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Volatility Spillovers between exchange rates and equity markets: evidence from Spain, Portugal and Italy

Lucia Morales and Mary O'Donnell

Abstract — This paper investigates the nature of volatility spillovers between stock returns and exchange rate changes for Italy, Spain and Portugal for the 1996-1998 period prior to the introduction of the Euro as well as the 1999-2001 and 1992-2006 periods since the Euro has been introduced. We use an EGARCH model which takes into account whether bad news has the same impact on volatility as good news. We also investigate whether volatility spillovers between exchange rates and equity markets is stronger for some currencies than others. We find that there were no significant volatility spillovers from stock returns to exchange rates prior to the introduction of the Euro in all countries. However, since the introduction of the Euro, there were significant volatility spillovers from stock returns to exchange rates in all countries for all currencies, with the exception of Portugal in the more recent 2002-2006 period. The introduction of the Euro appears to have had little impact on the nature of volatility spillovers from exchange rates to stock returns which were generally insignificant prior to the introduction of the Euro as well as for the 1999-2006 period.

Index Terms — Volatility spillover; stock markets, exchange rates, EGARCH modelling.

1 INTRODUCTION

International financial markets have experienced an increase in the degree of integration. The abolition of capital and exchange controls has produced an increase in the volume of cross-border transactions in securities and currencies, [1]. Economic theory suggests that these fund flows may create interdependence between stock and exchange rate returns. The extent of linkages across stock and currency markets is an issue of great interest for investors. It is well know that stock traders incorporate into their decisions as much information as they can gather form the financial markets, as an increasing integration in Europe has led researchers to question whether financial markets have responded by also becoming more integrated. The introduction of the Euro in January 1999 represents the most dramatic step to date in European Economic integration [2]. The Euro removes the potentially important uncertainty connected with exchange rate fluctuations, and hence should reduce uncertainties concerned with stock market investments across country borders within the Euro zone.

Our study intends to explore the presence of volatility spillovers among three European markets named: Italy, Portugal and Spain. The international flow of funds reveal that European stock markets are now the most important destinations of international equity capital, dominating the leadership that US and Japanese markets experienced in previous periods [3] have demonstrated.

We analyze the effect of a number of exchange rates on stock return volatility in three European markets in order to identify volatility in which currencies are generating the biggest impact on the volatility of stock returns. As the Euro amalgamated the currencies of 12 European countries, we want to analyse whether the impact of currency volatility on the volatility of stock returns has changed since the introduction of the Euro as well as which currencies generate the biggest impact on the volatility of equity markets in each country.

Our motivation for including a number of currencies is that despite the apparent symmetry in bilateral exchange rates, currencies are not symmetric, and some have grater economic importance than others [4]. This base currency effect is similar to the volatility feedback effect in equity markets. It is likely to be stronger in some currencies than in others. For example, the higher expected USD/EUR volatility may lead Europeans to sell USD denominated assets and Americans to sell EUR denominated assets. To the extent that the Euro area and the US are of similar sizes and level of economic development, the base currency effect should be weaker for the USD/EUR rate than it is for other currencies. The introduction of the Euro has

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eliminated all currency fluctuations within the Euro-zone, therefore, the cost of hedging against currency risk has disappeared.

Exchange rate volatility effects are important in terms of the European Central Bank (ECB) monetary policy, political and economic integration, international trade relations, investments, and so on. Before the introduction of the Euro, if a country experienced a shock to economic growth than more of the other EMU members experienced, traditionally the National Central Bank would adjust its monetary policy to cater for the new economic circumstances. Under the EMU's single monetary policy, no such adjustment would take place, because it could not be justified as beneficial to the economic situation of the rest of the EMU countries [5]. To date research has not examined the presence of volatility spillovers between the Euro exchange rates against US dollar, Japanese Yen, Swiss Franc and British pound and European financial markets. In this paper we employ EGARCH modelling in order to analyse this issue for Italy, Portugal and Spain. The layout of this paper is as follows: Section 2 provides a brief literature review and sets out the available empirical evidence to date on this issue. Section 3 describes the data and methodology; section 4 presents the empirical results and section 5 draws some conclusions from our analysis.

2 Literature Review

Several theoretical models have analysed the link between stock markets and currency markets. The asset market approach to exchange rate determination [6]; [7], posits that causality will run from stock prices to exchange rate changes as expectations of financial asset price movements affect the dynamics of exchange rates. Estimable equations for the exchange rate where the stock price is included as an explanatory variable have been derived previously [8]. The goods market approach suggests causality runs in the opposite direction, from exchange rates to stock prices [9], [10], [11]. In these models, movements in exchange rates affect the international competitiveness of firms which affects real income and output and eventually stock prices.

Much of the available empirical evidence on the linkages between stock markets and exchange rates has concentrated on the first moments. It has been noted that there is a dearth of empirical evidence that concentrates on the linkages between the second moments of the distribution of the variables [12]. A number of studies however have examined the extent to which volatility from one stock market spills over into other stock markets or between different assets . Kanas [13] was one of the first studies which analysed volatility spillovers from stock returns to exchange rate changes in the USA, the UK, Japan, Germany, France and Canada. He found evidence of spillovers from stock returns to exchange rate changes for all countries except Germany, suggesting that the asset approach to exchange rate determination is valid when formulated in terms of the second moments of the exchange rate distribution for the countries included in his analysis. Volatility spillovers from exchange rate changes to stock returns were insignificant for all countries. Yang and Doong [12] explored the nature of the mean and volatility transmission mechanism between stock and foreign exchange markets for the G-7 countries. The results point to significant volatility spillovers and an asymmetric effect from the stock market to the foreign exchange market for France, Italy, Japan and the US, suggesting integration between stock and foreign exchange markets in these countries. Wang and Yang [4] find evidence of asymmetric volatility in daily realized volatilities of AUD, GBP and JPY against USD, as well as daily GARCH-estimated volatilities in trade weighted indices. They found no asymmetric volatility in EUR against USD and its trade weighted indices and also document a strong impact from long-run price trends to daily realized volatility. Savva, Osborn and Gill [2] investigate the transmission of price and volatility spillovers across the New York, London, Frankfurt and Paris stock markets under the framework of the multivariate EGARCH model, the found evidence that domestic stock returns and volatilities are influenced by the behaviour of foreign markets, with both volatilities and conditional correlations responding asymmetrically to news/innovations in other markets. Their findings also indicate that the correlations of returns have increased for all markets since the launch of the Euro. Wu [14], examined volatility spillovers between stock prices and exchange rates for Japan, South Korea, Indonesia, Philippines, Singapore, Thailand and Taiwan for the period 1997-2000, splitting the sample into crises and recovery periods. He found a bi-directional relationship between the volatility of stock returns and exchange rate changes during the recovery period in all countries except South Korea, as well as significant contemporaneous relationships between the two markets for most of the countries. Furthermore, he found volatility spillovers increased in the period after the Asian crises. Dark, Raghavan and Kamepalli [1] examined volatility spillover effects between the US dollar/Australian dollar (USD/AUD), and the Australian All Ordinaries index (AOI). The empirical findings provide evidence of unidirectional volatility spillover effects from the USD/AUD to the AOI.

3 Data and Methodology

The data set consists of daily closing values for the Portuguese stock exchange, PSI 20, the Spanish stock exchange, IBEX 35 and the Milan stock exchange, MIB 30 stock market indices, and the Euro exchange rate against US dollar, Swiss Franc (CHF), Japanese Yen and British Pound. Our sample covers the period 1 January 1999 to 31 December 2006 giving a total of 2010 observations. All data are taken from DataStream. Given that we are interested in examining the extent to which volatility spillovers have been affected by the introduction of the Euro, we split our sample into three sub periods as follows; the pre-Euro period, covering 1/1/96-31/12/98, the period immediately following the introduction of the Euro, 1/1/99-31/12/01 and the more recent period covering 1/1/02- 31/12/06. Following Kanas [13] we use continuously compounded stock returns and exchange rate changes calculated as the first differences of the natural log. That is, S= Stock Prices, $S_t = \ln\left(P_t^s\right) - \ln\left(P_{t-1}^s\right)$, and E= Exchange Rates, $E_t = \ln\left(P_t^e\right) - \ln\left(P_{t-1}^e\right)$. .

As an initial step we perform a stationary test on each of the relevant variables that are included in our analysis to ensure that the results from the analysis are not spurious. We apply the Dickey Fuller (DF) test, or Augmented Dickey-Fuller test (ADF) procedure if serial correlation is present. We also apply the Lagrange Multiplier (LMF) test, to ensure that a sufficient number of lags have been added in the ADF test to ensure that there is no serial correlation present and the results of the ADF test are valid. The LMF test is applied given that it is valid in the presence of lagged dependent variables as well as having the advantage of testing for first and higher orders of serial correlation. If we found that our variables are an I(0) process, meaning that they are stationary in levels, we will proceed to perform our EGARCH (p,q) analysis, otherwise if we found that our variables are not an I(0) process, what it means that they are stationary in levels then we will need to proceed and perform unit root test in our variables, applying to them first differences, if we found that our variables are an I(d) process, it will means that they have to be integrated at the same order then we will be able to proceed with the cointegration test on our variables as is stated in the cointegration test methodology [15], [16] and [17]. Using the Johansen cointegration test to investigate the long-run relationship between Stock Prices and Exchange Rates, as Enders [15] notes given that the results of the test can be quite sensitive to the lag length, the most common procedure is to estimate a Vector Autoregression (VAR) model on the undifferenced data in order to determine the lag length for the Johansen test. We estimate the lag selection tests up 20 lags. In terms of choosing between the various lag length selection criteria we follow Johansen, Mosconi and Nielsen [18] who suggest that when different information criteria suggest different lag lengths, it is common practice to prefer Hannan-Quinn (HQ) criteria. Again, we ensure that the lag length selected for the VAR model is free from serial after performing by applying the LMF test to test for serial correlation up to the number of lags in the VAR model. There are five possible models to choose from for the Johansen test as follows.

$$H_2(r): \Pi y_{t-1} + B x_t = \alpha B' y_{t-1} \quad (1)$$

$$H^*_1(r): \Pi y_{t-1} + B x_t = \alpha (B' y_{t-1} + p_0) \quad (2)$$

$$H_1(r): \Pi y_{t-1} + B x_t = \alpha (B' y_{t-1} + p_0) + \alpha_\perp \gamma_0 \quad (3)$$

$$H^*(r): \Pi y_{t-1} + B x_t = \alpha(B' y_{t-1} + p_0 + p_1 t) + \alpha_\perp \gamma_0 \quad (4)$$

$$H(r): \Pi y_{t-1} + B x_t = \alpha(B' y_{t-1} + p_0 + p_1 t) + \alpha_\perp(\gamma_0 + \gamma_1 t) \quad (5)$$

Equation 1 has no deterministic trends in the level data and no intercepts in the cointegrating equations. Equation 2 has no deterministic trends in the level data and the cointegrating equations have intercepts. Equation 3 has linear trends in the level data but the cointegrating equations only have intercepts. Equation 4 has linear trends in both the level data and the cointegrating equations, and equation 5 has quadratic trends in the level data and linear trends in the cointegrating equations. Harris and Sollis [17] note that model 1 i.e. with no deterministic components in the data or cointegration relations, is unlikely to occur in practice, as generally an intercept is needed to take account of the units of measurement of the variables; they also note that model 5 with quadratic trends, is economically hard to justify, as if the variables are entered in logs, as they are in our model, as this would imply an every increasing or decreasing rate of change. This leaves a choice between models 2-4. Johansen, Mosconi and Nielsen [18] suggests choosing the appropriate model according to the Pantula principle; all three models are estimated; the Pantula principle involves moving through each model for the null hypothesis of r=0, then r=1 etc., and picking the model where the null hypothesis is rejected for the first time. Chang and Caudill [18] note that the λ trace test statistic is more robustness to both skewness and excess kurtosis than the λ max test statistic; for comparative purposes, we show both the results of the λ trace and the λ max test statistics.

We then proceed with our volatility analysis and apply a bivariate extension of the EGARCH (p,q) model in order to examine whether the volatility of stock returns affects and is affected by the volatility of exchange rate changes within each economy. The EGARCH specification [20] is used in order to test whether the volatility spillover effects are asymmetric. For example, an asymmetric spillover from stock returns to exchange rate changes would suggest that the effect of "bad" stock market news on the exchange rate change is greater than the effect of "good" news. The model is specified as follows:

$$S_t = a_{s,0} + \sum_{i=1}^{r} a_{s,i} S_{t-i} + \sum_{i=1}^{r} a_{e,i} E_{t-i} + \beta_s \lambda_{s,t-1} + e_{S,t} \quad (6)$$

$$E_t = a_{E,0} + \sum_{i=1}^{r} a_{E,i} E_{t-i} + \sum_{i=1}^{r} a_{S,i} S_{t-i} + \beta_E \lambda_{E,t-1} + e_{E,t} \quad (7)$$

where $e_{S,t} / \Omega_{t-1} \approx N(0, \sigma^2_{S,t})$

$e_{E,t} / \Omega_{t-1} \approx N(0, \sigma^2_{E,t})$

The conditional variances of stock returns and exchange rates changes are specified as follows:

$$\sigma^2_{S,t} = \exp\Big\{ c_{S,0} + \sum_{j=1}^{pS} b_{S,j} \log(\sigma^2_{S,t-j}) + \delta_{S,S}\big[\big(|z_{S,t-1}| - E|z_{S,t-1}| + \theta_{S,S}z_{S,t-1}\big) + \delta_{S,E}\big[\big(|z_{E,t-1}| - E|z_{E,t-1}| + \theta_{S,E}z_{E,t-1}\big)\big] \quad (8)$$

$$\sigma^2_{E,t} = \exp\Big\{ c_{E,0} + \sum_{j=1}^{pS} b_{E,j} \log(\sigma^2_{E,t-j}) + \delta_{E,E}\big[\big(|z_{E,t-1}| - E|z_{E,t-1}| + \theta_{E,E}z_{E,t-1}\big) + \delta_{E,S}\big[\big(|z_{S,t-1}| - E|z_{S,t-1}| + \theta_{E,S}z_{S,t-1}\big)\big]\big] \quad (9)$$

The lag truncation length *p* in the EGARCH model is determined using the Likelihood Ratio (LR) test on alternative specifications. Hamilton [21] defines the LR test as follows: $2\big[L(\hat{\theta}) - L(\tilde{\theta})\big] \approx \chi^2(m)$ where $L(\hat{\theta})$ denotes the value of the log likelihood function at the unrestricted estimate and $L(\tilde{\theta})$ denotes the value of the log likelihood function of the restricted estimate. Bollerslev-Woolridge robust t-statistics are derived to take into account possible non-normality of the residuals. All results are generated using the EVIEWS statistical program.

4 Empirical Results

We begin by providing descriptive statistics for stock returns and exchange rates in order to summarise the statistical characteristics of our sample which are set out in Tables 1 for the stock returns and Table 2 for the exchange rates.

For the 1996-1998 period, prior to the introduction of the Euro, we found that the sample means are positive for the stock returns in Portugal, Spain and Italy (PSI 20, IBEX 35 and MIB 30 respectively). For the 1999-2001 period the means are negative for all the countries, while during 2002-2006 the means are positive for all the countries. The standard deviations of stock returns for 1996-1998 are 1.28% for PSI 20, 1.46% for IBEX 35 and 1.66% for MIB 30. The standard deviations of the stock returns range from 1.5% to 1.2% for the 1999-2001 period and 1.2% to 0.076% in the 2002-2006, indicating that the volatility of stock returns in general were lower after the single currency was introduced in these financial markets, in particular for the 2002-2006 period, while the standard deviations (SD) were higher for the rest of the sample periods. Both the skewness and kurtosis coefficients indicate that stock returns are leptokurtic relative to the normal distribution, which Caporale, Pittis and Spagnolo [22] note is a common finding for stock returns. The Jarque-Bera test also rejects the hypothesis that stock returns are normally distributed in all countries for all periods.

TABLE 1
Descriptive Statistics Stock Returns

	Mean	SD	Skewness	Kurtosis	JB
1996-1998					
PSI 20	0.0014	0.0128	-0.781	13.377	3459
IBEX 35	0.0013	0.0146	-0.502	6.800	485
MIB 30	0.0012	0.0166	-0.064	4.981	124
1999-2001					
PSI 20	-0.0005	0.0120	-0.101	4.499	71
IBEX 35	-0.0003	0.0151	-0.178	4.291	56
MIB 30	-0.0002	0.0147	-0.220	5.372	183
2001-2006					
PSI 20	0.0003	0.0077	-0.281	5.998	486
IBEX 35	0.0004	0.0120	0.079	6.175	529
MIB 30	0.0002	0.0112	-0.144	6.194	538

The descriptive statistics for the exchange rate returns in Table 2 show that the sample means are negative for the sample period 1996-1998 in the case of Portugal when we analyze the Escudo against the Swiss Franc and Dutch Mark, while the means are positive in the case of the Escudo against the Japanese Yen, British Pound and US Dollar. In the case of Spain the means are positive just in the case of the Peseta against Swiss Frank, for the rest of the cases, Pta/¥, Pta/DM, Pta/£ and Pta/$ the means are positive. With regard to Italy we found that the means are negative in the case of Lira/CHF, Lira/¥ and Lira/DM, while the means are positive for the Lira/£ and Lira/$. The sample means are positive for the Euro against Swiss Franc, Japanese Yen, British Pound and US Dollar for the 2002-2006 period, and for 1999 to 2001 the means are negative for all the cases. The standard deviation for the 1996-1998 sample period range between 0.17% (Escudo/DM) to 0.7% (Escudo/¥) for Portugal, for Spain between 0.16% (Pta/DM) to 0.77% (Pta/¥) and for Italy between 0.27% (Lira/DM) to 0.78% (Lira/¥). The volatility of exchange rate returns ranged from 0.07% in the case of the Euro against Japanese Yen to 0.02% in the case of Euro against Swiss Franc for the entire period; volatility was higher during the 1999 to 2001 period, in the immediate aftermath of the introduction of the Euro. Again the skewness and kurtosis statistics indicate that the distribution of exchange rate returns are non-normal and the Jarque-Bera test also rejects the hypothesis of normally distributed returns for all periods for all countries.

TABLE 2
Descriptive Statistics Exchange Rates

	Mean	SD	Skewness	Kurtosis	JB
Escudo/CHF	-5.20E-05	0.0032	0.2943	5.341	183
Escudo/¥	6.35E-05	0.0078	0.7567	6.7936	524
Escudo/DM	-2.30E-05	0.0017	-0.4687	11.8265	2475
Escudo/£	0.000263	0.0053	-0.244	3.7409	25
Escudo/$	0.000175	0.0052	-0.2708	3.9822	40
Peseta/CHF	-1.70E-05	0.0033	0.2832	5.3402	182
Peseta/¥	9.79E-05	0.0077	0.6933	6.6867	487
Peseta/DM	1.15E-05	0.0016	0.1099	8.2949	882
Peseta/£	0.000298	0.0052	-0.2245	3.7523	24
Peseta/$	0.00021	0.0051	-0.3073	3.9991	43
Lira/CHF	-0.00016	0.0039	0.3087	5.4278	197
Lira/¥	-4.30E-05	0.0078	0.7519	6.8662	541
Lira/DM	-0.00013	0.0027	0.1394	10.1224	1596
Lira/£	0.000157	0.0052	-0.2417	3.8241	29
Lira/$	6.91E-05	0.0049	-0.1732	4.016	36
1999-2001					
€/CHF	-0.00011	0.0024	-0.6152	12.3727	2800
€/¥	-0.00018	0.009	0.0618	4.102	39
€/£	-0.00021	0.0053	0.0834	4.0346	34
€/$	-0.00039	0.0066	0.2514	3.9876	38
2002-2006					
€/CHF	6.66E-05	0.0021	-0.2991	4.2208	97
€/¥	0.000234	0.0055	-0.2774	4.5475	141
€/£	7.28E-05	0.0038	0.1982	4.5268	130
€/$	0.000311	0.0058	-0.1351	3.4397	14

The results from the Augmented Dickey Fuller tests are given in Table 3. The values of the test statistics indicate that we can reject the null hypothesis of the existence of unit root in levels for all variables in all periods indicating that all series are I(0). Given that all variables are integrated of the same order, and also given that they are an I(0) process is no need to process we the Cointegration tests, we will proceed directly to perform our volatility analysis using EGARCH (p,q) modelling.

TABLE 3
AUGMENTED DICKEY FULLER
TEST RESULTS

	1996-1998	1999-2001	2002-2006
PSI 20	-12.68*	-19.83*	-9.05*
IBEX 35	-45.22*	-27.12*	-8.52*
MIB 30	-16.68*	-11.95*	-13.64*
Escudo/CHF	-11.49*	na	na
Escudo/¥	-29.26*	na	na
Escudo/DM	-23.72*	na	na
Escudo/£	-14.06*	na	na
Escudo/$	-15.47*	na	na
Peseta/CHF	-5.37*	na	na
Peseta/¥	-28.47*	na	na
Peseta/DM	-25.44*	na	na
Peseta/£	-19.77*	na	na
Peseta/$	-27.91*	na	na
Lira/CHF	-6.00*	na	na
Lira/¥	-20.34*	na	na
Lira/DM	-25.26*	na	na
Lira/£	-29.39*	na	na
Lira/$	-15.45*	na	na
€/CHF	na	-11.04*	-35.70*
€/¥	na	-26.54*	-14.21*
€/£	na	-10.79*	-17.64*
€/$	na	-10.57*	-6.73*

TABLE 4
Likelihood Ratio Test Results 1996-1998

IBEX 35 Peseta/$	0.24	25.42*
MIB 30 Lira/CHF	1.94	2.49
MIB 30 Lira/¥	2.11	0.25
MIB 30 Lira/DM	3.81	5.52
MIB 30 Lira/£	2.12	0.13
MIB 30 Lira/$	1.56	4.95

The results in Table 4 indicate that for 1996-1998 the EGARCH (2,1) was selected in the case of the stock returns equation for the Portugal, while the EGARCH (1,1) was selected for Spain and Italy. With regard to the exchange rate equation we select the EGARCH (2,1) in the case of Escudo/¥, Escudo/$, while the EGARCH (1,1) was selected for Escudo/CHF, Escudo/¥ and Escudo/£. For Spain, the EGARCH (2,1) model was selected for Pta/¥, Pta/DM and Pta/$, the EGARCH (1,1) was selected for Pta/CHF and Pta/£. Finally and in relation to Italy we select the EGARCH (1,1) in all the cases. The results in Table 5 indicate that for the 1999-2001 period for stock prices the EGARCH(1,1) was selected for the three countries. In the case of exchange rate changes, the EGARCH (2,1) model is selected for Spain (Euro against Pound) for the 1999-2001 period, for the rest of exchange rates the model selected was the EGARCH (1,1), finally the EGARCH (2,1) model was selected for the period 2002-2006 in the case Euro against US Dollar, in the case of Portugal, Spain and Italy.

TABLE 5
Likelihood Ratio Test Results 1999-2006

	Stock Returns		Exchange Rates	
	1999-2001	2002-2006	1999-2001	2002-2006
PSI 20 €/CHF	0.00	0.436	0.214	0.2
PSI 20 €/¥	0.038	0.168	3.674	1.838
PSI 20 €/£	0.00	0.184	9.814*	0.15
PSI 20 €/$	0.006	0.058	4.764	35.14*
IBEX 35 €/CHF	3.98	5.92	0.176	0.084
IBEX 35 €/¥	2.64	5.63	3.97	1.45
IBEX 35 €/£	3.95	5.47	11.27*	0.112
IBEX 35 €/$	3.58	4.72	4.74	36.29*
MIB 30 €/CHF	1.77	0.372	0.916	0.042
MIB 30 €/¥	1.192	1.432	3.092	1.058
MIB 30 €/£	0.507	1.158	0.414	0.14
MIB 30 €/$	0.238	1.42	1.962	38.16*

The estimated parameters from the EGARCH estimation are set out in Tables 6-8, together with the p-values for each coefficient. We have grouped the results for each term of interest together for the three countries. Firstly, the results indicate that for volatility persistence, there is significant persistence in the volatility of stock returns for all three countries in all periods. The p-values indicate that this is significant at 1% level with the exception of some of the coefficients for Portugal which were significant at 5% level for the 2002-2006 period. The significant persistence of volatility of exchange rates was somewhat less widespread. This was significant at least at 5% level in the pre-Euro period for all countries for all cross exchange rates, with the exception of Spain and Portugal for their currencies against the $ and for Portugal and Italy against the CHF. In the post Euro period it was significant at least 10% level for all countries for all Euro cross rates except that against the dollar; the result was the same for the 2002-2006 period except the significance level was at least 5% level. The somewhat weaker significance levels in the post Euro period across all countries indicates that the persistence of exchange rates has ameliorated somewhat since the introduction of the Euro and the lack of significance for the Euro against the $ indicates that there has been some benefit from the introduction of the Euro in terms of less persistence in the volatility of the Euro against the $.

TABLE 6
EGARCH Results Volatility Persistence

Exchange rates	0.147	0.092	0.200	-0.078
	0.000	-0.094	-0.012	-0.412
Italy				
Stock returns	0.230	0.254	0.263	0.267
	0.000	0.000	0.000	0.000
Exchange rates	0.154	0.106	0.254	-0.105
	0.003	0.079	0.003	0.124
2002-2006				
Portugal				
Stock returns	0.119	0.121	0.120	0.122
	-0.013	-0.010	-0.009	-0.010
Exchange rates	0.111	0.064	0.098	-0.102
	-0.001	-0.015	0.000	-0.226
Spain				
Stock returns	0.121	0.121	0.124	0.125
	0.000	0.000	0.000	0.000
Exchange rates	0.113	0.063	0.099	-0.105
	-0.001	-0.015	0.000	-0.206
Italy				
Stock returns	0.066	0.077	0.074	0.083
	0.000	0.000	0.000	0.000
Exchange rates	0.092	0.049	0.045	-0.093
	-0.001	-0.029	-0.002	-0.209

In terms of the coefficients for the volatility spillover effects we observe some differences across all three time periods for all countries for all exchange rates. All coefficients for spillovers from stock returns to exchange rates and from exchange rates to stock returns are insignificant at 1% level for all the countries for the 1996-1998 time period although there are significant spillovers from exchange rates to stock returns at 10% level across all three countries for the CHF. For the 1999-2001 period there were significant spillovers from stock returns to exchange rates across all countries and currencies at least at 5% level. Results for the 2002-2006 period were similar in that volatility spillovers from stock returns to exchange rates were again significant for Spain and Italy across all currencies at 1% level, but insignificant for Portugal. The significant coefficients for spillovers from stock returns to exchange rates in the post-Euro period, in contrast to the pre-Euro period indicates that the volatility of stock returns has been a determinant of the volatility of the exchange rate in the aftermath of the introduction of the Euro as well as being indicative of integration between stock markets and exchange rate markets which appears to have been absent in these countries prior to the Euro. Furthermore, the significance of volatility spillovers from stock markets to exchange rates indicates that volatility information contained in stock prices impacted on the behaviour of exchange rates in these markets.

With regard to volatility spillovers from exchange rates to stock returns in the post-Euro period all coefficients are insignificant for all countries across all cross exchange rates with the exception of spillovers from the CHF and the Yen in the 1999-2002 period which were significant at least at 5% level. The lack of significant spillovers generally from exchange rates to stock return in the post Euro period in all markets at 1% level indicates that both in the period following the introduction of the Euro as well as in more recent years, there is potential for diversification between stock markets and different currencies in these countries. Furthermore the lack of significant spillovers from exchange rate changes to stock returns generally found here is consistent with results from Jorion [23] as well as with Yang and Doong [12]. Jorion [23] explained the lack of spillovers as possibly due to positive exchange rate volatility on stock returns for some firms offsetting negative exchange rate volatility on stock returns for other firms to give an insignificant or weak effect overall. In addition to this, the use of instruments to hedge exchange rate risk, may reduce the impact of exchange rate volatility on stock markets; Grant and Marshall [24], and Bodnar et al. [25] both note that the use of hedging instruments to ameliorate exchange rate risk is pervasive amongst larger companies which are the main components of national stock market indices. The lack of significant spillovers from exchange rates to stock markets in the post Euro period may thus be indicative of wider use of hedging by firms listed on the stock markets in these countries than prior to the introduction of the Euro; it is also likely that the introduction of the Euro itself may have contributed to more extensive use of hedging against foreign exchange rate risk.

TABLE 7

EGARCH Results Volatility Spillovers

Portugal				
S to E	-0.027	-0.027	-0.027	-0.026
	-0.171	-0.180	-0.175	-0.201
E to S	0.005	-0.006	-0.005	0.005
	-0.862	-0.765	-0.814	-0.702
Spain				
S to E	-0.080	-0.079	-0.080	-0.081
	-0.001	-0.001	-0.001	-0.001
E to S	0.002	-0.007	-0.006	0.005
	-0.937	-0.727	-0.777	-0.730
Italy				
S to E	-0.098	-0.092	-0.100	-0.087
	0.000	0.000	0.000	0.000
E to S	0.002	-0.003	0.004	0.003
	-0.925	-0.867	-0.775	-0.799

For the asymmetric spillover effects from stock returns to exchange rates, for all periods coefficients for all countries across all cross exchange rates are generally significant at 1% level; the exception is for Italy for the CHF and Yen for the 1999-2001 period where the coefficients were significant at 5% level.

For the asymmetric volatility spillover effects from exchange rates to stock returns we find that for the period prior to the introduction of the Euro, all coefficients were significant at 1% level for Italy, while for Spain there were significant asymmetric spillovers from the Yen and £ but not for the $ and CHF.

TABLE 8
EGARCH Results Asymmetric Spillovers

	0.000	0.000	0.000	0.000
Spain				
S to E	0.978	0.979	0.978	0.978
	0.000	0.000	0.000	0.000
E to S	0.981	0.985	0.973	0.978
	0.000	0.000	0.000	0.000
Italy				
S to E	0.988	0.988	0.987	0.988
	0.000	0.000	0.000	0.000
E to S	0.967	0.994	0.998	0.981
	0.000	0.000	0.000	0.000

Results for the 1999-2001 period were similar in that again there were significant asymmetric spillover effects for all countries from all Euro cross exchange rates except against the $, and against the £ for Spain. The existence of insignificant coefficients indicate that the spillover effects in these instances are symmetric, that is that positive and negative shocks have the same impact on volatility, or that a decrease in stock returns has the same impact on exchange rate volatility as an increase in stock returns. For the most recent period, all coefficients for all countries for all Euro cross exchange rates were significant at 1% level. The lack of significant asymmetric volatility from the €/$ exchange rate here is consistent with results from Wang and Yang [4]. The more widespread significance of asymmetric spillovers from stock markets to exchange rates than from currencies to stock markets indicates that bad news from stock markets has a bigger impact on the volatility of currencies than bad news on currencies has on the volatility of stock markets. This may be because bad news on domestic stocks fuels demand for currencies as foreign investors diversify away from these markets into other stock markets; bad news on these currencies may not impact on these peripheral European stock markets because of their lesser importance in the overall Euro area.

The diagnostic tests on the standardised residuals are not shown here for brevity and are relegated to the supplemental material with this paper. The results from the Jarque-Bera test indicated that we reject the hypothesis that the residuals are normally distributed, hence justifying the use of the Bollerslev-Woolridge robust t-statistics. The Ljung-Box statistics for all three periods for all countries indicated that there were no residual linear or non linear dependencies. If we analyze the 1999-2001 we found that in the exchange rate equation there is a problem of non-linear dependencies, where the non-linear dependencies is corrected in the case of $LB^2(25)$:44.479(0.010) for the Euro/Pound for Spain,, $LB^2(23)$:40.911(0.012) and $LB^2(16)$: 30.035(0.018) for Euro/Pound and Euro/Dollar respectively in the case of Italy.

Finally to check the validity of the assumption of constant correlation adopted in the estimation of the bivariate models the LB statistics for the cross products of the standardised residuals from the stock returns equation and from the exchange rate equation were calculated for the three countries for each time period and the p-values were insignificant in all cases indicating that the assumption of constant correlation over time can be accepted.

5 Conclusions

Relationships between equity returns and exchange rates are of particular interest for academics and practitioners due to the fact that these two variables play a crucial role in portfolio and risk management. Equity returns and exchange rate movements may be used to hedge portfolios against currency movements, where risk management will have to take into consideration the linkages between these to markets in order to design the appropriate strategies.

This paper set out to examine the volatility linkages between stock returns and exchange rates in three European markets. While there is a significant body of evidence which investigates the relationship between the first moments of exchange rates and stock returns, the evidence on volatility linkages between the two markets is scarce and has generally been confined to investigation of the relationship for developed country markets. Thus our analysis make a clear contribution in providing more up to date information of the volatility linkages between stock prices and exchange rates which serves as a basis for increasing our understanding of the nature of integration of stock and exchange rate markets in the countries we have examined.

We examined two main periods, before the introduction of the Euro 1996-1998 and after the introduction of the single currency 1999-2006 and we split the post-Euro sample in order to compare and contrast the volatility linkages between exchange rates and equity markets during the first years of the introduction of the Euro (1999-2001) and after the currency have been physically introduced in the market (2002-2006). Our results indicated that there were no significant volatility spillovers from stock returns to exchange rates or vice versa prior to the introduction of the Euro. However, since the introduction of the Euro, there were significant volatility spillovers from stock returns to exchange rates in all countries for all currencies, with the exception of Portugal in the more recent 2002-2006 period. Thus, the introduction of the Euro may have bought benefits in the form of exchange rate stability but having a currency which is now a key world currency has affected these countries. The presence of this volatility after the introduction of the Euro may be because these countries are attracting a higher proportion of foreign investors in their stock markets by virtue of being part of the single currency and stock market volatility thus spills over into currency volatility as foreign investors diversify away from these smaller more peripheral European markets. Volatility spillovers from exchange rates to stock returns appear to be absent in almost all cases. Our results show that the volatility of stock prices affects the volatility of exchange rates movements while volatility in exchange rates have less direct impact on the volatility of stock prices; these results are consistent with Kanas [13], and Yang and Doong [12] who found significant volatility spillovers from stock returns to exchange rates and insignificant volatility spillovers from exchange rates to stock returns. As we pointed out earlier in this paper, the empirical research examining volatility transmission and spillover effects is scant and provides mixed results. Further research on other countries both within the Euro area as well as outside the Euro area is needed to establish the extent to which the results contained in this paper can be generalised to other countries.

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SUPPLEMENTAL MATERIAL: Diagnostic Tests on EGARCH Model

TABLE 9

1996-1998

	Esc/CHF	Esc/¥	Esc/DM	Esc/£	Esc/$
			PORTUGAL		
Stock return equation					
Jarque-Bera	383	424	360	330	461
LB(20)	44.732	48.61	47.139	46.703	45.566
	-0.001	-0.002	-0.001	-0.001	-0.002
$LB^2(20)$	10.969	10.171	10.77	10.264	11.194
	-0.947	-0.965	-0.952	-0.963	-0.941
Exchange rate equation					
Jarque-Bera	81	111	365	23	25
LB(20)	14.081	10.312	91.762	16.134	16.884
	-0.777	-0.502	0	-0.708	-0.724
$LB^2(20)$	16.667	8.715	11.736	25.058	30.116
	-0.674	-0.986	-0.925	-0.199	-0.068
Cross Products					
LB(20)	13.537	12.316	27.082	21.164	20.681
	-0.053	-0.905	-0.133	-0.300	-0.416
$LB^2(20)$	21.392	7.1936	49.858	21.881	1.7535
	-0.374	-0.996	(0.000)*	-0.347	-1
			SPAIN		
	Pta/CHF	Pta/¥	Pta/DM	Pta/£	Pta/$
Stock return equation					
Jarque-Bera	92	431	03	330	040
LB(20)	24.702	28.535	24.43	28.377	24.667
	-0.213	-0.097	-0.224	-0.101	-0.214
$LB^2(20)$	12.683	6.757	18.379	7.639	6.775
	-0.89	-0.997	-0.502	-0.394	-0.997
Exchange rate equation					
Jarque-Bera	62	91	383	16	18
LB(20)	17.213	18.249	47.398	14.785	16.833
	-639	-0.571	-0.001	-0.789	-0.664
$LB^2(20)$	11.303	8.77	16.207	15.042	30.315
	-0.936	-0.965	-0.57	-0.739	-0.014
Cross Products					
LB(20)	17.253	26.969	17.47	20.853	30.666
	-0.636	-0.136	-0.622	-0.406	-0.06
$LB^2(20)$	20.91	8.8837	8.0752	2.6205	3.2098
	-0.402	-0.984	-0.991	-1	-1
			ITALY		
	Lira/CHF	Lira/¥	Lira/DM	Lira/£	Lira/$
Stock return equation					
Jarque-Bera	15	31	20	26	43
LB(20)	23.843	23.466	29.863	23.745	22.535
	-0.249	-0.266	-0.072	-0.254	-0.312
$LB^2(20)$	10.007	16.502	17.702	17.049	14.667
	-0.458	-0.679	-0.607	-0.65	-0.795
Exchange rate equation					
Jarque-Bera	46	137	103	21	38
LB(20)	11.204	15.531	31.492	19.333	13.682
	-0.941	-0.745	-0.046	-0.5	-0.846
$LB^2(20)$	19.695	6.613	18.171	19.55	37.219
	-0.477	-0.968	-0.576	-0.486	-0.011
Cross Products					
LB(20)	24.965	10.677	29.421	29.74	12.336
	-0.203	-0.954	-0.08	-0.374	-0.904
$LB^2(20)$	0.0149	0.5007	0.7520	4.9999	0.8451
	-0.985	-1	-0.986	-1	-1

TABLE 10

1999-2001

Statistics	€/CHF	€/¥	€/£	€/$
		PORTUGAL		
Stock return equation				
Jarque-Bera	20	21	18	21
LB(20)	31	31.997	31.442	31.796
	-0.057	-0.043	-0.05	-0.046
$LB^2(20)$	25.19	25.908	25.49	25.183
	-0.194	-0.169	-0.183	-0.195
Exchange rate equation				
Jarque-Bera	347	27	33	35
LB(20)	19.787	20.25	23.301	27.445
	-0.471	-0.442	-0.082	-0.123
$LB^2(20)$	17.506	16.386	15.729	35.986
	-0.62	-0.692	-0.671	-0.015
Cross Products				
LB(20)	16.046	13.912	17.44	11.687
	0.771	0.94	0.624	0.03
$LB^2(20)$	19.166	3.19	25.001	9.066
	0.673	1	0.201	0.093
		SPAIN		
	€/CHF	€/¥	€/£	€/$
Stock return equation				
Jarque-Bera	8	9	8	8
LB(20)	21.632	21.981	21.323	21.348
	-0.361	-0.342	-0.378	-0.372
$LB^2(20)$	18.809	18.307	13.819	17.913
	-0.534	-0.567	-0.534	-0.593
Exchange rate equation				
Jarque-Bera	355	27	25	38
LB(20)	20.598	19.42	23.046	27.027
	-0.421	-0.495	-0.087	-0.119
$LB^2(20)$	16.351	17.329	42.010	36.094
	-0.695	-0.602	(0.000)*	-0.015
Cross Products				
LB(20)	15.821	11.291	10.12	18.861
	-0.723	-0.938	-0.966	-0.531
$LB^2(20)$	2.239	6.992	12.979	20.819
	-1	-0.997	-0.878	-0.408
		ITALY		
	€/CHF	€/¥	€/£	€/$
Stock return equation				
Jarque-Bera	6	9	6	5
LB(20)	27	23.386	23.145	23.009
	-0.142	-0.27	-0.282	-0.288
$LB^2(20)$	16.578	18.114	13.437	19.109
	-0.66	-0.58	-0.689	-0.515
Exchange rate equation				
Jarque-Bera	411	31	28	48
LB(20)	22.291	20.469	23.594	30.895
	-0.325	-0.429	-0.096	-0.055
$LB^2(20)$	15.365	16.068	41.263	41.967
	-0.755	-0.712	(0.005)*	(0.013)*
Cross Products				
LB(20)	23.862	13.011	20.214	29.864
	-0.243	-0.877	-0.445	-0.072
$LB^2(20)$	10.566	23.052	42.596	23.923
	-0.957	-0.286	(0.002)*	-0.246

Table 11
2002-2006

Statistics	€/CHF	€/¥	€/£	€/$
		PORTUGAL		
Stock return equation				
Jarque-Bera	511	568	563	557
LB(20)	43.335	46.152	45.926	46.868
	(0.002)*	(0.001)*	0.001	(0.001)*
LB^2(20)	19.290	19.423	19.340	19.604
	-0.503	-0.495	-0.499	-0.481
Exchange rate equation				
Jarque-Bera	98	133	62	6
LB(20)	16.048	33.133	21.391	26.958
	-0.714	-0.033	-0.374	-0.136
LB^2(20)	11.741	12.211	14.568	22.88
	-0.925	-0.909	-0.801	-0.295
Cross Products				
LB(20)	6.249	21.396	28.685	20.921
	-0.999	-0.374	-0.094	-0.402
LB^2(20)	1.149	55.849	4.546	19.254
	-1	(0.000)**	-1	-0.505
		SPAIN		
	€/CHF	€/¥	€/£	€/$
Stock return equation				
Jarque-Bera	207	208	197	208
LB(20)	20.746	20.12	19.875	19.583
	-0.412	-0.45	-0.466	-0.484
LB^2(20)	19.379	18.606	19.838	18.628
	-0.407	-0.549	-0.469	-0.546
Exchange rate equation				
Jarque-Bera	101	132	63	6
LB(20)	14.050	34.517	21.42	27.623
	-0.784	-0.023	-0.373	-0.119
LB^2(20)	11.46	12.804	14.193	22.499
	-0.933	-0.886	-0.821	-0.314
Cross Products				
LB(20)	17.879	9.19	28.351	23.494
	-0.595	-0.981	-0.101	-0.265
LB^2(20)	8.013	10.664	21.926	0.925
	-0.992	-0.954	-0.346	-1
		ITALY		
	€/CHF	€/¥	€/£	€/$
Stock return equation				
Jarque-Bera	43	60	65	58
LB(20)	16.12	18.992	17.646	16.745
	-0.709	-0.522	-0.611	-0.669
LB^2(20)	10.368	7.4098	9.1597	8.4719
	-0.961	-0.995	-0.981	-0.988
Exchange rate equation				
Jarque-Bera	93	136	51	11
LB(20)	17.629	31.613	21.434	28.688
	-0.612	-0.048	-0.372	-0.094
LB^2(20)	12.27	13.516	20.000	20.070
	-0.906	-0.054	-0.457	-0.390
Cross Products				
LB(20)	21.918	34.941	19.765	46.811
	-0.346	-0.112	-0.471	(0.000)***
LB^2(20)	16.934	15.265	11.048	40.239
	-0.657	-0.761	-0.945	(0.005)***