Modelling Volatility in Currency Futures for Developed and Emerging Markets

John M. Sequeira[a] **and Pang Chia Chiat**[a] **and Michael McAleer**[b]
[a]*Department of Finance and Accounting, National University of Singapore (fbajms@nus.edu.sg)*
[b]*Department of Economics, University of Western Australia (mmcaleer@ecel.uwa.edu.au*

Abstract This paper examines volatility models of currency futures contracts for three developed markets and two emerging markets. For each contract, standard models of the Unbiased Expectations Hypothesis (UEH) and Cost-of-Carry (COC) model are extended to derive volatility models corresponding to each of the two standard approaches. Each volatility model is formulated as a system of individual equations for the conditional variances of futures returns, spot returns and the domestic risk-free interest rate. The findings suggest that the conditional volatility of futures returns for emerging markets is significant in explaining the conditional volatility of returns in the underlying spot market. For developed markets, however, the conditional volatility of spot returns is significant in explaining the conditional volatility of futures returns. Moreover, it is found that the domestic risk-free interest rate has little impact on the conditional variances of the futures, spot and domestic risk-free interest rates.
Keywords: Futures prices; Spot prices; Volatility; Developed markets; Emerging markets

1. INTRODUCTION

Over the last 25 years, financial innovation and competitive pressures have forced massive changes on the structure and institutions of the foreign exchange market. The Bank for International Settlements[1] surveys estimate that the total daily worldwide foreign exchange trading volume in 1998 alone was $1.5 trillion per day, or nearly $400 trillion per year. Trading volume on foreign exchange markets is massive. By comparison, only $58.8 billion in equities was traded on the busiest day in the history of the New York Stock Exchange, on 19 April 1999[2]. The volatility in these markets became apparent after the devaluation of the pound sterling in November 1967, when a series of international financial crises ensued until the Smithsonian agreement in 1971. Consequently, this led to the introduction of trading in foreign currency futures on the International Monetary Market (IMM) of the Chicago Mercantile Exchange in May 1972.

Increasingly, studies in futures markets tend to focus on some common issues, namely the determination of optimal hedge ratios [Kroner and Sultan, 1993], international transmission of information across different international futures markets trading identical futures contracts [Tse et al., 1996; Najan et al., 1992], and price volatility and trading volume [Bessembinder and Seguin, 1993], among others. There are few known studies that examine the interactions between the volatilities in the spot and futures markets. In a recent study, McAleer and Sequeira [1999] examined spot and futures market volatilities of Australian dollar futures contracts traded on the IMM using a univariate approach. They provided evidence that the volatility in futures returns was strongly affected by the volatility in the underlying spot market and the volatility in the foreign risk-free rate, but not by volatility in the domestic risk-free interest rate.

In this paper we formulate volatility models of currency futures contracts. The approach differs from McAleer and Sequeira [1999] in that a system of equations is formulated to represent a volatility model. Two standard models in Sequeira et al. [2001] are extended to estimate a volatility model for each of these two well-known approaches in modelling futures prices, namely the Cost-of-Carry (COC) model and the Unbiased Expectations Hypothesis (UEH). This estimation method is preferred as a systems approach is more efficient than the univariate methods used in McAleer and Sequeira [1999].

The COC and UEH volatility models are estimated for currency futures contracts from three developing and two emerging countries traded on the International Monetary Market of the Chicago

[1] Bank for International Settlements, 1999.
[2] New York Stock Exchange Factbook (1999).

Mercantile Exchange (CME). A primary objective in analyzing the models according to their separate groupings is to examine the relative impacts of spot and futures volatilities in each of the markets and to identify patterns that are common within each group. Interestingly, the results indicate there is systematic behaviour in the conditional variances in both developed and emerging markets.

The remainder of the paper is organized as follows. In Section 2, we discuss the formulation of volatility models of futures contracts based on the two main hypotheses for futures pricing. Then we examine the data in Section 3. In Section 4, we highlight the main results obtained in the paper. Section 5 provides some concluding remarks.

2. VOLATILITY MODELS OF FUTURES CONTRACTS

Sequeira et al. [2001] developed systems equations of Australian dollar futures contracts based on the two main hypotheses for pricing futures contracts, namely the Cost-of-Carry (COC) model and Unbiased Expectations Hypothesis (UEH). The error correction representation of the COC model, with one cointegrating vector among the futures price, spot price, domestic interest rate and foreign interest rate, assuming that all four variables are I(1) and the domestic interest rate is determined exogenously (the foreign risk-free rate is assumed to have a negligible influence on the domestic rate), is given as:

$$\Delta s_t = a_0 + a_1\Delta s_{t-1} + a_2\Delta f_{t-1} + a_3\Delta r^d_{t-1} + a_4\Delta r^f_{t-1} + \quad (1a)$$
$$....+ a_5(f_{t-1} - b_1 s_{t-1} - b_2 r^f_{t-1} - b_3 r^d_{t-1}) + \varepsilon^s_t$$

$$\Delta f_t = a_{10} + a_{11}\Delta s_{t-1} + a_{12}\Delta f_{t-1} + a_{13}\Delta r^d_{t-1} + a_{14}\Delta r^f_{t-1} + \quad (1b)$$
$$....+ a_{15}(f_{t-1} - b_1 s_{t-1} - b_2 r^f_{t-1} - b_3 r^d_{t-1}) + \varepsilon^f_t$$

$$\Delta r^f_t = a_{20} + a_{21}\Delta s_{t-1} + a_{22}\Delta f_{t-1} + a_{23}\Delta r^d_{t-1} + a_{24}\Delta r^f_{t-1} + \quad (1c)$$
$$....+ a_{25}(f_{t-1} - b_1 s_{t-1} - b_2 r^f_{t-1} - b_3 r^d_{t-1}) + \varepsilon^r_t ,$$

with the single error correction term given by $(f_{t-1} - b_1 s_{t-1} - b_2 r^f_{t-1} - b_3 r^d_{t-1})$ in the COC model.

For the UEH, assuming that the futures and spot prices are I(1) and that a cointegrating relationship exists between the two prices, is given as:

$$\Delta s_t = c_0 + c_1\Delta s_{t-1} + c_2\Delta f_{t-1} + c_3(f_{t-1} - d_1 s_{t-1}) + \varepsilon^s_t \quad (2a)$$

$$\Delta f_t = c_{10} + c_{11}\Delta s_{t-1} + c_{12}\Delta f_{t-1} + c_{13}(f_{t-1} - d_1 s_{t-1}) + \varepsilon^f_t \quad (2b)$$

$$\Delta r^f_t = c_{20} + c_{21}\Delta r^f_{t-1} + c_{22}\Delta r^d_{t-1} + \varepsilon^r_t , \quad (2c)$$

where $(f_{t-1} - d_1 s_{t-1})$ represents the error correction term between the futures and spot prices. There is no cointegrating relationship between the domestic and foreign risk-free rate, so that interest rate parity is not necessary for equation (2c), which is optional for the system. Equation (2c) is included in the system to enable a comparison between the UEH and COC models.

In this paper, we extend the models in Sequeira et al. [2001] to incorporate the second moments of futures returns, for which the variance of the COC model is given corresponding to the particular equation. by equations (1a)-(1c) as follows:

$$\text{var}\,\Delta s_t = a_0 + a_1 \text{var}\,\Delta s_{t-1} + a_2 \text{var}\,\Delta f_{t-1} + a_3 \text{var}\,\Delta r^d_{t-1} \quad (3a)$$
$$...+ a_4 \text{var}\,\Delta r^f_{t-1} + a_5 \text{var}(f_{t-1} - b_1 s_{t-1} - b_2 r^f_{t-1} - b_3 r^d_{t-1}) + \varepsilon^s_t$$

$$\text{var}\,\Delta f_t = a_{10} + a_{11} \text{var}\,\Delta s_{t-1} + a_{12} \text{var}\,\Delta f_{t-1} + a_{13} \text{var}\,\Delta r^d_{t-1} \quad (3b)$$
$$...+ a_{14} \text{var}\,\Delta r^f_{t-1} + a_{15} \text{var}(f_{t-1} - b_1 s_{t-1} - b_2 r^f_{t-1} - b_3 r^d_{t-1}) + \varepsilon^f_t$$

$$\text{var}\,\Delta r^f_t = a_{20} + a_{21} \text{var}\,\Delta s_{t-1} + a_{22} \text{var}\,\Delta f_{t-1} + a_{23} \text{var}\,\Delta r^d_{t-1} \quad (3c)$$
$$+ a_{24} \text{var}\,\Delta r^f_{t-1} + a_{25} \text{var}(f_{t-1} - b_1 s_{t-1} - b_2 r^f_{t-1} - b_3 r^d_{t-1}) + \varepsilon^r_t \; .$$

Equations (3a)-(3c) are denoted as the COC Volatility Systems (COCVS) model with one cointegrating vector. Covariances between the variables in each equation are subsumed into the error terms

A similar procedure is applied to the UEH model given by equations (2a)-(2c) to obtain the UEH Volatility Systems (UEHVS) model, as follows:

$$\text{var}\Delta s_t = c_0 + c_1 \text{var}\Delta s_{t-1} + c_2 \text{var}\Delta f_{t-1} + c_3 \text{var}(s_{t-1} - d_1 f_{t-1}) + \varepsilon^s_t \quad (4a)$$

$$\text{var}\Delta f_t = c_{10} + c_{11} \text{var}\Delta s_{t-1} + c_{12} \text{var}\Delta f_{t-1} + c_{13} \text{var}(s_{t-1} - d_1 f_{t-1}) + \varepsilon^f_t \quad (4b)$$

$$\text{var}\,\Delta r^f_t = c_{20} + c_{21} \text{var}\,\Delta r^f_{t-1} + c_{22} \text{var}\,\Delta r^d_{t-1} + \varepsilon^r_t . \quad (4c)$$

The covariances are, as before, subsumed into the error term.

For the COC model with two cointegrating vectors, we assume a cointegrating relationship between the spot and futures returns, and also between the domestic and foreign risk-free interest rate, as follows:

$$\Delta s_t = a_0 + a_1\Delta s_{t-1} + a_2\Delta f_{t-1} + a_3\Delta r^d_{t-1} + a_4\Delta r^f_{t-1} \quad (5a)$$
$$...+ a_5(f_{t-1} - b_1 s_{t-1}) + a_6(r^f_{t-1} - b_2 r^d_{t-1}) + \varepsilon^s_t$$

$$\Delta f_t = a_{10} + a_{11}\Delta s_{t-1} + a_{12}\Delta f_{t-1} + a_{13}\Delta r^d_{t-1} + a_{14}\Delta r^f_{t-1} \quad (5b)$$
$$...+ a_{15}(f_{t-1} - b_1 s_{t-1}) + a_{16}(r^f_{t-1} - b_2 r^d_{t-1}) + \varepsilon^f_t$$

$$\Delta r^f_t = a_{20} + a_{21}\Delta s_{t-1} + a_{22}\Delta f_{t-1} + a_{23}\Delta r^d_{t-1} + a_{24}\Delta r^f_{t-1} \quad (5c)$$
$$...+ a_{25}(f_{t-1} - b_1 s_{t-1}) + a_{26}(r^f_{t-1} - b_2 r^d_{t-1}) + \varepsilon^r_t \; ,$$

where $(f_{t-1} - b_1 s_{t-1})$ is the error correction term between the futures and spot prices and $(r^f_{t-1} - b_2 r^d_{t-1})$ is the error correction term between the domestic and foreign risk-free interest rates. Based on equations (5a)-(5c), we formulate the COC Volatility Systems (COCVS) model with two cointegrating vectors, as follows:

$$\mathrm{var}\Delta s_t = a_0 + a_1 \mathrm{var}\Delta s_{t-1} + a_2 \mathrm{var}\Delta f_{t-1} + a_3 \mathrm{var}\Delta r^d_{t-1} \quad (6a)$$
$$\ldots + a_4 \mathrm{var}\Delta r^f_{t-1} + a_5 \mathrm{var}(f_{t-1} - b_1 s_{t-1}) + a_6 \mathrm{var}(r^f_{t-1} - b_2 r^d_{t-1}) + \varepsilon^s_t$$
$$\mathrm{var}\Delta f_t = a_{10} + a_{11} \mathrm{var}\Delta s_{t-1} + a_{12} \mathrm{var}\Delta f_{t-1} + a_{13} \mathrm{var}\Delta r^d_{t-1} \quad (6b)$$
$$\ldots + a_{14} \mathrm{var}\Delta r^f_{t-1} + a_{15} \mathrm{var}(f_{t-1} - b_1 s_{t-1}) + a_{16} \mathrm{var}(r^f_{t-1} - b_2 r^d_{t-1}) + \varepsilon^f_t$$
$$\mathrm{var}\Delta r^f_t = a_{20} + a_{21} \mathrm{var}\Delta s_{t-1} + a_{22} \mathrm{var}\Delta f_{t-1} + a_{23} \mathrm{var}\Delta r^d_{t-1} \quad (6c)$$
$$\ldots + a_{24} \mathrm{var}\Delta r^f_{t-1} + a_{25} \mathrm{var}(f_{t-1} - b_1 s_{t-1}) + a_{26}(r^f_{t-1} - b_2 r^d_{t-1}) + \varepsilon^r_t.$$

The UEHVS model is a special case of the COCVS model with two cointegrating vectors as equations (6a) – (6c) reduce through parametric restrictions to the system of equations given by (4a)-(4c). Equation (6) reduces to (4) by eliminating: (i) the conditional variances of the two interest rates; (ii) the conditional variances of the error correction term between the two interest rates from the spot and futures equations (6a)-(6b); (iii) the conditional covariances of both spot and futures prices; (iv) the conditional variances of the error correction terms between the spot and futures prices and between the two interest rates from the foreign interest rate equation.

As the UEHVS model is nested within the COCVS model with two cointegrating vectors, it can be tested by applying the following parametric restrictions on the COCVS model (with two cointegrating vectors), as follows:

$$H_0: a_3 = a_4 = a_6 = a_{13} = a_{14} = a_{16} = a_{21} = a_{22} = a_{25} = a_{26} = 0 \cdot \quad (7)$$

The Wald statistics on the parametric restrictions can be used to test the validity of these restrictions. Under the null hypothesis, the error correction term between the interest rates is deleted from equations (6a)-(6c) and the error correction term between the futures and spot prices is deleted from equation (7).

3. DATA

Daily spot and futures settlement prices for the Brazilian Real (BRR), French Francs (FRF), German Deutsche Mark (DEM), Japanese Yen (JPY) and the Mexican Peso (MXN) traded on the International Monetary Market (IMM) of the Chicago Mercantile Exchange (CME) are analyzed in this paper. These futures contracts and their corresponding spot rates represent a sample of currencies from both developed and emerging markets. In this paper, currency futures contracts on developed markets are the French Franc, German Deutsche Mark and Japanese Yen, while those on emerging markets are the Brazilian Real and Mexican Peso. The sample for the DEM and JPY covers the period October 1989 to October 2000, for a total of 2878 observations. Sample observations for the other currencies have different starting dates due to the unavailability of data prior to October 1989. We use the risk-free interest rate of the domiciled currency as the foreign risk-free rate, and the US Treasury Bill rate as the domestic risk-free interest rate. Daily observations on futures and spot prices, and domestic and foreign risk-free rates, are obtained from the DATASTREAM International database. Returns of the futures and spot prices are determined as the logarithmic differences of the respective prices. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are applied to the futures and spot prices, and the domestic and foreign risk-free interest rates, for all five currencies, and it is found that these variables are I(1).[3]

For the Cost-of-Carry model, a long run relationship is assumed to exist between four variables, namely the futures price, spot price, domestic risk-free rate and foreign risk-free rate. Cointegration tests among the four variables are conducted using Johansen's [1991] procedures to identify the number of cointegrating relationships. Two cointegrating vectors are obtained among the four variables for the Brazilian Real and Deutsche Mark, comprising one long-run relationship between the futures and spot prices, and another between the domestic and foreign risk-free rates. One cointegrating vector is obtained among the four variables for the French Franc, Japanese Yen and Mexican Peso, describing one long-run relationship among the four variables. Johansen's [1991] procedures confirm the existence of a cointegrating relationship between the spot and future prices for the Unbiased Expectations Hypothesis.

4. ESTIMATION RESULTS

The symmetric GARCH (1,1) process [see Bollerslev, 1986] is estimated for the conditional variances of the futures and spot returns, and the domestic and foreign interest rates. Conditional variances for the error correction terms for both the Cost-of-Carry Volatility System and Unbiased Expectations Hypothesis Volatility System for the five currencies are also estimated. Using these estimates of the conditional variances, both the Cost-of-Carry and the Unbiased Expectation Hypothesis volatility systems are estimated using the Seemingly Unrelated Regression Equations method. Estimates for the three equation systems corresponding to the Cost-of-Carry volatility system with one cointegrating vector, the Cost-of-Carry volatility system with two cointegrating

[3] ADF and PP statistics are available upon request.

vectors, and the Unbiased Expectation Hypothesis volatility system, are given in Tables 1, 2 and 3, respectively.

4.1 Cost-of-Carry Volatility System with One Cointegrating Vector

Table 1 presents the estimates of the COC volatility system with one cointegrating vector. The conditional variance of the futures returns for the Mexican Peso is significant in explaining the conditional variance of the respective spot returns. However, the conditional variance of the futures returns is not significant in explaining the conditional variance of the spot returns for either the French Franc or Japanese Yen. It is found that the conditional variance of the spot returns is significant in explaining the conditional variance of futures returns for both the French Franc and Japanese Yen. The reverse does not, however, hold for both these contracts. It is also found that the conditional variance of the domestic interest rates does not have a significant effect on the conditional variance of the futures returns for these three currencies. The conditional variance of the domestic risk-free interest rate does not have a significant influence on the conditional variance of the foreign risk-free interest rate in France, Japan and Mexico. However, the conditional variance of the foreign interest rate in Japan and Mexico is significant in explaining the conditional variance of their respective futures returns. For Japan, the conditional variance of the foreign interest rate is significant in explaining the conditional variance of the spot returns.

4.2 Cost-of-Carry Volatility Systems with Two Cointegrating Vectors

for models of developed markets. The domestic risk-free rate is not significant in explaining the conditional variance of the foreign risk-free rate, but the conditional variance of the foreign risk-free rate is significant in explaining the conditional variance of the spot rate. The conditional variance of the foreign risk-free rate is not significant in explaining the conditional variance of the futures and spot returns.

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Table 1
Estimation of the Cost-of-Carry Volatility System with One Cointegrating Vector

	French Franc			Japanese Yen			Mexican Peso		
Variables	var(Δs_t)	var(Δf_t)	var(Δr_t^f)	Var(Δs_t)	var(Δf_t)	var(Δr_t^f)	var(Δs_t)	var(Δf_t)	var(Δr_t^f)
Constant	0.000**	0.000**	0.002	0.000	0.000	0.000	0.000	0.000**	0.017
	(0.002)	(0.000)	(0.119)	(0.086)	(0.132)	(0.765)	(0.195)	(0.001)	(0.602)
var(Δs_{t-1})	0.972**	0.043**	370.3**	0.983**	0.037*	- 16.137	0.776**	0.064	-1.090
	(0.000)	(0.002)	(0.000)	(0.000)	(0.016)	(0.333)	(0.000)	(0.132)	(0.995)
var(Δf_{t-1})	0.008	0.915**	-428.5**	-0.014	0.940**	26.634	0.051**	0.455**	- 85.804
	(0.609)	(0.000)	(0.000)	(0.402)	(0.000)	(0.101)	(0.000)	(0.000)	(0.454)
var (Δr^d_{t-1})	0.000	0.000	-0.078	0.000	0.000	0.000	-0.001	- 0.001	-0.339
	(0.955)	(0.671)	(0.547)	(0.544)	(0.502)	(0.996)	(0.465)	(0.697)	(0.955)
Var (Δr^f_{t-1})	0.000	0.000	0.783**	0.000**	0.000**	0.934**	0.000	0.000*	0.884**
	(0.673)	(0.901)	(0.000)	(0.000)	(0.000)	(0.000)	(0.589)	(0.023)	(0.000)
Ect	0.003*	0.001	48.7**	0.124**	0.103**	-5.775	0.074**	0.131**	507.2**
	(0.032)	(0.742)	(0.000)	(0.000)	(0.000)	(0.790)	(0.000)	(0.000)	(0.000)
R^2	0.968	0.933	0.746	0.959	0.970	0.891	0.605	0.329	0.824
DW	1.908	1.929	1.910	1.899	1.929	1.559	1.935	1.997	2.110

Notes:
(1) Ect represents the error correction term among the futures, spot, domestic interest rates and the foreign interest rates in the COCVS from equations 3(a)-3(c).
(2) Figures in parentheses are p-values.
(3) ** Denotes significance at the 1% level; * denotes significance at the 5% level.

Table 2
Estimation of the Cost-of-Carry Volatility System with Two Cointegrating Vectors

	Brazilian Real			Deutsche Mark		
Variables	var(Δs_t)	var(Δf_t)	var(Δr_t^f)	var(Δs_t)	var(Δf_t)	var(Δr_t^f)
Constant	0.000	0.000	0.001**	0.000*	0.000**	0.000**
	(0.133)	(0.311)	(0.002)	(0.015)	(0.000)	(0.000)
Var(Δs_{t-1})	0.616**	0.606	0.991	0.981**	0.102**	-0.292
	(0.000)	(0.247)	(0.576)	(0.000)	(0.000)	(0.828)
var(Δf_{t-1})	0.118**	0.881**	0.631	0.004	0.630**	1.824
	(0.000)	(0.000)	(0.457)	(0.178)	(0.000)	(0.095)
var(Δr^d_{t-1})	-0.001	0.000	0.013	0.000	0.000	0.000
	(0.254)	(0.999)	(0.799)	(0.986)	(0.526)	(0.958)
var(Δr^f_{t-1})	- 0.000*	0.000	0.912**	0.000	0.000	0.448**
	(0.027)	(0.377)	(0.000)	(0.845)	(0.392)	(0.000)
Ect1	0.132**	0.095**	-0.118	0.002*	0.019**	1.545**
	(0.000)	(0.000)	(0.852)	(0.022)	(0.001)	(0.000)
Ect2	0.000	0.000	0.000**	0.000	0.000	0.000
	(0.728)	(0.682)	(0.000)	(0.381)	(0.587)	(0.402)
R^2	0.909	0.882	0.875	0.946	0.478	0.217
**DW	2.267	2.275	1.63	1.984	1.996	2.014

Notes:
(1) Ect1 represents the error correction for the futures and spot price, and Ect2 represents the error correction term for the foreign and domestic risk-free interest in the COCVS system with two cointegrating vectors given by equations 6(a)-6(c).
(2) Figures in parentheses are p-values.
(3) ** Denotes significance at the 1% level; * denotes significance at the 5% level.

Table 3
Estimation of the Unbiased Expectations Hypothesis Volatility System

	Brazilian Real			Deutsche Mark			French Franc			Japanese Yen			Mexican Peso		
Variables	$var(\Delta s_t)$	$var(\Delta f_t)$	$var(\Delta r_t^f)$	$var(\Delta s_t)$	$Var(\Delta f_t)$	$var(\Delta r_t^f)$	$var(\Delta s_t)$	$var(\Delta f_t)$	$var(\Delta r_t^f)$	$var(\Delta s_t)$	$var(\Delta f_t)$	$Var(\Delta r_t^f)$	$var(\Delta s_t)$	$var(\Delta f_t)$	$var(\Delta r_t^f)$
Constant	0.000	0.000	0.001**	0.000**	0.000**	0.001**	0.000*	0.000**	0.001**	0.000**	0.000*	0.001**	0.000**	0.000**	0.094**
	(0.463)	(0.437)	(0.000)	(0.000)	(0.000)	(0.000)	(0.015)	(0.000)	(0.003)	(0.003)	(0.031)	(0.004)	(0.001)	(0.000)	(0.001)
$var(\Delta s_{t-1})$	0.612**	0.053	—	0.982**	0.100**	—	0.978**	0.040**	—	0.981**	0.035*	—	0.788**	0.102*	—
	(0.000)	(0.310)		(0.000)	(0.000)		(0.000)	(0.001)		(0.000)	(0.022)		(0.000)	(0.015)	
$var(\Delta f_{t-1})$	0.112**	0.874**	—	0.003	0.627**	—	0.003	0.917**	—	-0.003	0.950**	—	-0.049**	0.448**	—
	(0.000)	(0.000)		(0.270)	(0.000)		(0.801)	(0.000)		(0.875)	(0.000)		(0.001)	(0.000)	
$var(\Delta r^d_{t-1})$	—	—	0.002	—	—	-0.002	—	—	-0.128	—	—	0.048	—	—	-3.216
			(0.973)			(0.828)			(0.324)			(0.361)			(0.591)
$var(\Delta r^f_{t-1})$	—	—	0.935**	—	—	0.459**	—	—	0.856**	—	—	0.940**	—	—	0.906**
			(0.000)			(0.000)			(0.000)			(0.000)			(0.000)
Ect	0.138**	0.107**	—	0.002**	0.016**	—	0.010**	0.002		0.013**	0.014**	-	0.018**	0.058**	-
	(0.000)	(0.000)		(0.012)	(0.002)		(0.001)	(0.611)		(0.001)	(0.000)		(0.000)	(0.000)	
R^2	0.909	0.882	0.873	0.976	0.478	0.211	0.968	0.933	0.735	0.959	0.969	0.890	0.596	0.332	0.818

Notes:
(1) Ect represents the error-correction term in the UEH volatility system, given by equations 14(a)-14(c).
(2) Figures in parentheses are *p*-values.
(3) ** denotes significance at the 1% level; * denotes significance at the 5% level.

4.4 Unbiased Expectations Hypothesis Volatility System

Table 3 presents estimates of the Unbiased Expectations Hypothesis Volatility System. As for the Cost-of-Carry Volatility System, the conditional variance of futures returns is significant in explaining the conditional variance of spot returns for currencies of emerging markets, but not vice-versa. The conditional variance of spot returns is significant in explaining the conditional variance of the futures returns, as observed for currencies in developed markets. An exception is the Mexican Peso, where the conditional variance of the futures returns is significant in explaining the conditional variance of the futures returns. The domestic risk-free rate is not significant in explaining the conditional variance of the futures, spot and foreign risk-free rate for currencies using the UEHVS model. This suggests that the conditional variance of the domestic risk-free interest rate does not affect the conditional variance of the currency spot and futures markets in either the developed or emerging markets.

4.5 Comparisons Between the Two Models

The coefficient of lagged spot prices in the Cost-of-Carry Volatility System with one cointegrating vector is close to minus unity, with values in the range (-0.99819, -1.00720), while values are in the range (-0.99942, -1.0064) for the Cost-of-Carry Volatility System with two cointegrating vectors. Coefficients of lagged spot prices in the Unbiased Expectations Hypothesis Volatility System are also very close to minus unity, with values in the range (-0.99150, -1.01294). These results are consistent with recent empirical results in Brenner and Kroner (1995)[4]. Moreover, the magnitudes of the interest rate variables are very close to zero and insignificant in most of the currency contracts.

As the Cost-of-Carry Volatility System with two cointegrating vectors nests the Unbiased Expectations Hypothesis Volatility System, it is possible to determine the appropriate model on the basis of testing parametric restrictions. If the restrictions are valid, the Cost-of -Carry Volatility System reduces to the Unbiased Expectations Hypothesis Volatility System. The Wald test procedure is used to test the null hypothesis that the restrictions are valid. Of the five currencies, only the models for the Brazilian Real and the Deutsche Mark with two cointegrating vectors are tested. The Wald statistics, which are highly significant at 30.5 and 39.1 for the Brazilian Real and the Deutsche Mark, respectively, suggest that the appropriate model for the two currencies is the Cost-of-Carry Volatility System with two cointegrating vectors.

5. CONCLUSION

Multinational firms are subject to the changing patterns of currency volatility that have a tremendous impact on their performance. The

[4] Brenner and Kroner (1995) documented recent empirical studies of currency futures markets. The cointegrating vector was found to be close to (-1,1) and the coefficient of the lagged futures price was in the range (-1.03, -0.95).

introduction of derivative products has increased in recent years, indicating the emphasis that financial institutions place on these products to counter both exchange rate and interest rate movements. Although corporations are aware of such innovations, there is still a heavy reliance on the traditional hedging tools afforded by forward and futures contracts. There is a need for a deeper understanding of the nature and behaviour of currency futures contracts and their impact on spot markets.

In this paper, we have modelled the conditional variances between spot and futures markets for both developed and emerging markets. The. of conditional volatility peculiar to each grouping. It is found that the conditional variance of futures returns is significant in explaining the conditional variance of spot returns in emerging markets. For developed markets, the conditional variance of spot returns is significant in explaining the conditional variance of futures returns. These results are interesting because they suggest that exchange rate volatility in emerging markets is driven by volatility in their respective futures contracts. The currencies of emerging markets are subject to international influences, which provides some support for government intervention to maintain exchange rate stability. For developed markets, the influence of foreign agents tends to be more controlled as the results suggest that the conditional volatility in spot returns drives conditional volatility in futures returns. The case for reduced intervention in foreign exchange markets becomes apparent for developed markets

The empirical results suggest a characteristic pattern The empirical results also show that the conditional variance of the domestic risk-free rate does not have a significant influence on the conditional variance of the spot, futures or foreign risk-free rate. Moreover, the conditional variances of the foreign risk-free rates in the Japanese and Mexican markets are significant in explaining the conditional volatility of futures returns. In the same way, the conditional variances of the foreign risk-free rate in the Japanese and Brazilian markets are significant in explaining the conditional variance of spot returns.

We also compared the Cost-of-Carry Volatility System with two cointegrating vectors and the Unbiased Expectation Hypothesis Volatility System using nested tests. It was found that the Cost-of-Carry Volatility System outperforms the Unbiased Expectations Hypothesis Volatility System for both the Brazilian Real and Deutsche Mark.

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