The Economic and Social Review, Vol. 22, No. 1, October, 1990, pp. 35-42

Further Evidence of Forward Exchange Market Efficiency: An Application of Cointegration using German and UK Data

JIM NUGENT*
Central Bank of Ireland

I INTRODUCTION

The purpose of this paper is to explore the hypothesis that the Irish forward exchange market is efficient. The simple market efficiency hypothesis assumes investors are risk neutral and that agents are rational, i.e., they use all available information. Testing for efficient markets is thus a test of a joint hypothesis. In the case of forward market efficiency, the forward rate is required to be an unbiased predictor of the future spot rate. However, rejection of the joint hypothesis does not necessarily imply market inefficiency. If investors are risk-averse, then they will require a risk premium to compensate for bearing exchange rate risk. But this does not give rise to profitable arbitrage opportunities. Only if there is inefficient use of available information, will there be unexploited profits – and by definition, market inefficiencies present.

In the tests that follow, forward exchange market efficiency is examined using Irish spot and forward exchange rates against sterling and the Deutschmark. Monthly data (expressed in logs), ranging from January 1984-March

Paper presented at the Fourth Annual Conference of the Irish Economics Association.

*I wish to thank Rodney Thom, Michael Moore, Gabriel Fagan and two anonymous referees for helpful comments. The views expressed in this paper are not necessarily those held by the Bank and are the sole responsibility of the author. Comments and criticisms are welcome.

1989, are used which gives a total of 63 observations. Some of the more recent studies on the topic have used cointegration analysis, and as the title of this paper suggests, the technique will be used throughout in testing the various hypotheses. The plan of the paper is as follows: in Section II the assumptions underlying the simple efficient markets hypothesis are discussed plus the implications of a violation of its assumptions. In Section III the connection between cointegration and market efficiency, and its application to Irish spot and forward rates are examined. The results of the various tests are discussed in Section IV, while some tentative conclusions are offered in Section V.

II FORWARD MARKET EFFICIENCY

The simple efficient markets hypothesis assumes (i) investors are risk neutral, and (ii) agents rationally use all available information (i.e., expectations are rational). Hence the forward rate for maturity in period t+1 (f_t^{t+1}) is set equal to the expected spot rate in period t+1 (S_{t+1}^e) and the forecast error in the latter is random. That is:

$$S_{t+1}^e = f_t^{t+1} \tag{1}$$

and

$$S_{t+1} = S_{t+1}^e + u_t \tag{2}$$

where u_t is iid with zero mean and constant variance. Hence:

$$S_t = f_{t-1}^t + u_t. \tag{3}$$

That is, the period t spot rate equals the one period forward rate plus a random disturbance. More generally we write:

$$S_t = \alpha + \beta f_{t-1}^t + \theta_t \tag{4}$$

Thus, if speculators are risk neutral then market efficiency requires that $(\alpha,\beta) = (0,1)$ and that θ is a "white noise" error term.

If investors are risk-averse then assumption (i) is violated – investors will therefore demand a risk premium. As a result of the risk premium, the equality between f_t^{t+1} and S_{t+1}^e is broken, (i.e., we can reject the hypothesis that $(\alpha,\beta) = (0,1$ and that the error term is "well behaved"). Allowing for a risk premium, though, does not imply that markets are "inefficient" since profits earned

through forward speculation merely compensate for the additional risk incurred. Market efficiency, in the presence of a risk premium, requires that:

$$S_{t+1} = RP_t + F_t^{t+1} + e_t \quad (5)$$

where RP represents the risk premium and e is the error term. Thus, in (4), the variables that explain the risk premium would be contained in the intercept. Stockman (1978) examines market efficiency by testing whether the forward rate is an unbiased predictor of the future spot rate. By means of model incorporating uncertainty about the money supply, he shows that a risk premium may emerge which will result in the forward rate being a biased predictor. He also found that risk premium was not stable when it was significant, i.e., that it varied across time. This means that autocorrelation in the forecast error $(S_{t+1} - F_t)$, if present, is evidence of non-stationary risk premium. Therefore, only if the residual term e_t is "white noise" will the risk premium, hence the forecast error, be stationary.

Both Leddin (1988) and Lucey (1988) find evidence in favour of stationary risk premia, the former using quarterly data – the latter daily rates, both using sterling with Lucey using dollar rates as well.

Table 1 shows the results of Fama's (1984) test for the existence of risk premia in forward contracts. In this example, Irish spot and forward exchange rates against the Deutschmark are examined. The premium in the forward rate over the spot rate $(F_t - S_t)$ equals RP_t and the expected change in the spot rate $E(S_{t+1}) - S_t$.

Table 1: *Fama's (1984) Test for the Existence of Risk Premium*

$$(S_{t+1} - S_t) = a + b(F_t - S_t) + e_t$$

$$(DM_{t+1} - DM_t) = -0.01 - 0.15(FDM_t - DM_t)$$
$$(1.23) \quad (0.64)$$

$$R^2 = 0.007 \qquad DW = 1.40$$

A negative sign on b indicates that variations in the forward rate are due to changes in RP. The Durbin-Watson statistic indicates the presence of serial correlation, and there is a poor fit to the equation. Even though b has a negative sign, it is insignificantly different from zero. The results are poor and

no firm conclusions can be drawn – this concurs with the results obtained by Leddin using sterling rates.

III MARKET EFFICIENCY AND COINTEGRATION

Market efficiency as postulated by Fama (1970), is defined as asset prices "fully reflecting" all available information. Even allowing for the existence of transaction costs, so long as the investors fully utilise the information set, i.e., all available information, the market can still be efficient, in the sense that current asset prices may still fully reflect past prices. Serial correlation among lagged asset prices may mean that there are market inefficiencies present, however there is no general agreement as to the severity of autocorrelation needed to make profitable arbitrage opportunities available.

In relation to exchange rates, there is evidence to support the view that spot and forward exchange rates follow random walks, e.g., Thom (1989). This means that the best predictor of future spot rates are their current values. In relation to cointegration, in-depth discussion is not followed. However, references to Engle and Granger (1987), and examples of its application discussed in Lucey (op. cit.), Hurley and Guiomard (1989) and Thom (op. cit.) are helpful.

Granger (1986) shows that asset prices from two efficient markets cannot be cointegrated. Therefore, an Error Correction Model (ECM) cannot be constructed (see Lucey (ibid.) for an explanation). Hakkio and Rush (1989) show that a necessary (but not sufficient) condition for foreign exchange market efficiency would require in my particular tests that:

- spot sterling (ST) is *not* cointegrated (CI) with spot Deutschmark (DM);
- forward sterling (FST) is *not* CI with forward Deutschmark (FDM);
- ST is CI with FST;
- DM is CI with FDM.

Also, in the ECM representation:

$$(S_{t+1} - S_t) = a(S_t - bF_{t-1}) + c(F_t - F_{t-1}) + e_t \qquad (6)$$

we would require $-a = c = b = 1$. In addition, any lagged terms if included in (6), should be insignificant.

IV RESULTS AND IMPLICATIONS

The results of the various unit root and cointegration tests along with critical values are contained in Tables 2 and 3 respectively. Results in Table 2 clearly show that Irish spot and forward exchange rates against sterling and the

Deutschmark follow random walks, i.e., the series are I(1) or non-stationary processes. The Augmented Dickey-Fuller (ADF) test statistics are given – the statistics Φ_2 and Φ_3 test the hypothesis that the exchange rates follow random walks without drift and with drift respectively. We accept that exchange rates follow a random walk both at the 5 per cent and the 10 per cent level.

Table 2: *Unit Root Tests*

	Sterling		*Deutschmark*		*Critical Values*	
	Spot	*Forward*	*Spot*	*Forward*	*5%*	*10%*
DW	2.11	2.29	1.40	1.55	0.386	0.322
DF	1.94	1.98	0.53	0.93	3.37	3.03
ADF						
Φ_2	0.82	0.90	1.64	1.38	5.13(4.88)	4.31(4.16)
Φ_3	1.23	1.33	1.69	1.53	6.73(6.49)	5.61(5.47)

Notes: Φ_2 is the Dickey-Fuller (1981) statistic for H_0: random walk without drift.
Φ_3 is the Dickey-Fuller statistic for H_0: random walk with drift.
Sample sizes for ADF critical values are n=50 (values for n=100 are given in parentheses), sample sizes elsewhere refer to n=100.

Table 3 gives the results of the cointegration tests for the spot and forward exchange rates for the Irish pound against sterling and the German mark. A couple of points should be noted. First, the DW tests on the equilibrium regressions reject the hypothesis of cointegration of the two spot and the two forward rates in Table 3(i) – indicating that they follow an AR(1) process. This result is supported by the DF and ADF tests on the residuals from the cointegration regressions. Hakkio and Rush (op. cit.) state that this is evidence of spot and forward market efficiency – as long as the Deutschmark and sterling are considered different assets.

Second, in Table 3(ii), the future spot rates are regressed on the current forward rates and the residuals are calculated. The results favour cointegration of the future spot and current forward exchange rates of both currencies with both the DW and ADF statistics greater than their respective critical values at 5 per cent – again consistent with the efficient markets hypothesis. Thus, if a risk premium exists, as explained already, it must be stationary. The results are in agreement with Leddin (1988) and Leddin (1989), but inconsistent with the findings of Lucey (1988). It should be noted that Leddin uses quarterly data, Lucey daily data and I use monthly. In addition, the authors use different estimation periods. The main problem with the Lucey

paper is the use of overlapping data so that there is a loss of information in making the frequency of observation equivalent to the maturity time of the forward contract. Hansen and Hodrick (1980) show that applying OLS to a regression of, say, the forecast error ($S_{t+1} - F_t$) on its lagged values, will yield consistent, but inefficient estimates of the regression parameters. So caution must be taken when interpreting Lucey's results.

Table 3: *Cointegration Tests*

(i) *UK and German Assets*

	ST-DM Spot	*FST-FDM Forward*	*Critical Values 5%*	*10%*
DW	0.23	0.28	0.386	0.322
DF	1.66	1.89	3.37	3.03
ADF	1.10	1.42	3.17	2.84

Cointegration Regressions

$ST = 0.38 - 0.48DM_t \quad R^2 = 0.35$
$\quad (4.02) \quad (5.74)$

$FST_t = 0.41 - 0.54FDM_t \quad R^2 = 0.44$
$\quad (5.60) \quad (6.79)$

(ii) *Spot and Forward Rates*

	Future ST - FST	*Future DM - FDM*	*Critical Values 5%*	*10%*
DW	1.60*	1.24*	0.386	0.322
ADF	3.43*	3.91*	3.17	2.84

Cointegration Regressions

$ST_{t+1} = -0.02 + 0.88FST_t \quad R^2 = 0.77$
$\quad (1.58) \quad (14.14)$

$DM_{t+1} = 0.01 + 1.00FDM_t \quad R^2 = 0.97$
$\quad (0.46) \quad (44.20)$

The * denotes evidence of cointegration at the 5 per cent level, i.e., we "accept" the hypothesis that the series are cointegrated.

Finally, as regards my estimation results, only 63 observations are used, these are not strictly consistent with the (n=100) critical values in Engle and Granger's paper, which possibly may or may not result in improper inferences being made.

V CONCLUSIONS

This paper has explored the hypothesis that the Irish forward exchange market is efficient using cointegration techniques. The necessary requirements for market efficiency are that asset prices from two efficient markets cannot be cointegrated, the future spot rate and the forward rate are cointegrated (with the cointegration vector = 1) and the forward rate is an unbiased predictor of the future spot rate. Subsequent tests carried out showed that the two spot and forward exchange rates examined (i.e., German mark and sterling) are not cointegrated. Furthermore, the future spot rate and forward rate are cointegrated in both cases. The evidence is therefore consistent with market efficiency. In addition, there was no evidence of risk premia being present in forward contracts which is contrary to the results found in the recent literature on the Irish case.

Testing for efficient markets is a test of a "joint" hypothesis – that investors are risk neutral and that agents make rational use of all available information. This joint hypothesis would be rejected if a risk premium was present or if there were unexploited profit opportunities (i.e., a departure from interest rate parity). From the ECM representation, one could accept (i.e., if - a = c = 1 in the ECM) or reject this joint hypothesis, though the source of this rejection could not be determined. Due to time constraints, I am prevented from constructing such a model at present, though in the near future I hope to do so.

REFERENCES

DICKEY, D.A., and W.A. FULLER, 1981. "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root", *Econometrica*, Vol. 49, pp. 1957-1072.

ENGLE, R., and C.W. GRANGER, 1987. "Co-integration and Error Correction: Representation, Estimation and Testing", *Econometrica*, Vol. 55, pp. 251-276.

FAMA, E.F., 1970. "Efficient Capital Markets: A Review of Theory and Empirical Work", *Journal of Finance*, May, pp. 383-417.

FAMA, E.F., 1984. "Forward and Spot Exchange Rates", *Journal of Monetary Economics*, pp. 319-338.

GRANGER, C.W., 1986. "Developments in the Study of Co-integration Variables", *Oxford Bulletin of Economics and Statistics*, Vol. 49, pp. 213-228.

HAKKIO, C.S., and M. RUSH, 1989. "Market Efficiency and Cointegration: An Application to the Sterling and Deutschmark exchange markets", *Journal of International Money and Finance*, Vol. 8, pp. 75-78.

HANSEN, L.P., and R.J. HODRICK, 1980. "Forward Exchange Rates as Optimal Predictors of Future Spot Exchange Rates: An Econometric Analysis", *Journal of Political Economy*, Vol. 88, pp. 829-853.

HURLEY, M., and C. GUIOMARD, 1989. "Determinants of Money Demand in Ireland 1970 to 1988 . . .", *Central Bank of Ireland*, 2/RT/89.

LEDDIN, A., 1988. "Interest and Price Parity and Foreign Exchange Market Efficiency: The Irish Experience in the European Monetary System", *The Economic and Social Review*, Vol. 19, pp. 215-231.

LEDDIN, A., 1989. "Efficiency in the Forward Exchange Market: An Application of Cointegration: A Comment", *The Economic and Social Review*, Vol. 20, pp. 281-285.

LUCEY, B., 1988. "Efficiency in the Forward Exchange Market: An Application of Cointegration", *The Economic and Social Review*, Vol. 20, pp. 25-36.

STOCKMAN, A., 1978. "A Theory of Exchange Rate Determination", *Journal of Political Economy*, pp. 673-699.

THOM, R., 1989. "Real Exchange Rates, Cointegration and Purchasing Power Parity: The Irish Experience in the EMS", *The Economic and Social Review*, Vol. 29, pp. 147-163.