STOCKS AND CURRENCIES: ARE THEY RELATED?

by

Li Lian Ong

DISCUSSION PAPER 96-16

DEPARTMENT OF ECONOMICS

THE UNIVERSITY OF WESTERN AUSTRALIA
NEDLANDS, WESTERN AUSTRALIA 6907

ISSN 0811-6067
ISBN 0-86422-030-9

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ABSTRACT

With the advent of flexible exchange rates, research into the foreign exchange expectation relation based on the purchasing power parity and interest rate parity conditions has shown that the speed of transmission of economic variables such as the price level and interest rates on exchange rates, is not rapid enough to maintain parity in the foreign exchange market on a short-term basis. The *asset market approach* to exchange rate determination is based on the notion that exchange rates, like asset prices, are driven by "news" or unanticipated announcements of changes in economic variables. We use this approach to investigate the validity of the International Equity Parity theory, *i.e.*, the possibility of a distinct, short-term relationship between international equity and foreign exchange markets. Our results show that equity parity is achieved within a very short time, in some cases, within a one-week period. While new information appears to flow from the exchange rate market to the equity market (and *vice-versa*), we find that share markets are also subject to influences other than exchange rate movements. Furthermore, consistent with previous research, we find evidence to support the existence of currency blocs. We suggest that these findings could have practical applications for international investors.

* This paper is based on my PhD thesis, jointly supervised by Professor H.Y. Izan of the Department of Accounting and Finance, and Professor K.W. Clements of the Economic Research Centre, The University of Western Australia. I would like to thank the Macquarie Bank, Sydney, for providing the exchange rate database, Larry Sjaastad for helpful comments, and the Australian Agency for International Development (AusAID) and the Department of Accounting and Finance, The University of Western Australia, for financial support.

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"An increasingly integrated, securitised, and open world financial system suggests important questions, and offers a rich set of data with which to attempt to answer them.....To what extent are markets in fact now integrated across countries?.....What is the role of the specific times and locations around the world at which stocks are traded?"

Jeffrey Frankel (1994)

1. INTRODUCTION

With the advent of flexible exchange rates, following the collapse of the Bretton Woods system in 1973, great interest has been shown by international investors in foreign exchange movements, and the risks inherent in their volatility. Today, more than ever, exchange rate forecasts play an important role in exposure management by international market players, and are considered invaluable for long-term strategic planning by corporations.

Previous research into the foreign exchange expectation relation has dwelt on the doctrine of purchasing power parity and the interest rate parity conditions, with national price indices and nominal interest rates as the respective transmitting variables. To date, the empirical evidence has shown that the speed of transmission of economic variables such as the price level¹ and interest rates² on exchange rates, is not rapid enough to maintain parity in the foreign exchange market on a short-term basis.

The *asset market approach to exchange rate determination* is based on the notion that the exchange rate, being the relative price of two durable assets (monies), is best analysed within the same framework as that of other asset prices. Within this

¹ See Dufey and Srinivasulu (1983), Frenkel (1981), Manzur (1990), Officer (1976).

² See Cumby and Obstfeld (1984), Edison and Melick (1995), Hodrick (1979), Mark (1985), Mishkin (1984) and Solnik (1991).

framework, exchange rates, like asset prices, are seen to be driven by "news" or unanticipated announcements of changes in economic variables.³ It is our contention that share prices, with their rapid adjustment to new information, are suitable indicators of real economic activity that could be used in models of exchange rate determination. Thus, the principal aim of this paper is *to use the asset market theory rationale to investigate the validity of the International Equity Parity (IEP) theory, i.e., the possibility of a distinct relationship between international equity and foreign exchange markets*. Two main hypotheses will be tested in this study:

1. There is a significant relationship between foreign exchange and equity markets;
2. Equity parity holds in the shorter-term, *i.e.*, reactions of equity markets to foreign exchange rate movements (and/or *vice-versa*) are much quicker than those of prices and interest rates.

The empirical model used in this chapter incorporates the asset market approach to exchange rate determination within the framework established by Scacciavillani and Sjaastad (1996), and Sjaastad (1990). Using Sjaastad's (1990) concept of relative market power in the context of our research, we define a "large" country as one that is able to affect returns on share prices when it revalues/devalues its currency (and *vice-versa*). A "major" currency, then, is that whose appreciation/depreciation would have a major impact on share prices. When a large country has total dominance in terms of "news" disseminated, then any change in the real exchange rate between it and a "small" country will be fully reflected in an equi-proportionate change in the real rate of return on share prices in that smaller country. On the other hand, changes in the real exchange rate of the small country would have no effect on the share prices in the large country. Instead, the effects are reflected only in the share prices of the small country.

3 Edwards' (1982) empirical analysis supports the view that exchange rate movements are basically a response to new information.

Our results show that equity parity is achieved within a very short time, in some cases, within a one-week period. While new information appears to flow from the exchange rate market to the equity markets (and *vice-versa*) we find that share markets are also subject to exogenous influences other than exchange rate movements. Furthermore, consistent with previous research, we find evidence to support the existence of currency blocs. We suggest that these findings could have practical applications for international investors. Since portfolio returns are measured as the weighted sum of the assets' returns in local currency terms plus any currency movements, information on how, and to what extent, exchange rates affect asset prices (and/or *vice-versa*) could play an important role in risk management strategies.

This chapter is organised as follows. Section 2 details the database, followed by stationarity and serial correlation tests on our time-series data in Section 3. Section 4 subsequently looks at the development and application of the IEP model. The response time of equity markets to movements in exchange rates (and *vice-versa*) is incorporated into the model in Section 5. We conclude with a summary of our findings in Section 6.

2. THE DATA

The weekly data consist of spot and 90-day forward exchange rates, and spot and 90-day futures equity prices for Australia and the Group of 7 countries. These markets are chosen as they are amongst the more established of the industrialised nations. Exchange rates are available for Australia and the Group of 7 countries, while equity prices are available for Australia, Britain, France and the US.⁴ The

⁴ The Australian All Ordinaries Index (AAOI) for Australia, the Financial Times Stock Exchange 100 (FTSE) for Britain, *Compagnie des Agents de Change General 40* (CAC) for France, and the Standard and Poor's 500 (S&P) for the US.

weekly share price indices and their respective futures prices for the period 1 October 1986 to 16 December 1992, are taken from the Financial Times, London, whilst the spot and forward exchange rates for the same period are obtained from the Macquarie Bank, Sydney. Wednesday's closing share prices and exchange rates, per Australian Eastern Standard Time, are used to avoid the non-trading effects over long weekends.

We choose to construct *forecast error data* for the equity and exchange rate returns instead of using either spot or forward prices in our empirical tests, since it has been well-documented that share price and exchange rate levels, as well as share price returns, are usually *non-stationary* over time.⁵ Based on the hypothesis that equity and exchange rate markets are efficient, the use of forecast errors on returns solves this problem as forecast errors are stationary and non-serially correlated in efficient markets. These return forecast errors, defined as the difference between predicted and actual returns, are constructed from spot and forward/futures data, such that

$$Z_{R_{j,t,90}} = R_{j,t,90}^f - R_{j,t+90}^s, \text{ and} \quad (1)$$

$$Z_{E_{ij,t,90}} = E_{ij,t,90}^f - E_{ij,t+90}^s, \quad (2)$$

where $R_{j,t,90}^f$ and $E_{ij,t,90}^f$ are the predicted 90-day equity and exchange rate returns at time t , respectively,⁶ and $R_{j,t,90}^s$ and $E_{ij,t+90}^s$ are respectively the actual equity and exchange rate returns between time t and $t+n$.⁷ As a result, although each data set of

⁵ See French *et al.* (1987), Jorion (1985), Makridakis and Wheelwright (1974), Maldonado and Saunders (1981), and Pagan and Schwert (1990) for evidence on share markets, and Blundell-Wignall *et al.* (1993), Edison and Pauls (1993) and Froot and Rogoff (1994) for evidence on exchange rates.

⁶ $R_{j,t,90}^f = \log \left(I_{j,t,90}^f / I_{j,t}^s \right)$ and $E_{ij,t,90}^f = \log \left(e_{ij,t}^s / e_{ij,t,90}^f \right)$, where $I_{j,t}^s$ and $I_{j,t,90}^f$ are the spot and 90-day futures share price index for country j at time t ; respectively, and $e_{ij,t}^s$ and $e_{ij,t,90}^f$ are the spot and 90-day forward exchange rate of currency j in terms of currency i at time t , respectively.

⁷ $R_{j,t+90}^s = \log \left(I_{j,t+90}^s / I_{j,t}^s \right)$ and $E_{ij,t+90}^s = \log \left(e_{ij,t}^s / e_{ij,t+90}^s \right)$, where $I_{j,t}^s$ and $e_{ij,t}^s$ are the spot share price index of country j and exchange rate of currency j in terms of currency i at time $t+90$, respectively.

share market prices and exchange rates consists of 325 weekly observations, the useful data set is reduced to 312 overlapping observations from 1 October 1986 to 16 September 1992. This is because the 90-day forecast error data require the spot series to lead the forward series by 13 weeks. Alternatively, the data could be grouped into 13 subsets of 24 non-overlapping observations, *i.e.*, one observation per quarter per subset.

The calculation of the 90-day exchange rate return forecast errors, $Z_{E_{ij,t},90}$, is relatively straightforward, given that all 90-day forward rates quoted at a specific date represents the predicted spot rate 90 days from the date of quotation, as shown in Figure 1(I). However, as Figure 1(II) demonstrates, the derivation of 90-day equity return forecast errors, $Z_{R_{j,t},90}$, is not as simple since the share price index futures quoted on any one day reflects the settlement price at the end of that particular calendar quarter only. Therefore, unless the day of quotation is 90 days from settlement day, it would not be possible to directly obtain the predicted spot index 90 days from quotation date. So, where the 90-day period spans two quarters, the method used to calculate the 90-day index return forecast error is a proration of the forecast error components over the relevant two quarters. The actual and predicted returns for each quarter, *i.e.*, 13-week period, are calculated based on the assumption that the settlement date for each futures contract is represented by the last Wednesday of the settlement week in each quarter. A representation of the forecast error calculations for exchange rate returns is shown in Figure 2(I), along with the proration method for share market return forecast errors in Figure 2(II).

The suitability of the above method is first tested for the null hypothesis that aggregate sub-period return forecast errors over a certain period are not significantly different from that for period itself. We use the French spot and futures share price index series, from February 1990 to May 1992, as the test sample since monthly and quarterly quotations are available for that market. Figure 3 shows the calculations of

the forecast error terms. Note that the quotations on the last Wednesday of each month/quarter are used as proxy for the settlement prices of that month/quarter.

Preliminary *t*-tests are applied to the CAC return forecast errors to determine the validity of the data. Since each weekly observation of the forecast errors is shared by 12 other 90-day periods per quarter, and by 3 other 30-day periods per month, we also test a set of non-overlapping data to control for the possible effects of serial dependency. Subsequently, our results for both the overlapping and non-overlapping data in Table 1 indicate that, on average, the aggregate monthly forecast errors for 3 individual months is not significantly different from the forecast error for the corresponding quarter, at any level less than 10 percent.

Table 1
Proportionality of Forecast Errors for the CAC Index:
February 1990 - December 1992

	Monthly contracts	Quarterly contracts
Overlapping data (n=119)		
Mean	0.0134	0.0129
Variance	0.0094	0.0099
<i>t</i> -statistic	0.0403	
Level of significance (%)	-	
Non-overlapping data (n=10)		
Mean	0.0350	0.0292
Variance	0.0161	0.0174
<i>t</i> -statistic	0.1016	
Level of significance (%)	-	

Figure 1
Price Quotations and Settlement Dates

I. Forward Exchange Rates

II. Share Market Index Futures

Note: $e_{ij,t}^s$ and $e_{ij,t,n}^f$ are the spot and n -day forward exchange rates for currency j in terms of currency i at time t , respectively, and $I_{j,t}^s$ and $I_{j,t,n}^f$ are the share market index spot and n -day futures prices for country j at time t , respectively.

Figure 2
Forecast Error Calculations

I. Exchange Rates

$$Z_{E_{ij,t,t+90}} = \log \left(\frac{e_{ij,t}^s}{e_{ij,t,t+90}^f} \right) - \log \left(\frac{e_{ij,t}^s}{e_{ij,t+90}^s} \right)$$

II. Share Market Indices

$$Z_{R_{j,t,t+45}} = \log \left(\frac{I_{j,t,t+45}^f}{I_{j,t}^s} \right) - \log \left(\frac{I_{j,t+45}^s}{I_{j,t}^s} \right)$$

$$Z_{R_{j,t+45,t+90}} = Z_{R_{j,t+45,t+135}} - Z_{R_{j,t+90,t+135}}$$

$$= \left[\log \left(\frac{I_{j,t+45,t+135}^f}{I_{j,t+45}^s} \right) - \log \left(\frac{I_{j,t+135}^s}{I_{j,t+45}^s} \right) \right] -$$

$$\left[\log \left(\frac{I_{j,t+90,t+135}^f}{I_{j,t+90}^s} \right) - \log \left(\frac{I_{j,t+135}^s}{I_{j,t+90}^s} \right) \right]$$

$$\therefore Z_{R_{j,t,t+90}} = Z_{R_{j,t,t+45}} + Z_{R_{j,t+45,t+90}}$$

Note: $Z_{E_{ij,t,t+90}}$ and $Z_{R_{j,t,t+90}}$ are the exchange rate and equity return forecast errors for country j , respectively.

Figure 3
Forecast Error Calculations for the CAC 40 Index

Note: $Z_{R_{FRA,t,t+90}}^Q$ and $Z_{R_{FRA,t,t+90}}^M$ are quarterly and monthly return forecast errors for the French share market, respectively.

3. TESTS OF STATIONARITY AND SERIAL CORRELATION

Before proceeding with our empirical tests, we first subject our forecast error data to tests of stationarity and market efficiency.⁸ We perform the tests on 13 subsets of *non-overlapping* forecast error data since each weekly observation in the overlapping forecast error data series is "shared" by 12 other 90-day periods, suggesting the possibility of serial dependence.

The standard Dickey and Fuller (1979, 1981) test for unit roots is used to determine stationarity in the data. This test assumes that the time series data follow a random walk with no drift, *i.e.*, *the null hypothesis is that of non-stationarity in the data*. The augmented Dickey-Fuller test results show that the null hypothesis of non-stationarity (of orders 0 and 1) can be rejected for all forecast error series, at the 5 percent level of significance, except the Australian and Canadian currencies. However, the null hypothesis cannot be rejected with the increase in lags.⁹ We suggest that the results may not be reliable with the higher order lags as the reduced number of observations could affect the power of the tests.

We subsequently run tests on serial correlation to support our findings. Moreover, since market efficiency requires that forecast errors be serially uncorrelated, the Ljung-Box (1978) Q^* statistic¹⁰ is used to test the *null hypothesis of no serial correlation* in the non-overlapping data sets, as proof that both the equity and foreign exchange markets are indeed efficient. Under the null hypothesis, this test statistic is distributed as a *chi-square* random variable with degrees of freedom

⁸ Note that although the tests are performed on exchange rates expressed relative to the US dollar, the results will be similar if a different currency is used as the reference currency, due to the triangular arbitrage condition wherein there will only be two independent exchange rates. Once these two rates are known, all other quotations can be derived using the Levi's (1983) chain rule.

⁹ Detailed results of the Dickey-Fuller test are not included in the paper but are available on request.

¹⁰ The Ljung-Box (1978) Q^* statistic is a modified version of Box and Pierce's (1970) Q statistic, and is considered more reliable in small samples (see Harvey, 1981, p. 211, and Kendall *et al.*, 1983, Chs. 48 and 50).

equal to the number of lags being tested. The Ljung-Box Q^* statistics for orders 1 to 6 indicate that the null hypothesis cannot be rejected at the 5 percent level of significance for any of the share market return forecast error series. Furthermore, although serial correlation appears to exist in a couple of subsets of the Deutsche mark, Japanese yen and French franc data,¹¹ the conclusion of no serial correlation could generally be said to apply to the exchange rate return forecast errors as well.

4. THE INTERNATIONAL EQUITY PARITY MODEL

Our empirical model uses the asset market approach to exchange rate determination within the framework established by Sjaastad (1990, 1992), as discussed in Section 1. In our case, we define a "large" country as one that is able to affect the returns on share prices of another country when it revalues/devalues its currency (and/or *vice-versa*).

We begin by looking at the IEP model, which relates the exchange rate between two countries to their respective equity markets. It is assumed here that there are 8 countries (Group of 7 plus Australia) involved in international equity trading. This assumption appears reasonable given that these countries account for approximately 86 percent of world market capitalisation.¹² Transport costs, tariffs and other barriers to trade are ignored as they are relatively stable over time. Thus, the law of one price should hold, such that

$$R_i = R_j + E_{ij} ,$$

where R_i is the rate of return on the country i index,

R_j is the rate of return on the country j index, and

¹¹ Detailed results of the Ljung-Box test not included in the paper but are available on request.

¹² Morgan Stanley MSCI NewsWatch, Vol. 2(6), 2 August 1995.

E_{ij} is the rate of appreciation of currency j against currency i .

Intuitively, when currency j appreciates against currency i , R_j should be commensurately lower than R_i so that the return from investing in either country is the same after adjusting for exchange rate differences. In economic terms, investors see a currency depreciation as leading to higher exports and therefore higher nominal corporate profits, resulting in higher share prices. As an example, since the Plaza Agreement in 1985, the US dollar has depreciated approximately 60 percent against the Japanese yen and Deutsche mark, while the US share market has tripled in value during that time.¹³

Any excess demand for equity in country j , denoted D_{R_j} , is a function of the real rate of return from investing in that country, and a vector X_{R_j} of other fundamental variables, so that

$$\begin{aligned} D_{R_j} &= D_{R_j} \left((R_j - P_j), X_{R_j} \right) \\ &= D_{R_j} \left((R_i - E_{ij} - P_j), X_{R_j} \right), \end{aligned} \quad (3)$$

where P_j is the change in the price level in country j . The excess demand for equity in country j can be shown as a function of the difference between the real rate of return on the country i index, and the bilateral real exchange rate between countries i and j , by adding and subtracting P_i from the function in Equation (3):

$$\begin{aligned} D_{R_j} &= D_{R_j} \left((R_i - P_i) - (E_{ij} + P_j - P_i), X_{R_j} \right) \\ &= D_{R_j} \left((R_i^r - E_{ij}^r), X_{R_j} \right), \end{aligned}$$

where $R_i^r = R_i - P_i$ is the real rate of return on the country i index, and

¹³ "American Stockmarkets: Steady Going," The Economist, 6 May 1995, p. 79.

$E_{ij}^r = E_{ij} + P_j - P_i$ is the bilateral real exchange rate between countries i and j .¹⁴

Given the nature of equity markets, whereby the mechanics of demand and supply are reflected in share price fluctuations, the equity markets clear continuously so that the sum of M excess demand for equity in country j is zero at any time:

$$\sum_{j=1}^M D_{R_j} = 0 \quad , \quad (4)$$

where $D_{R_j} = D_{R_j}(R_i^r - E_{ij}^r, X_{R_j})$. Subsequently, by defining $i = 1$, that is, the currency of country 1 as the reference currency, R_1^r can be extracted by differentiating Equation (4):

$$\sum_{j=1}^M D'_{R_j} (dR_1^r - dE_{1j}^r) + \text{something} = 0 \quad ,$$

where $D'_{R_j} \equiv \partial D_{R_j} / \partial (R_1^r - E_{1j}^r)$ is the change in excess demand for equity in country j relative to the change in the real rate of return on the country j index, and the "something" involves the X_{R_j} term. Thus, we obtain

$$\left[\sum_{j=1}^M D'_{R_j} \right] \cdot dR_1^r = \left[\sum_{j=1}^M D'_{R_j} \right] \cdot dE_{1j}^r - \text{something} \quad . \quad (5)$$

By rearranging (5), we arrive at

$$dR_1^r = \left[\sum_{j=1}^M D'_{R_j} \right] \cdot \left[\sum_{j=1}^M D'_{R_j} \right]^{-1} \cdot dE_{1j}^r - \text{something} \cdot \left[\sum_{j=1}^M D'_{R_j} \right]^{-1} \quad .$$

This equation is then integrated, with $\sum_{j=2}^M \Theta_{R_j}$ defined as

¹⁴ According to Mussa (1984), since short-term changes in the prices of assets traded in organised markets are not closely correlated with short-term changes in the general price level, as measured by the consumer price index, most nominal price changes are also real price changes.

$\left[\sum_{j=1}^M D'_{R_j}\right] \cdot \left[\sum_{j=1}^M D'_{R_j}\right]^{-1}$, and $K(X_R)$ representing the integral of the term, *something* $\cdot \left[\sum_{j=1}^M D'_{R_j}\right]^{-1}$, giving

$$R_1^r = \text{constant} + \sum_{j=2}^M \Theta_{R_j} \cdot E_{1j}^r + K(X_R) . \quad (6)$$

Here, $K(X_R)$ denotes the effect of the vectors X_{R_j} , and Θ_{R_j} could be interpreted as both the elasticity of the *nominal* return in currency 1 with respect to the *nominal* exchange rate of country j , and the elasticity of the *real* return in currency 1 with respect to the PPP *real* exchange rate between countries 1 and j . Note that while excess demand for equity in country j , D_{R_j} , may be either positive or negative, D'_{R_j} is positive as the excess demand for equity j increases when its real rate of return increases. Furthermore, since all terms are expressed in logarithmic form, $E_{11}^r \equiv 0$ and the summation across j in equation (6) excludes 1. Hence, Θ_{R_1} is derived as $1 - \sum_{j=2}^M \Theta_{R_j}$, i.e., Θ_{R_1} and Θ_{R_j} are non-negative fractions that sum to unity.

Θ_{R_j} measures the relative market power possessed by each country involved in the international equity trade, i.e., its ability to influence the rate of return of shares in another country *via* movements in its own currency. Given that the effect of any appreciation in currency 1 against all other currencies on the share market return of country j is defined as $\Theta_{R_1} \equiv 1 - \sum_{j=2}^M \Theta_{R_j}$, when $\Theta_{R_j} = 0$, then country j is a price-taker on the international equity market, and a change in its real exchange rate with respect to reference currency 1 will have no effect on the rate of return of shares in country 1. Thus, the entire impact would be reflected in the real rate of return of its own shares. Conversely, if $\Theta_{R_j} = 1$, then country j would be a price-maker in world equity markets, wherein any change in its real exchange rate with country 1 would be fully reflected in an equi-proportionate change in the real rate of return from share prices in country 1.

The existence of highly organised spot and forward markets for the major equity markets and currencies enable the derivation of two versions of equation (6), that is,

$$R_{1,t+n}^{r,s} = constant + \sum_{j=2}^M \Theta_{R_j} \cdot E_{1,j,t+n}^{r,s} + K^s(X_R) , \quad (7)$$

where $R_{1,t+n}^{r,s}$ and $E_{1,j,t+n}^{r,s}$ are the "spot" real equity rate of return and exchange rate appreciation at time $t+n$, respectively, and

$$R_{1,t,n}^{r,f} = constant + \sum_{j=2}^M \Theta_{R_j} \cdot E_{1,j,t,n}^{r,f} + K^f(X_R) , \quad (8)$$

where $R_{1,t,n}^{r,f}$ and $E_{1,j,t,n}^{r,f}$ are the n -period "forward" real equity rate of return and exchange rate appreciation at time t , respectively, and all Θ_{R_j} coefficients are the same for both equations in the short-term.

However, since the application of either of the above versions requires the specification of the variables $K(X_R)$, another alternative, whereby real return forecast errors are constructed from real spot and forward rates of return, is recommended. Since we assume that $K^s(X_R) = K^f(X_R)$ in the short-run, this term cancels out, so that,

$$Z_{R_{1,t,n}}^r \equiv R_{1,t,n}^{r,f} - R_{1,t+n}^{r,s} , \quad (9)$$

where $R_{1,t,n}^{r,f}$ and $R_{1,t+n}^{r,s}$ are the predicted and actual real equity returns between time t and $t+n$, respectively. Similarly, an equation can also be derived for the real exchange rate return forecast error:

$$Z_{E_{1,j,t,n}}^r \equiv E_{1,j,t,n}^{r,f} - E_{1,j,t+n}^{r,s} , \quad (10)$$

where $E_{1j,t,n}^{r,f}$ and $E_{1j,t,n}^{r,s}$ are the predicted and actual real exchange rate returns between time t and $t+n$, respectively. Note that equations (9) and (10) are the "real" versions of equations (1) and (2), derived in Section 2.

Furthermore, as discussed in Section 2, forecast error data are preferred over the spot and forward prices as it eliminates the problems of non-stationarity and high serial correlations. By lagging equation (7) n periods relative to equation (8), and subtracting the latter from the former per equations (9) and (10), the forecast-error version of equation (8) is arrived at:

$$Z_{R_{1,t,n}}^r = constant + \sum_{j=2}^M \Theta_{R_j} \cdot Z_{E_{1j,t,n}}^r \quad (11)$$

Equation (11) will be used in our empirical implementation of the IEP model.

The Θ_{R_j} ("market power") coefficients in equation (11) is estimated using OLS regression on the overlapping data sets. These Θ_{R_j} coefficients are represented by the resulting regression coefficients of the independent variables. Prior to analysing our results, we note that although the data are not serially correlated, the results from the regression estimates could show a high degree of serial correlation in the residuals due to the overlapping observations used. In this case, each observation shares up to 12 weeks of the 13-week forecast period with previous and following observations, thus introducing biases in the standard error estimates. When this occurs, we apply Hansen and Hodrick's (1980) correction method for serial correlation to make the necessary adjustments to the standard errors. The regression coefficients, however, remain unbiased.

We designate each of the three share markets in our sample as the "reference country" in turn, whereby all exchange rates are denominated in the reference

currency, with the share market return forecast errors as the dependent variable. This means that the results will be interpreted in the context relative to the market of the reference country. Preliminary tests¹⁵ based on the equation (11) regression using, in turn, Australia, Britain and the US as the reference country, suggest the existence of outliers during the October 1987 share market crash period for all three markets, as well as during the October 1989 correction period for the US market. Figures 4, (I) - (III) plot the forecast errors in share market returns (in bold) and exchange rate movements in foreign currency terms, for the Australian, British and US markets, respectively. Although the share returns and exchange rate changes seem to move in opposite directions as expected, the volatility of exchange rates does not appear to match that of the share prices during the crash periods.

We consequently include a dummy variable regressor with value "1" for the outliers relating to the October 1987 and October 1989 crash weeks and "0" for the rest, to account for these outlier occurrences. Equation (11) then becomes:

$$Z_{R_{l,t,n}}^r = \gamma_1 + \sum_{x=2}^3 \sum_{y=1}^2 \gamma_x \cdot (D_y) + \sum_{j=2}^M \Theta_{R_j} \cdot Z_{E_{lj,t,n}}^r, \quad (12)$$

where $Z_{R_{l,t,n}}^r$ is the reference country equity return forecast error,

Θ_{R_j} is the market power of the other equity markets,

$Z_{E_{lj,t,n}}^r$ is the exchange rate return forecast error for the other countries,

D_y is the dummy variable, such that

$D_1 = 1$ where positive outliers occur during the crash periods (October 1987 and October 1989), and

$= 0$ otherwise, and

$D_2 = 1$ where negative outliers occur during the crash periods, and

$= 0$ otherwise, and

γ_1 is the intercept for the non-crash periods, and $\gamma_1 + \gamma_2$ (or $\gamma_1 + \gamma_2 + \gamma_3$ for the US

¹⁵ The detailed results of these preliminary tests are not included in this paper.

market) is that for the crash period.

Results of the equation (12) regression are presented in Table 2. After correcting for outliers, we find substantial improvements in the $\bar{R}^2$ figures (between 30 to 50 percentage points), for all three regressions compared to the preliminary estimates of the equation (11) regressions. For instance, the $\bar{R}^2$ for the AAOI model improves from 28 percent to 70 percent, the FTSE model from 26 percent to 55 percent, while the S&P model increases its $\bar{R}^2$ from 15 percent to 64 percent. Similarly, the diagnostics indicate that the basic regression assumptions have generally been satisfied for the equation (12) model, except for the serial correlation problem. Also, note that since our earlier expositions on the regression models demonstrate that $\sum_{j=1}^M \Theta_{R_j} = 1$ and $\Theta_{R_j} > 0$, only the coefficients that satisfy these conditions are considered relevant for our analysis.

In Table 2(I), we find that while movements in the British pound, the Canadian dollar and the Deutsche mark appear to affect the AAOI returns, only the British pound and the Canadian dollar have significant influence. The sum of these coefficients are not significantly different from unity, suggesting that the excluded currencies have no effect on the Australian share market. The results of the equation (12) regression with the sum of the three exchange rate coefficients restricted to unity are presented under the "Restricted" panel of Table 2(I). Movements in the Canadian dollar appear to have the greatest effect on the AAOI, with a 10 percent real appreciation in that currency resulting in a 6.4 percent increase in Australian share market returns, while a similar appreciation in the British pound causes the AAOI returns to increase by 3.2 percent. However, when the "restricted" coefficients are corrected for the effects of serial correlation in the residuals, the increase in the standard errors results in the exchange rate coefficients being insignificantly different from zero.

Figure 4

Forecast Errors in Share Market Returns and Exchange Rate Movements

October 1986 - December 1992

I. Australian All-Ordinaries Index and Currencies

Quoted per Australian Dollar

II. Financial Times Stock Exchange 100 Index and Currencies

Quoted per British Pound

Figure 4 (cont'd)
Forecast Errors in Share Market Returns and Exchange Rate Movements
October 1986 - December 1992

Table 2(II) shows the influence of the Australian, Canadian, German and US currencies on the British market. The sum to unity of these currencies indicate that no other major currency affects the FTSE. When we subsequently restrict these currency coefficients to unity, only the Deutsche mark movements appear to have any significant bearing on the FTSE. In this instance, a 10 percent real appreciation in the Deutsche mark results in a 4.1 percent appreciation in the FTSE. However, when the Hansen and Hodrick (1980) correction method is implemented, all exchange rate coefficients appear insignificant.

The British pound, Canadian dollar and Italian lira are the three major currencies affecting US share market returns, as indicated in Table 2(III). Again, the sum of these exchange rate coefficients are not significantly different from unity. When we rerun regression (12) restricting the three coefficients to unity, we find that only movements in the Canadian dollar appear to have a significant effect on the

S&P returns. A 10 percent real appreciation in the Canadian dollar results in a 6.8 percent rise in US share price returns. However, as with the other two previous cases, the coefficient becomes insignificantly different from zero after we correct for serial correlation in the residuals.

As we would expect in all three markets, coefficients of the "restricted and corrected" dummy variables show that the share market crash of 1987 exerted significant influence on the AAOI and the FTSE, while the S&P was also significantly affected by the correction in October 1989.

Table 2
OLS Regression Results:
Forecast Errors in Share Market Returns and Exchange Rate Movements
October 1986 - December 1992

I. Australian All-Ordinaries Index and Currencies Quoted per Australian Dollar

Unrestricted				
Adjusted R ²	0.7027			
SE	0.0814			
Variable	Coefficient	Standard Error	t-Ratio	% Level of Significance
Intercept	-0.0091	0.0063	-1.449	-
DUM	0.5257	0.0251	20.928	0.1
STG	0.3428	0.1850	1.853	10
CAN	0.6665	0.2944	2.264	5
FRF	-0.9691	0.7042	-1.376	-
DEM	0.2107	0.6629	0.318	-
LIR	-0.0562	0.2861	-0.197	-
YEN	-0.0650	0.1301	-0.500	-
USD	-0.6888	0.2572	-2.678	1
Tests			Chi-Square Statistic	% Level of Significance
Serial Correlation			228.90	0.1
Functional Form			0.68	-
Normality			1.01	-
Heteroscedasticity			0.12	-
<u>Exchange Rate Coefficients</u>				
Sum of STG, CAN and DEM Coefficients				1.2199
Standard Error of Sum				0.7872
t-Ratio against Unity				0.2791
% Level of Significance				-
Restricted				
Adjusted R ²	0.7036			
SE	0.0813			
Variable	Coefficient	Standard Error	t-Ratio	% Level of Significance
Intercept	-0.0085	0.0060	-1.435	-
DUM	0.5253	0.0251	20.972	0.1
STG	0.3196	0.1650	1.937	10
CAN	0.6368	0.2740	2.324	5
FRF	-0.8139	0.4324	-1.882	10
DEM	0.0436	0.2865	0.152	-
LIR	-0.0196	0.2569	-0.076	-
YEN	-0.0507	0.1194	-0.425	-
USD	-0.6793	0.2545	-2.669	1
<u>Corrected for Serial Correlation</u>				
Variable	Coefficient	Standard Error	t-Ratio	% Level of Significance
Intercept	-0.0085	0.0193	-0.442	-
DUM	0.5253	0.0680	7.730	0.1
STG	0.3196	0.3706	0.862	-
CAN	0.6368	0.7135	0.893	-
FRF	-0.8139	1.7717	-0.459	-
DEM	0.0436	1.5821	0.028	-
LIR	-0.0196	0.6562	-0.030	-
YEN	-0.0507	0.3011	-0.168	-
USD	-0.6793	0.6327	-1.074	-

Notes: The regression variables are denoted as follows: STG = British pound, CAN = Canadian dollar, FRF = French franc, DEM = Deutsche mark, LIR = Italian lira, YEN = Japanese yen, USD = US dollar, DUM = dummy.

The level of significance in the last column, relating to the t-ratio, shows the probability of incorrectly rejecting the null hypothesis of a zero coefficient. Where "-" is indicated, the null hypothesis cannot be rejected at any level less than 10 percent.

Table 2 (cont'd)
 OLS Regression Results:
 Forecast Errors in Share Market Returns and Exchange Rate Movements
 October 1986 - December 1992

II. Financial Times Stock Exchange 100 Index and Currencies Quoted per British Pound

Unrestricted				
Adjusted R ²	0.5538			
SE	0.0713			
Variable	Coefficient	Standard Error	t-Ratio	% Level of Significance
Intercept	-0.0179	0.0055	-3.2659	1
DUM	0.3130	0.0220	14.2340	0.1
AUD	0.2047	0.1213	1.6876	10
CAN	0.2938	0.2580	1.1389	-
FRF	-0.8833	0.6198	-1.4252	-
DEM	0.8748	0.5849	1.4958	-
LIR	-0.8389	0.2596	-3.2312	1
YEN	-0.1164	0.1155	-1.0077	-
USD	0.1359	0.2261	0.6011	-
Tests			Chi-Square Statistic	% Level of Significance
Serial Correlation			240.24	0.1
Functional Form			0.22	-
Normality			0.38	-
Heteroscedasticity			4.11	5
Exchange Rate Coefficients				
Sum of AUD, CAN, DEM and USD Coefficients				1.5092
Standard Error of Sum				0.6400
t-Ratio against Unity				0.7963
% Level of Significance				-
Restricted				
Adjusted R ²	0.5538			
SE	0.0713			
Variable	Coefficient	Standard Error	t-Ratio	% Level of Significance
Intercept	-0.0160	0.0049	-3.2482	1
DUM	-0.3134	0.0220	14.2631	0.1
AUD	0.1873	0.1192	1.5714	-
CAN	0.2920	0.2578	1.1325	-
FRF	-0.4260	0.2319	-1.8371	10
DEM	0.4135	0.0764	5.4131	0.1
LIR	-0.7852	0.2505	-3.1343	1
YEN	-0.0762	0.1038	-0.7340	-
USD	0.1073	0.2230	0.4811	-
Corrected for Serial Correlation				
Variable	Coefficient	Standard Error	t-Ratio	% Level of Significance
Intercept	-0.0160	0.0141	-1.1347	-
DUM	0.3134	0.0543	5.7730	0.1
AUD	0.1873	0.2835	0.6606	-
CAN	0.2920	0.5910	0.4941	-
FRF	-0.4260	1.4897	-0.2860	-
DEM	0.4135	1.3746	0.3008	-
LIR	-0.7852	0.5716	-1.3736	-
YEN	-0.0762	0.2611	-0.2918	-
USD	0.1073	0.5353	0.2004	-

Table 2 (cont'd)
 OLS Regression Results:
 Forecast Errors in Share Market Returns and Exchange Rate Movements
 October 1986 - December 1992

III. Standard and Poor's 500 Index and Currencies Quoted per US Dollar

Unrestricted				
Adjusted R ²	0.6355			
SE	0.0572			
Variable	Coefficient	Standard Error	t-Ratio	% Level of Significance
Intercept	-0.0364	0.0044	-8.2993	0.1
DUM1	0.3381	0.0173	19.5456	0.1
DUM2	-0.2931	0.0585	-5.0118	0.1
AUD	-0.0346	0.0971	-0.3564	-
STG	0.0780	0.1395	0.5587	-
CAN	0.4853	0.2071	2.3434	5
FRF	-2.5958	0.4972	-5.2212	0.1
DEM	2.0364	0.4696	4.3368	0.1
LIR	0.1937	0.2083	0.9300	-
YEN	-0.1414	0.0922	-1.5344	-
Tests			Chi-Square Statistic	% Level of Significance
Serial Correlation			224.43	0.1
Functional Form			0.36	-
Normality			10.92	1
Heteroscedasticity			1.70	-
Exchange Rate Coefficients				
Sum of STG, CAN and LIR Coefficients				0.7569
Standard Error of Sum				0.2018
t-Ratio against Unity				-1.3108
% Level of Significance				-
Restricted				
Adjusted R ²	0.6346			
SE	0.0573			
Variable	Coefficient	Standard Error	t-Ratio	% Level of Significance
Intercept	-0.0356	0.0044	-8.1874	0.1
DUM1	0.3407	0.0172	19.7972	0.1
DUM2	-0.2941	0.0585	-5.0246	0.1
AUD	-0.0951	0.0856	-1.1112	-
STG	0.0669	0.1394	0.4799	-
CAN	0.6805	0.1441	4.7224	0.1
FRF	-2.6351	0.4969	-5.3031	0.1
DEM	2.0098	0.4697	4.2789	0.1
LIR	0.2526	0.2036	1.2407	-
YEN	-0.1149	0.0900	-1.2760	-
Corrected for Serial Correlation				
Variable	Coefficient	Standard Error	t-Ratio	% Level of Significance
Intercept	-0.0356	0.0127	-2.8129	0.1
DUM1	0.3407	0.0415	8.2184	0.1
DUM2	-0.2941	0.0501	-5.8728	0.1
AUD	-0.0951	0.2333	-0.4075	-
STG	0.0669	0.2978	0.2246	-
CAN	0.6805	0.4917	1.3841	-
FRF	-2.6351	1.2239	-2.1530	5
DEM	2.0098	1.1078	1.8143	10
LIR	0.2526	0.4669	0.5410	-
YEN	-0.1149	0.2082	-0.5518	-

5. RESPONSE LAGS

Thus far, it has been assumed that the response of equity markets to exchange rate news is instantaneous, when in actual fact lags may exist. The inclusion of this possibility means that equations (6) and (11) can be generalised to

$$R_t^r = \sum_{j=2}^M \Theta_{R_j}(L) \cdot E_{1j}^r + K[X_R(L)] \quad , \text{ and}$$

$$Z_{R_{1,t,n}}^r = \sum_{j=2}^M \Theta_{R_j}(L) \cdot Z_{E_{1j,t,n}}^r \quad , \text{ respectively,} \quad (13)$$

where L is the lag operator and k is the total number of lags. The dependent variable in equation (13), $Z_{R_{1,t,n}}^r$ can be rewritten as follows:

$$\alpha(L; k) \cdot Z_{R_{1,t,n}}^r = \sum_{j=2}^M \Theta_{R_j} \cdot Z_{E_{1j,t,n}}^r \quad , \quad (14)$$

where $\alpha(L; k)$ is a polynomial of the form, $\alpha_0 + \alpha_1 \cdot L + \alpha_2 \cdot L^2 + \dots + \alpha_k \cdot L^k$, and $\alpha_0 = -1$.

Let $\delta Z_{R_{1,t,n}}^r / \delta Z_{E_{1j,t_0,n}}^r$ be the effect on $Z_{R_{1,t,n}}^r$ of a shock to $Z_{E_{1j}}$, introduced during period t_0 . If the process is stable, $\delta Z_{R_{1,t,n}}^r$ eventually approaches a constant, and hence,

$$\alpha(L; k) \cdot \delta Z_{R_{1,t,n}}^r \rightarrow \alpha(l) \cdot \delta Z_{R_{1,t,n}}^r \quad .$$

This means that

$$\alpha(l) \cdot \delta Z_{R_{1,t,n}}^r \rightarrow \Theta_{R_j} \cdot \delta Z_{E_{1j,t,n}}^r \quad ,$$

where $\alpha(l)$ is the sum of the coefficients of the polynomial $\alpha(L; k)$, and $\Theta_{R_j} / \alpha(l)$ is the limiting value of $\delta Z_{R_{l,t,n}}^r / \delta Z_{E_{lj,t_0,n}}^r$, which represents the long-run value of Θ_{R_j} . Letting $\lambda_{R_j} = \Theta_{R_j} / \alpha(l)$, and substituting $\alpha(l) \cdot \lambda_{R_j}$ for Θ_{R_j} in equation (14), we obtain

$$\alpha(L; k) \cdot Z_{R_{l,t,n}}^r = \sum_{j=2}^M \alpha(l) \cdot \lambda_{R_j} \cdot Z_{E_{lj,t,n}}^r, \text{ or}$$

$$\alpha(L; k) \cdot Z_{R_{l,t,n}}^r - \sum_{j=2}^M \alpha(l) \cdot \lambda_{R_j} \cdot Z_{E_{lj,t,n}}^r = 0,$$

where $-\lambda_{R_j}$ is the long-run effect of a permanent shock to the j^{th} real exchange rate. $\alpha(L; k) \cdot \delta Z_{R_{l,t,n}}^r$ is then reparameterised to arrive at the non-linear least squares (NLLS) expression

$$\sum_{g=0}^{k-1} \left[\sum_{i=0}^g \alpha_i \right] \cdot \Delta Z_{R_{l,t-g,n}}^r + \alpha(l) \cdot \left[Z_{R_{l,t-k,n}}^r - \sum_{j=2}^M \lambda_{R_j} \cdot Z_{E_{lj,t,n}}^r \right] = 0, \quad (15)$$

where $g = k-1$. Equivalently, equation (15) can be written as

$$\Delta Z_{R_{l,t,n}}^r = \sum_{g=1}^{k-1} \left[\sum_{i=0}^g \alpha_i \right] \cdot \Delta Z_{R_{l,t-g,n}}^r + \alpha(l) \cdot \left[Z_{R_{l,t-k,n}}^r - \sum_{j=2}^M \lambda_{R_j} \cdot Z_{E_{lj,t,n}}^r \right], \quad (16)$$

wherein lags are introduced until $\alpha(l)$ stabilises. Since $\alpha(l)$ is the sum of the coefficients of $\alpha(L; k)$, the coefficient of the last lag, k , must be zero when $\alpha(l)$ stabilises.

As with the previous data sets, the crash outliers also manifest themselves in the first differenced error data (see Figures 5, (I) - (III)). Once again, we include

dummy variable regressors in our model, so that equation (16) becomes

$$\Delta Z_{R_{l,t,n}}^r = \sum_{g=1}^{k-1} \left[\sum_{i=0}^g \alpha_i \right] \cdot \Delta Z_{R_{l,t-g,n}}^r + \alpha(l) \cdot \left[Z_{R_{l,t-k,n}}^r - \sum_{j=2}^M \lambda_{R_j} \cdot Z_{E_{lj,t,n}}^r - \sum_{y=1}^2 \lambda_y \cdot D_y \right],$$

where D_y is the dummy variable, such that

$$\begin{aligned} D_1 &= 1 \text{ where positive outliers occur during the crash period, and} \\ &= 0 \text{ otherwise; and} \\ D_2 &= 1 \text{ where negative outliers occur during the crash period, and} \\ &= 0 \text{ otherwise.} \end{aligned}$$

Initial tests incorporating lags indicate that the Australian and British markets "stabilise" instantaneously, *i.e.*, all information is incorporated within a week of "news" occurring, which is consistent with our *asset market* hypothesis. This means that the OLS regression model of equation (12) is appropriate for the Australian and British markets. However, the US share market appears to take four weeks to "stabilise", as shown in Table 3. Interestingly, we find that approximately 40 percent of the information conveyed by movements in the Japanese yen is incorporated into the US market after one week; after two weeks, 58 percent is reflected in the share returns; and 82 percent of news is reflected after three weeks.¹⁶

At the end of the 4-week period, US share price returns appear to reflect information conveyed by movements in both the Japanese yen *and* the French franc. By this time, a real appreciation of 10 percent in the Japanese yen would have resulted in a 7.8 percent increase in the S&P returns (and *vice-versa*), while an appreciation of the same magnitude in the French franc would have caused a 1.3

¹⁶ $\Theta_{R_{JAP}} = 0.32$ after a 1-week lag; $\Theta_{R_{JAP}} = 0.45$ after a 2-week lag and $\Theta_{R_{JAP}} = 0.64$ after a 3-week lag.

Figure 5
Forecast Errors in Share Market Returns (First Differenced)
October 1986 - December 1992

I. Australian All-Ordinaries Index

II. Financial Times Stock Exchange 100 Index

Figure 5 (cont'd)
Forecast Errors in Share Market Returns (First Differenced)
October 1986 - December 1992

III. Standard and Poor's 500 Index

percent real increase in US share market returns (and *vice-versa*). However, as with the OLS results, the market power coefficients appear to be insignificantly different from zero. Our results are consistent with Amihud's (1992) and Bilson's (1992) in that they too find weak evidence of a delayed currency effect on share prices of US companies.

Table 3
NLLS Regression Results:
Forecast Errors in Share Market Returns (First Differenced) and Exchange Rate Movements
October 1986 - December 1992

Standard and Poor's 500 Index					
Adjusted R ²		0.7424			
SE		0.0310			
Variable	Lag	Coefficient	Standard Error	t-Ratio	% Level of Significance
AUD	0	-0.9169	1.1258	-0.8144	-
STG	0	-2.6048	1.8242	-1.4279	-
CAN	0	1.4982	2.0010	0.7487	-
FRF	0	0.1336	4.2205	0.0317	-
DEM	0	-1.3571	4.2857	-0.3167	-
LIR	0	3.0592	2.5322	1.2081	-
YEN	0	0.7817	1.0694	0.7310	-
D1	0	5.5062	2.4395	2.2571	5
D2	0	-5.4643	2.4853	-2.1986	5
ΔS&P	1	-0.1389	0.0339	-4.0967	0.1
"	2	-0.0980	0.0353	-2.7758	1
"	3	-0.0914	0.0370	-2.4744	5
"	4	-0.0862	0.0357	-2.4126	5
S&P	5	-0.0556	0.0245	-2.2704	5
Tests				Chi-Square Statistic	% Level of Significance
Serial Correlation				1.8903	-
Functional Form				0.2452	-
Normality				8.3503	5
Heteroscedasticity				1.3026	-
Exchange Rate Coefficients					
Sum of FRF and YEN					0.9153
Wald Statistic against Unity					0.0003
% Level of Significance					-

A summary of the "market power" of the relevant countries and the corresponding share markets is presented in Table 4. Interestingly enough, we find that there is a tendency for inter-market influence amongst the English-speaking countries of Australia, Britain, Canada and the US. These inter-relationships are alluded to in Frankel and Wei's (1995) research into currency blocs. Moreover, the yen's apparent lack of influence on the British and Australian markets is consistent with Frankel and Wei's results, as is the Deutsche mark's influence on European markets (in our case, the British market). Japan's influence on the US market is hardly surprising, given the very strong trade links between the two countries. Furthermore, our finding that other markets appear to have little effect on the US is consistent with Eun and Shim (1989), who suggest that the dominance of the US in the world economy makes it "the most important producer of information affecting the world share market" (p. 254).

Table 4
Summary of "Market Power" Estimates

Index	Currency	Θ
1. Australian All-Ordinaries	STG	0.3196
	CAN	0.6368
	DEM	0.0436
2. Financial Times Stock Exchange 100	AUD	0.1873
	CAN	0.2920
	DEM	0.4135
	USD	0.1073
3. Standard and Poor's 500	FRF	0.1336
	YEN	0.7817

6. SUMMARY AND CONCLUSION

We can reasonably conclude from our results that equity parity holds between the share markets and exchange rates to the extent that a depreciation in a country's currency would cause its share market returns to rise, while an appreciation would have the opposite effect. It is also apparent that the reaction of share prices to exchange rate changes (and *vice-versa*) is a very rapid one. With the exception of the US market, which appears to take 4 weeks to fully incorporate new information conveyed by currency movements, the Australian and British share markets appear to react instantaneously to news. Furthermore, our results also support the existence of currency bloc influence on equity markets.

We are unable to infer from our findings that the relationship between equity and exchange rate markets is a significant one, however. Also, it appears that while equity markets react to information conveyed by currency movements, they are also subject to other shocks, as demonstrated by the lack of corresponding volatility in exchange rates during the share market crash of 1987 and correction of 1989.¹⁷

Overall, our results demonstrate that the relationship between exchange rates and share prices is much more dynamic than that between exchange rates and inflation rates, and between exchange rates and interest rates, as evidenced by previous research. Our results have practical implications for portfolio management in that investors in international equity markets would be able to hedge their portfolios against currency movements, using the relationships between equity returns and exchange rate movements derived earlier. As an example, let

¹⁷ See Jalleh (1989) for a detailed analysis of exchange rate/equity return co-movements during the Crash.

$$\begin{pmatrix} \% \text{ expected change} \\ \text{in US equity returns} \end{pmatrix} = \Theta_{R_{JAP}} \begin{pmatrix} \% \text{ expected appreciation} \\ \text{in Japanese yen relative} \\ \text{to the US dollar} \end{pmatrix}$$

where $\Theta_{R_{JAP}}$ (which also represents the hedge ratio) measures the sensitivity of US equity returns to changes in the value of the Japanese yen. Then, using our results, we could rewrite this equation as

$$\begin{pmatrix} \% \text{ expected change} \\ \text{in US equity returns} \end{pmatrix} = 0.78 \begin{pmatrix} \% \text{ expected appreciation} \\ \text{in Japanese yen relative} \\ \text{to the US dollar} \end{pmatrix},$$

which means that in order to hedge a US\$1 million investment in US equities, the investor should short-sell US\$0.78 million worth of Japanese yen.

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