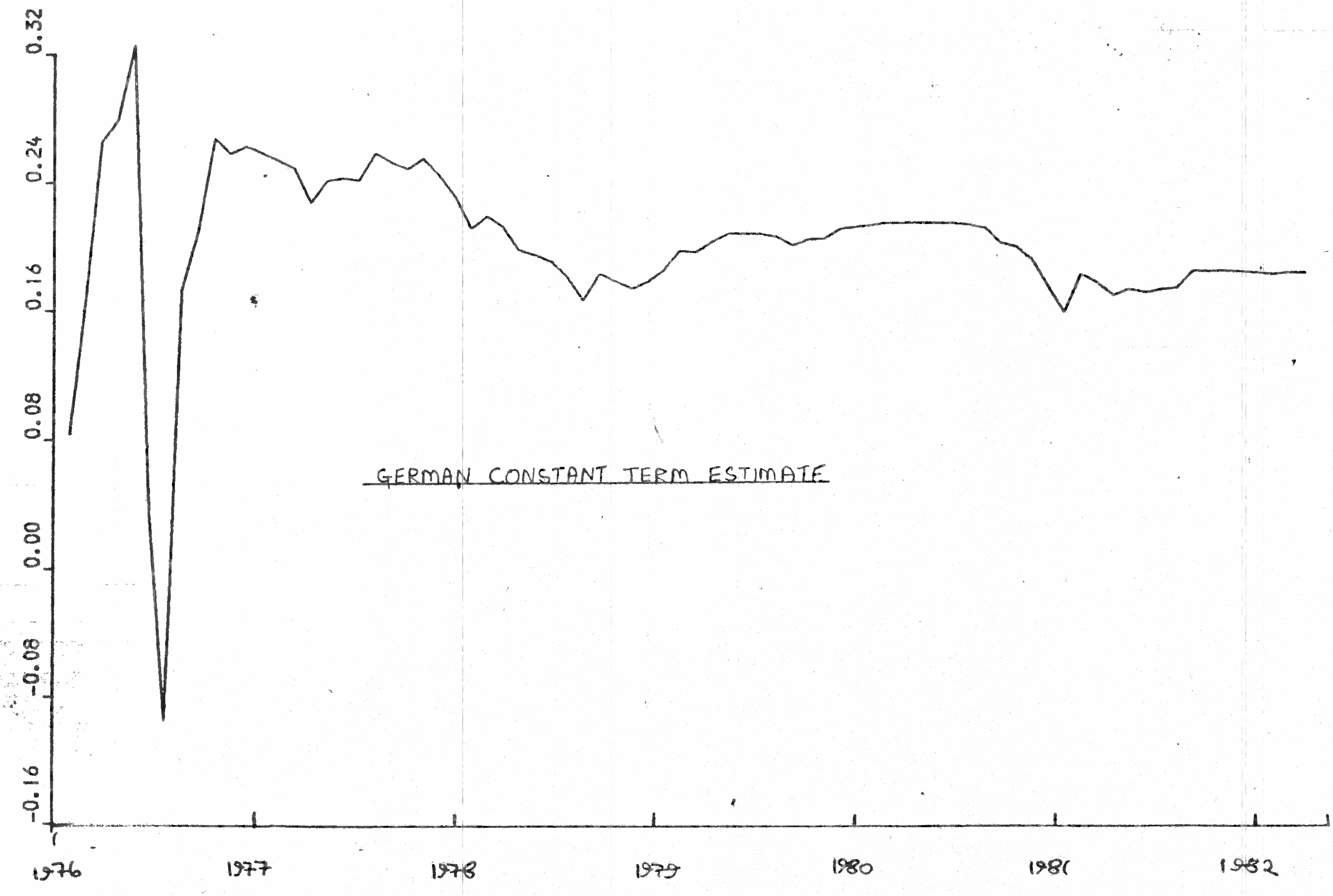


DIAGRAM NINE

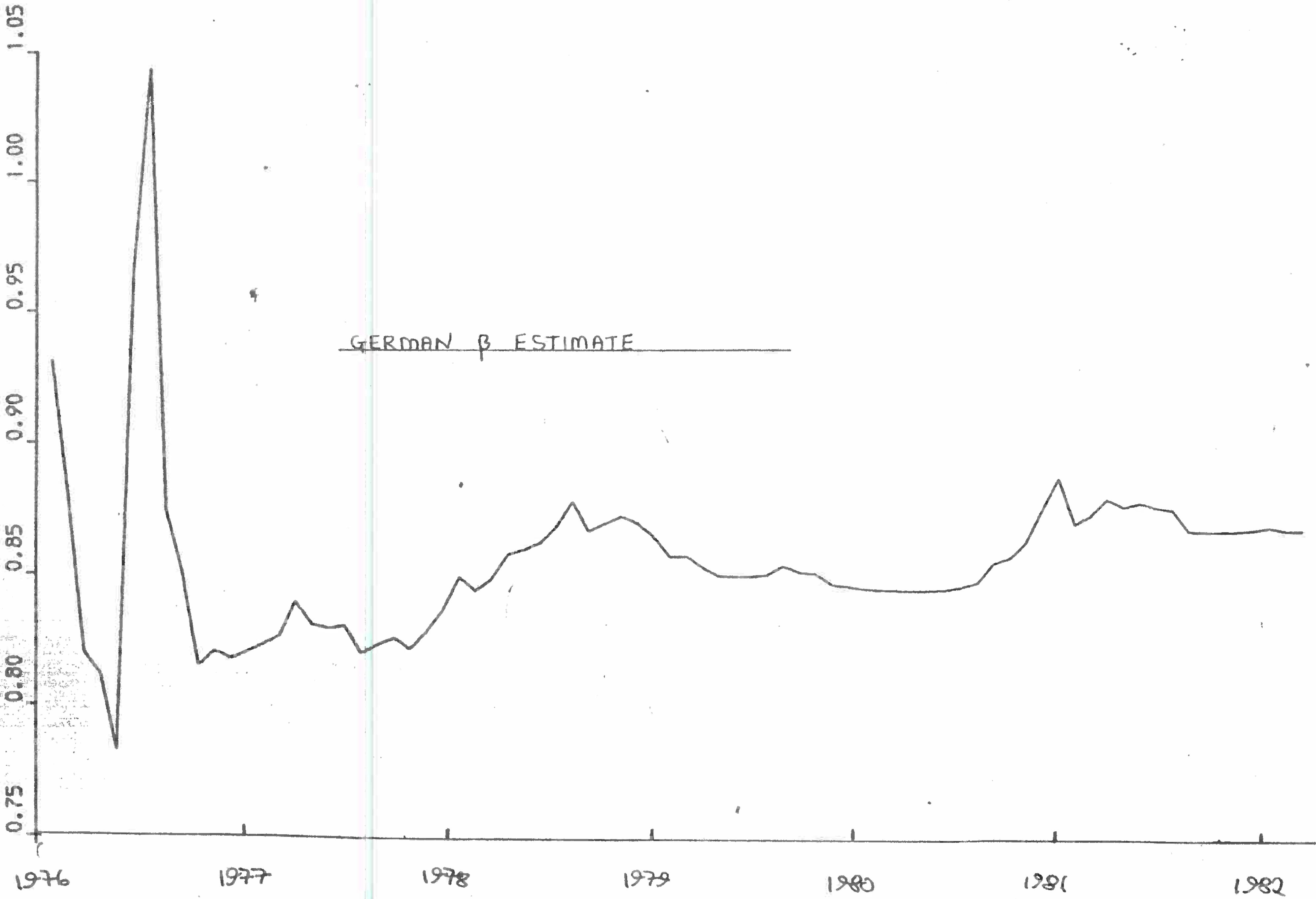

GERMAN β ESTIMATE
1.05
1.00
0.95
0.90
0.85
0.80
0.75
1976
1977
1978
1979
1980
1981
1982

DIAGRAM TEN

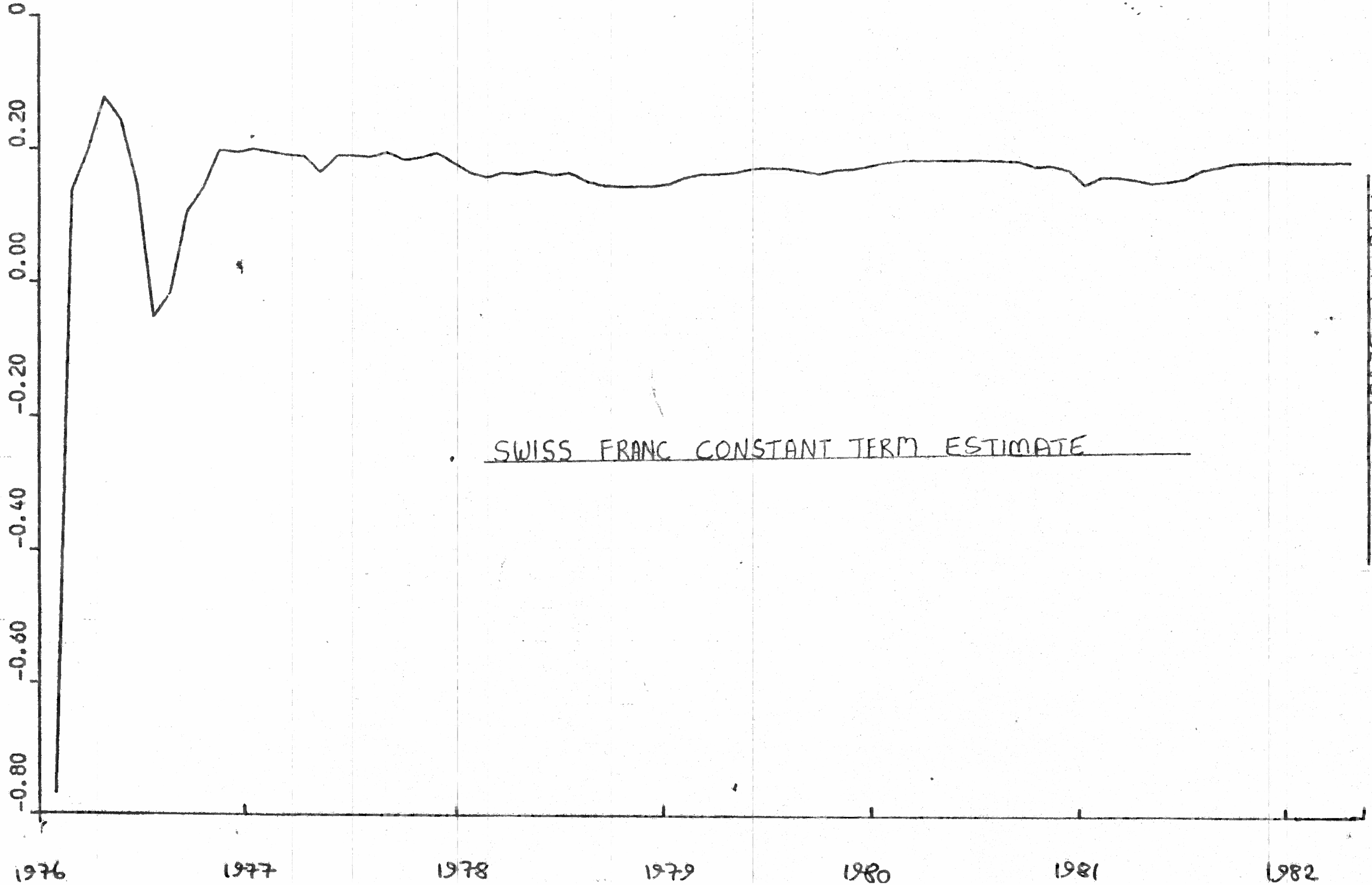


DIAGRAM SEVEN

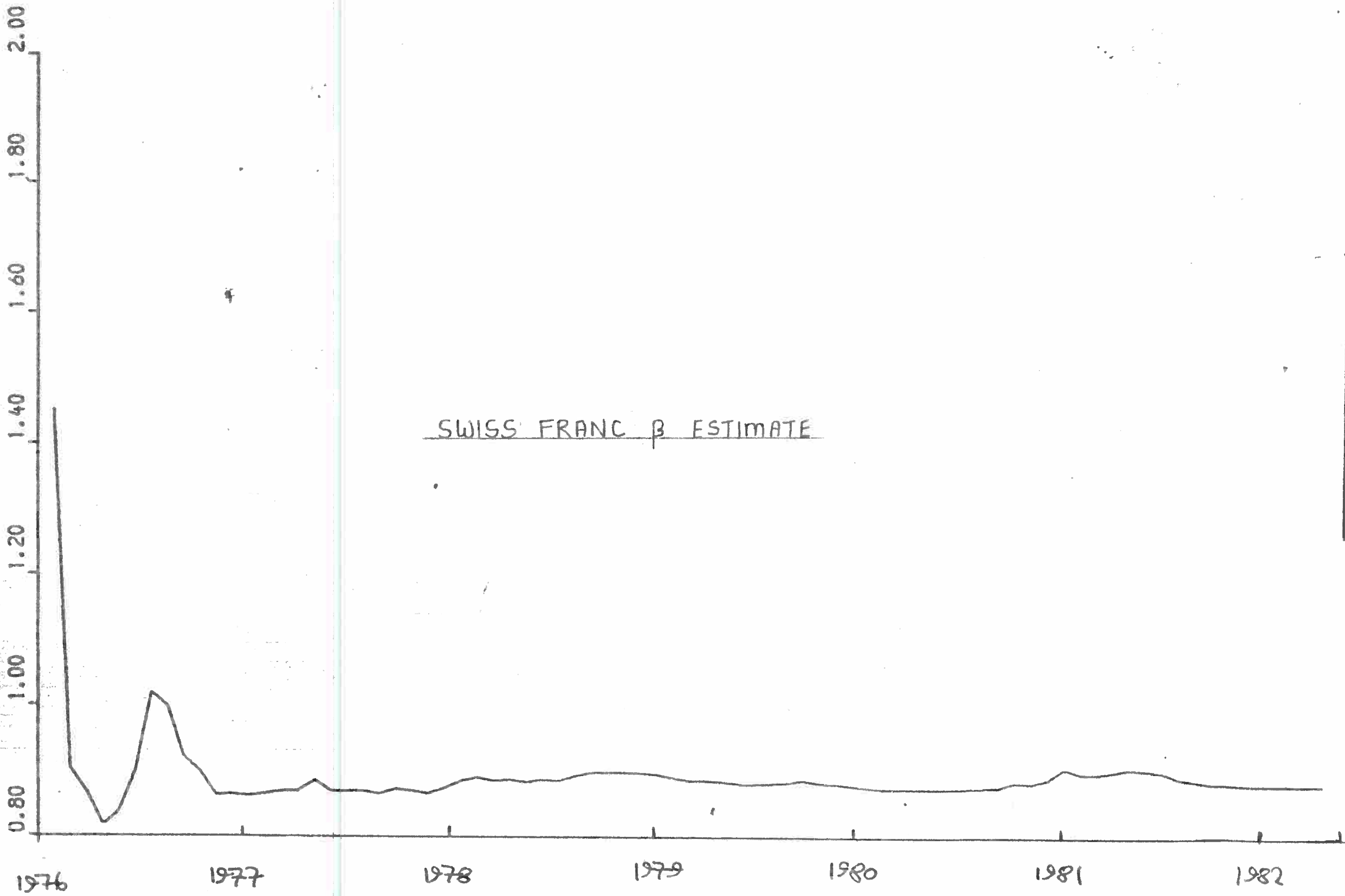


DIAGRAM EIGHT

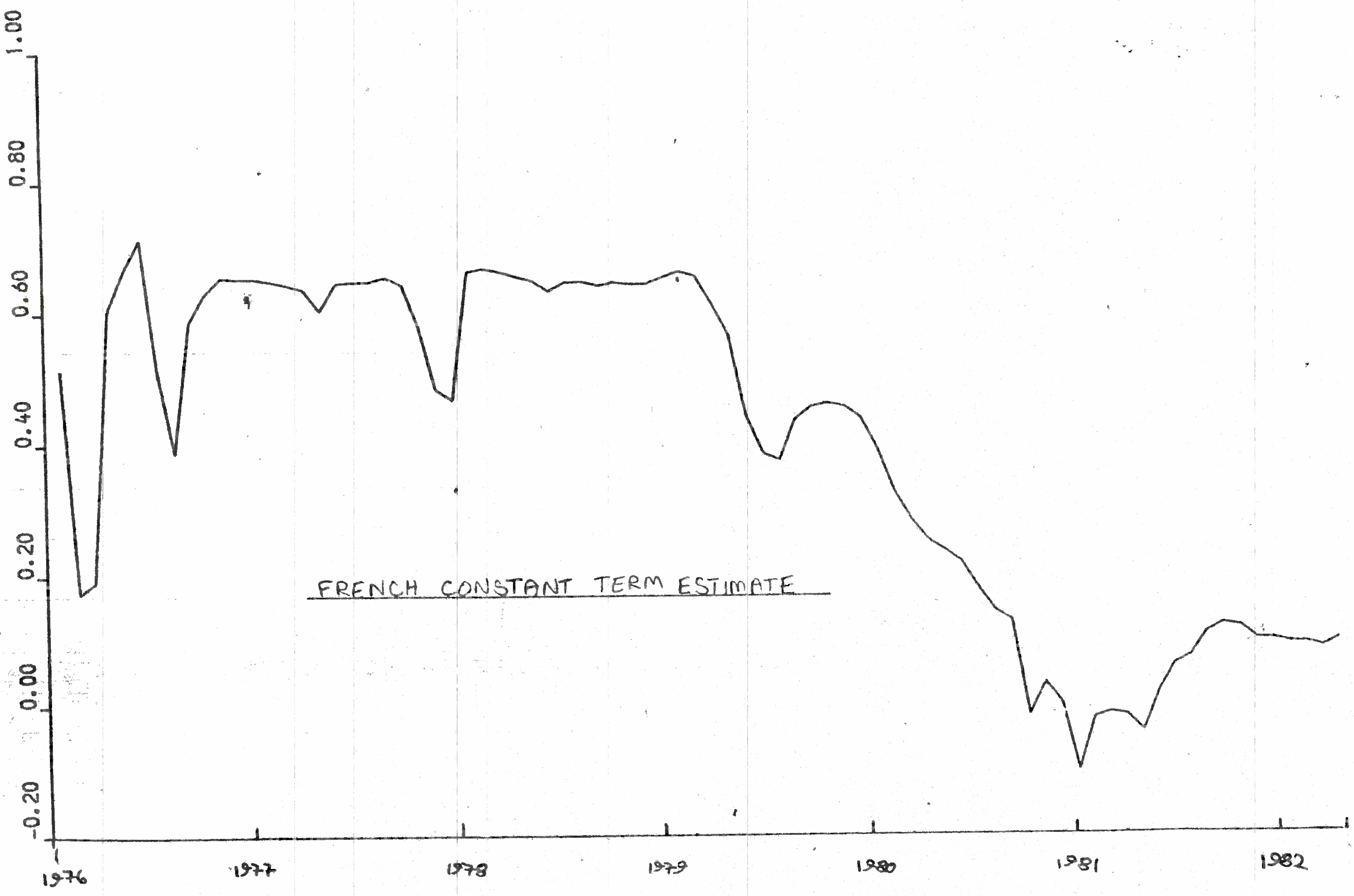


DIAGRAM FIVE

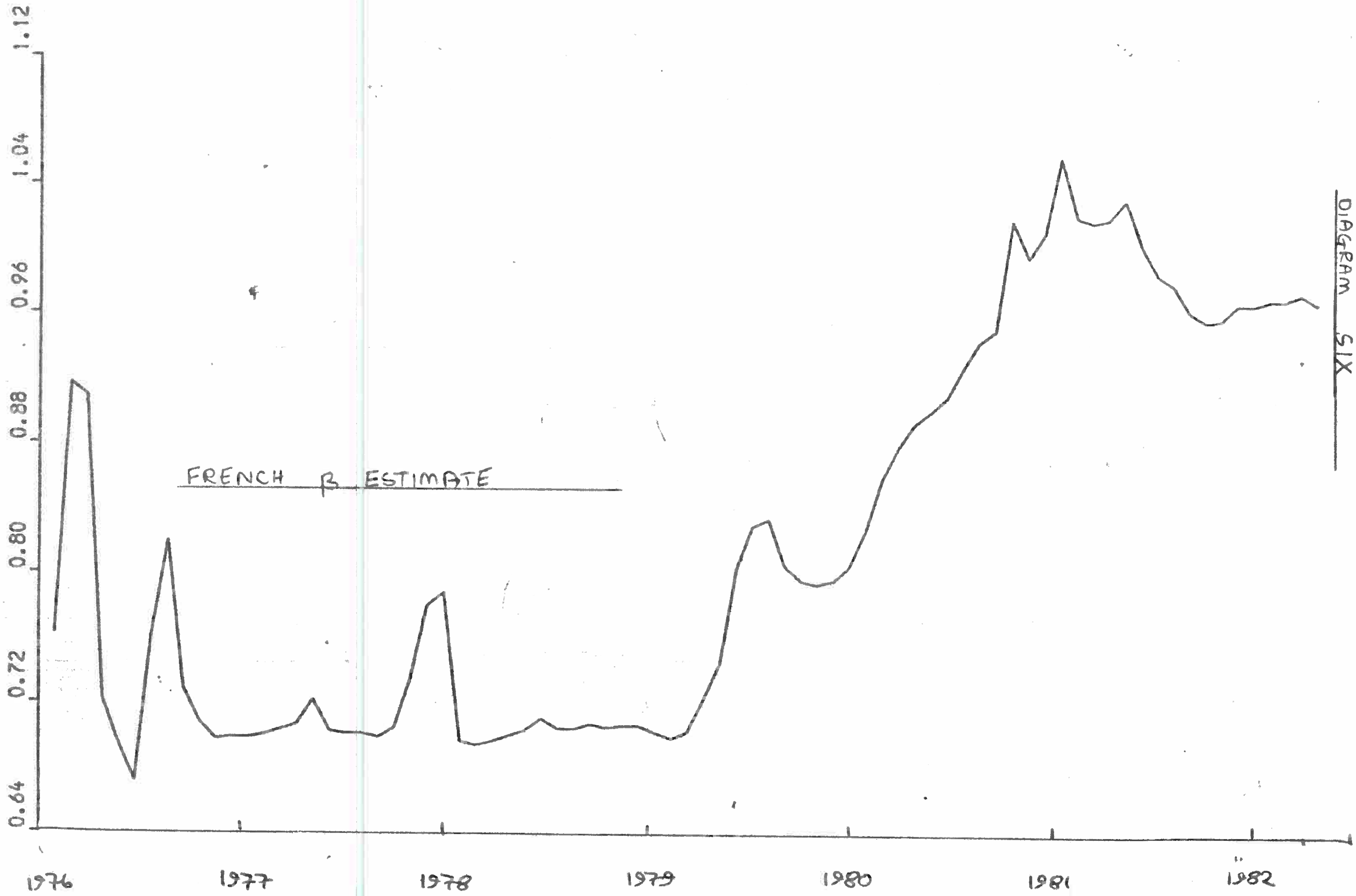

1.12
1.04
0.96
0.88
0.80
0.72
0.64
FRENCH β ESTIMATE
1976
1977
1978
1979
1980
1981
1982

DIAGRAM SIX

with the 1979 election, and the accession of a government whose policies, if credible, had important implications for exchange rate behaviour. In contrast, the Swiss Franc series coefficients are quite straight; this suggests that no factors other than the expected spot rate determined the forward rate in this case. The diagrams for the Deutschemark and the Canadian Dollar suggest that some form of structural change occurred over the period, in the latter case as a result of a major shock in about July 1977. Indeed, the lack of stability in the coefficient paths for three of the curriencies can be interpreted as evidence that variables other than the expected spot rate determine the forward rate.

CONCLUSION

The results presented here are not favourable to the proposal that, for the four currencies examined over the specified time period, the forward markets operated efficiently and in the absence of a risk premium. It was established that forward rates are not unbiased predictors of the level of or changes in future spot rates. Though suggestive of inefficiency, this issue was not resolved. A joint hypothesis was tested and the analysis was not sufficiently powerful to separate the pertinent issues of risk and efficiency. Although the results do question the success of earlier studies which found the evidence to be consistent with the efficient operation of forward markets, no firm conclusions can be drawn, for definitive studies in this area will have to use more data than just spot and forward exchange rates.

NOTES

1. Proponents of the relevance of efficient markets are implicitly assuming that expectations are formed rationally. Indeed, Begg (1982) defines the efficient markets hypothesis as having two components, "the hypothesis that expectations are rational so that individuals avoid knowable forecasting errors, and the hypothesis that any discrepancy between the expected rate of return of different assets is quickly arbitrated to eliminate expected supernormal profit".

2. The issue raised by Grossman and Stiglitz (1976) (1980), that prices cannot perfectly reflect all information since this could allow the uninformed to become informed at no cost and thus eliminate any incentive for agents to expend resources on data collection, is not dealt with here.

3. This is the so-called 'Peso Problem'. See Krasker (1979).

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