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THE EFFECT OF THE INTRODUCTION OF THE EURO ON ASYMMETRIC STOCK MARKET RETURNS VOLATILITY ACROSS THE EURO-ZONE

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ABSTRACT

The aim of this paper is to examine the effect that the increase in integration, culminating in the introduction of the euro currency, had on returns volatility across the different members of the currency union. We analyse the twelve countries that adopted the euro in January 2002, over the sample period July 1990 to December 2006. Volatility is measured across each of four sub-periods for TARCH and APARCH models because of their ability to account for asymmetries in the data. We find that overall there is a distinct change in the dynamics of asymmetric volatility across the various stages in the introduction of the euro. The first sub-period shows evidence of asymmetric volatility in only a few countries. The relaxation of the rejection criterion in the second sub-period allows for an increase in the number of countries where asymmetric volatility is present and in the third and fourth sub-periods almost all of the countries analysed display asymmetric volatility.

Euro Introduction; Stock Return Volatility; Asymmetry; European Markets

JEL code: G15

INTRODUCTION

The aim of this paper is to examine the effect that the introduction of the euro had upon stock market volatility across Europe. In particular, the focus will be on asymmetric equity market return volatility, in which negative shocks have a greater effect on volatility than positive shocks of the same magnitude. A large amount of

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research has shown that such asymmetry holds true for numerous financial markets. In particular, this paper investigates if the increased integration of European markets brought about by the stages leading up to the introduction of the new currency led to an increase in asymmetric stock market volatility across the countries who adopted the Euro.

The EU rose from the ashes of World War 2. The series of treaties that ensued in the decades following the War led to the creation of a unique area of large scale political integration and monetary co-operation. Expansions over the last decade have resulted in an EU that comprises 27 individual member states, with 17 of these member states adopting the euro. This study however, focuses only upon the 12 countries that adopted the euro at its physical introduction in January 2002.

The inception of the euro dates back to 1957 when there was tentative talk about co-ordinated monetary policy amongst the members of the European Economic Community (EEC) which was the pre-cursor to the EU. The first stage of the Economic and Monetary Union (EMU), which saw the liberalisation of capital movements within the EU, came into force in July 1990. The second stage of the EMU began in January 1994 and resulted in intensified convergence of national economic policies in accordance with requirements agreed upon in the Treaty of Maastricht and also the creation of the European Monetary Institution (EMI). The EMI was to prove the forerunner to the European Central Bank (ECB). The third stage of the EMU was enacted in January 1999 and saw the introduction of the euro in scriptural form. The fourth and final phase of the introduction of the euro came about in January 2002 when the cash form of the euro was introduced to 12 EU member states. This study aims to use this timeline of the four phase introduction of the euro to create separate sample periods, to facilitate comparisons at different stages in the creation of the currency union. In theory, the EU became more integrated with each step of the EMU and hence asymmetric volatility should become more prevalent as shocks in one market should be more likely to affect other European markets.

The volatility of the market returns will be measured using ARCH family models that are able to illuminate asymmetries in the data. The asymmetric power ARCH (APARCH) and Threshold ARCH (TARCH) models are the specific models that will be employed. Both of these models give estimates that can be used to create a metric for asymmetric volatility which will allow comparisons across the different countries.

The rest of the paper is structured as follows. Section 1 provides a discussion of previous related research and also considers the financial crisis that coincides with the chosen sample periods. Section 2 outlines the data and our method. Section 3 details the results and the last section proffers some concluding remarks.

1. LITERATURE REVIEW

A large body of research has been conducted using the ARCH family of models in an endeavour to better understand the volatility dynamics of financial markets. A frequently observed dynamic in financial markets is asymmetric volatility and variations on the original ARCH model have been created to capture this behaviour. Numerous variations of the original ARCH model created by Engle (1982) have been developed over the years. Bollerslev's (1986) GARCH model was a particularly important improvement upon the original simple ARCH specification and this model has been widely used since.

Ding *et al*. (1993) introduced another important variation of the ARCH model that became known as the Asymmetric Power ARCH or APARCH model. The significance of this model was that instead of using fixed values for the power term akin to the Bollerslev (1986) variance GARCH model or the standard deviation model of Taylor (1986), the power term now became a parameter to be estimated. Applying their model to S&P 500 returns data, Ding *et al*. (1993) estimated the power term to be 1.43. This finding was significantly different from 1 (Taylor's model) and 2 (Bollerslev's model) implying that there was merit in estimating the power term as a parameter. Ding *et al*. (1993) also demonstrated the applicability of the model to the US stock market.

Hentschel (1995) acknowledged the asymmetric and leptokurtic nature of returns and investigated the numerous GARCH family models that have been spawned as a result of these stylised features in financial data. Hentschel (1995) proposed a broad unifying framework in which GARCH family models could be viewed and tested. The models in the family differed from one another in terms of their respective treatment of the power parameter and of asymmetric volatility. Two of the models that will be used in this study were nested within Hentschel's (1995) broad framework, namely the APARCH model of Ding *et al*. (1993) and the TARCH model introduced by Zakoian (1994). These models were both designed with capturing asymmetric volatility in mind and hence they provide the basis for this study.

Brooks *et al*. (2000) utilised the APARCH model of Ding *et al*. (1993) and applied it to a wider range of countries than previous studies, while also comparing it to the other ARCH/GARCH models nested within the APARCH specifications. The APARCH model nests two broad classes of ARCH models; that of Bollerslev (1986) which seeks to model variance and that of Taylor (1986) which aims to model the standard deviation. By specifying restrictions on the parameters to be estimated for the APARCH model, Brooks *et al*. (2000) were able to reproduce a plethora of nested models and examine their relative merits. They found that the general class of APARCH model was applicable to ten large developed markets for the period February 1989 to December 1996. They also found strong evidence of the leverage effect in the developed markets and once the leverage effect had been accounted for, the power term proved to be a constructive addition to the model.

The power term of unity was the most commonly appropriate model implying the standard deviation model of Taylor (1986) is well suited to more developed markets. The majority of the countries used in this study are developed markets so it will be interesting to establish if this same result holds for our analysis.

Jayasuriya (2005) examines the effect of stock market liberalisation on stock market volatility for a variety of emerging markets. The findings were that stock market liberalisation led to a change in market volatility, be it an increase or decrease, for all eighteen countries studied. Stock market liberalisation in this context can be defined as the removal of restrictions on foreign capital flows into the market. Jayasuriya (2005) goes further to question the reasons why volatility was altered in a different way across the various countries. To answer this question, Jayasuriya (2005) sorted the countries into two groups. One group contained the countries that experienced an increase in market volatility post-liberalisation and the other; the countries that experienced a decrease. Comparing the two groups in terms of market characteristics and quality of institutions, Jayasuriya (2005) found that countries with lower volatility post liberalisation were characterized by higher quality accounting standards and investor protection laws, and lower restrictions on foreign capital repatriation, as well as generally having higher quality institutions subject to less corruption.

Brooks (2007) applied the APARCH model to a broader range of developing markets than those examined by Jayasuriya (2005) in order to gain a clearer insight into the nature of volatility in emerging markets. Brooks found that the 23 emerging markets explored displayed a greater range of power values than those of developed markets and for a certain set of countries a conditional normal error distribution appears to fit the data. More importantly for the purpose of this study, Brooks (2007) found that asymmetric volatility varies across emerging markets. Accordingly, we want to examine if the same variation was present in emerging European markets at the beginning of our sample period and should there prove to be a wide range of variation, did the countries asymmetric volatility measures begin to converge as the European ties became stronger.

Jayasuriya *et al*. (2009) use an asymmetric power GARCH model and several nested models to measure asymmetric volatility across fourteen emerging markets and seven developed markets. They also sought answers as to the cause of asymmetric volatility across the different markets. Jayasuriya *et al*. (2009) found that emerging markets tended to have larger α's (i.e. the coefficient relating to last period's shock) and smaller β's (i.e. the coefficient relating to last period's volatility) than developed markets. For the first sub-period, all cases of the gamma coefficient (i.e. the coefficient relating to asymmetry) were significant for the mature markets indicating asymmetric volatility existed in these markets at that time. Nine of the emerging markets exhibited asymmetric volatility while the other five did not. The second sub-period ranges from July 1997 to August 2001. This sub-period encompasses the Asian financial crisis. The gamma coefficients are highly significant again for all of the mature markets and most of the emerging markets. Volatility was particularly large for this sub-period so these results support the idea that asymmetry is high when volatility is also high. The third sub-period spans from September 2001 to April 2007. Volatility is said to be relatively low for this sub-period however each of the mature markets exhibits asymmetric volatility as the gamma coefficients are significant. Nine of the emerging markets exhibit asymmetry. Jayasuriya *et al*. (2009) found that both mature and emerging markets exhibit asymmetric volatility and also that asymmetric volatility is highly affected by the general volatility conditions of the market. Our study extends the current literature by examining the change in volatility dynamics over the relevant time periods.

Talpsepp and Rieger (2010) used an asymmetric power GARCH model to estimate asymmetric volatility across 49 different countries and then tested various factors thought to be causal of asymmetric volatility. Their findings were consistent with Jayasuriya *et al*. (2009) in so far as developed markets tend to exhibit more asymmetry than emerging markets. Some of the potential causes of asymmetric volatility tested by Talsepp and Rieger (2010) included the leverage effect, time-varying risk premium and short selling. Their findings revealed that analysts' coverage, short selling, stock market participation and GDP per capita (used as a proxy for economic development) were all factors that appeared to increase the asymmetry of volatility across a broad spectrum of countries. There was some limited evidence to substantiate the leverage effect hypothesis however while not discarding the theory completely, the leverage effect was not considered to be significant.

Fratzscher (2002) examines how strongly European markets are integrated and questions if the degree of integration has increased over time. The author also asks what role has the EMU played in financial market integration. Fratzscher (2002) uses the three cornerstones of the EMU (monetary policy, real convergence and exchange rate stability) as factors to explain the time variation of equity markets in Europe. The sample period used by Fratzscher (2002) runs from January 1986 to June 2000 and hence does not benefit from the longer post EMU period that this study will use; however there are still some useful findings regarding integration dynamics within Europe during the 1990s. A tri-variate GARCH model with time varying coefficients was employed to estimate financial market integration. The findings were that equity markets across Europe are highly integrated and exhibit evidence of asymmetry and the threshold effect. He also found that the intensity of integration increased within the Euro zone with the announcement of which states would be adopting the Euro in May 1998. Another interesting finding was that financial market integration within Europe was significantly lower during the ERM crisis of 1992-1993. The most interesting finding from the point of view of our study is however that symmetry and threshold effects became stronger over time. Overall the degree of integration was highly volatile over the period in question (1986-2000).

Bun and Klaassen (2002) sought answers as to whether the introduction of the euro increased trade between EMU countries or not. Using yearly data from 1965 to 2001, they established that the exchange rate stability brought about by the euro introduction had a statistically insignificant effect on exports. The reasoning cited for this insignificance was that the exchange rates had been relatively stable before the introduction. This finding is supported by Fratzscher (2002) who observed significant convergence of the EMU economies from 1996 onwards. There was however evidence of a trade-enhancing effect of the single currency introduction. Bun *et al*. (2002) estimated a 40% increase in trade in the long run. More trade among European countries should imply more integrated supply chains. Therefore negative shocks that affect supply in one area of Europe should in theory have a ripple effect and be detrimental to production in other parts of the European Union. Asymmetric volatility should in theory increase.

Three significant financial crises occur during the chosen sample period. The first was the European Monetary System (EMS) crisis that began in 1992 and ran its course in 1993 and hence falls into the first of the sample periods. The EMS crisis had a dramatic effect on integration within the EU as Kim *et al*. (2005) document. The large number of negative shocks prominent at this time should theoretically imply that asymmetric volatility will be strongly present. On the other hand the large number of negative shocks may be offset by the low integration levels of European economies around this time and therefore market shocks may have had differing effects in different countries. This second potential scenario would imply that asymmetric volatility may not have been prevalent around the time of the EMS crisis.

The second relevant crisis was the Asian Tigers crisis of 1997 which fits into the second sample period. In July 1997 the Thai baht broke its peg against the US dollar and in the six months that followed saw financial chaos in Thailand and many of its near neighbours. Indonesia for example lost 71% of its stock market value in dollar terms and it was a similar story for many East Asian developing economies. The Asian crisis was not going to have as dramatic an effect on the EU as the ERM crisis for obvious reasons, however Chakrabarti and Roll (2002) showed that there was some noticeable change in the dynamics of the relationships among EU countries around the time of the Asian crisis. These authors found an increase in European regional average correlation, covariance and volatility. Our study will examine if these effects shown by Chakrabarti *et al*. (2002) are reflected in terms of asymmetric volatility.

The third crisis of interest is the “Dot com bubble” that developed in the US in the late 1990s and came to a climax in March 2000 – coinciding with the third sample period in our study. According to Ofek and Richardson (2003), prior to the bursting of the dot com bubble, the internet sector made up 6% of the market capitalisation of all public companies and 20% of all publicly traded equity volume. The US economy has long been the world’s largest economy and therefore has numerous trading partners and strong ties to the EU. The dot com bubble is a classic example of speculation fuelling market prices that appear to be warranted at the time however, with the benefit of hindsight they are revealed to have been massively over inflated. Similar to the Asian Tigers crisis, the dot com bubble fails to echo any effect on EU volatility in the studies mentioned earlier. Any irregularities that we discover when examining asymmetric volatility in any of the chosen sample periods will have to be interpreted with the relevant crisis in mind.

2. DATA AND METHODOLOGY

The data for each countries equity index were obtained from DataStream for the period from July 1990 to December 2006. The countries included in our study are the 12 countries that adopted the euro upon its introduction in January 2002, namely Germany, Ireland, Austria, Belgium, Finland, Greece, Italy, Netherlands, Portugal, Spain, Luxembourg and France. Non-trading days have been filtered from each of the series. Each of the national indices comprise most of the larger companies within each country spanning across a relatively broad range of industries. All returns have been calculated using a log difference and are denominated in their relevant national currency for the periods prior to the euro currency introduction. For reasons already outlined, the data has been broken up into four distinct sample periods: July 1990 to December 1993, January 1994 to December 1998, January 1999 to December 2001 and January 2002 to December 2006.

For each return series an first-order autoregressive specification (AR (1)) is employed to account for short-term autocorrelation. A constant was also included/omitted depending upon its significance/insignificance:

$$r_{i,t} = \alpha_0 + \alpha_1 r_{i,t-1} + \varepsilon_{i,t} \qquad (1)$$

The conditional errors $(\varepsilon_{i,t})$ are allowed to follow a normal or student's t distribution with time varying conditional variance $(\sigma^2_{i,t})$:

$$\varepsilon_{i,t} \sim N(0, \sigma^2_{i,t}) \qquad (2)$$

Both TARCH (1,1) and APARCH (1,1) models were estimated for each return series in each period. Both the TARCH and APARCH models are designed to capture asymmetric volatility.

The TARCH (1,1) model can be specified as follows:

$$\sigma^2 = \omega + \alpha\varepsilon^2_{t-1} + \gamma\varepsilon^2_{t-1} I_{t-1} + \beta\sigma^2_{t-1} \qquad (3)$$

where I_{t-1} is an indicator function that equals 1 if $\varepsilon_{t-1} < 0$ and 0 otherwise. The γ coefficient captures the presence of asymmetric volatility.

The APARCH model is similar to the TARCH model. The key difference being that the power parameter is estimated instead of being held fixed at 2. The APARCH (1,1) model can be specified as follows:

$$\sigma^{d} = \omega + \alpha(|\varepsilon_{t-1}| - \gamma\varepsilon_{t-1})^{d} + \beta\sigma_{t-1}^{d} \quad (4)$$

The boundary restriction of $|\gamma| \leq 1$ is imposed for both the TARCH and APARCH models. The α coefficient measures the weight applied to news associated with last period's shock. The higher the α coefficient, the more volatile a market becomes with the introduction of news. The β coefficient represents the weight applied to the previous forecast of volatility. The α and β coefficients are not bound by any restrictions when estimating either model. All of the results reported in tables in the main body of this analysis are taken from models which use a Student's t error distribution.

Following Brooks (2007), a metric measure of asymmetric volatility is also calculated:

$$\text{Asymmetric Volatility} = \left(\frac{1+\gamma}{1-\gamma}\right)^{d} \quad (5)$$

This metric will capture the extent to which the volatility in response to a negative shock is greater than the volatility in response to a positive shock.

3. RESULTS

3.1. Period 1 Results

Table 1. **Period 1 Estimation of the APARCH (1,1) Model**

Country	**ω**	**α**	**β**	**γ**	**d**	**SIC**
Germany	0.000299	0.093109	0.914629	0.383653	0.899965	-6.376
	(0.3812)*	(0.00)	(0.00)	(0.0193)	(0.0001)	
Ireland	4.55 E-05	0.127557	0.882677	0.094381	1.322705	-6.729
	(0.6672)*	(0.00)	(0.00)	(0.3841)*	(0.0003)	
Austria	7.11 E-05	0.191901	0.779914	0.252458	1.588818	-5.936
	(0.6738)*	(0.0001)	(0.00)	(0.0187)	(0.0034)	
Belgium	5.85 E-05	0.166758	0.833574	0.168887	1.389106	-7.017
	(0.6117)*	(0.00)	(0.00)	(0.1256)*	(0.0004)	
Finland	7.30 E-06	0.071620	0.927187	0.018607	1.655645	-6.311
	(0.6978)*	(0.0024)	(0.00)	(0.8496)	(0.001)	
Greece	0.001322	0.323460	0.669424	-0.098319	1.048156	-5.403
	(0.4771)*	(0.00)	(0.00)	(0.2288)	(0.0011)	
Italy	4.55 E-05	0.041438	0.963001	0.738875	1.055064	-5.825
	(0.5813)*	(0.0102)	(0.00)	(0.0292)	(0.0009)	

Country	ω	α	β	γ	d	SIC
Netherlands	0.000795	0.075400	0.91616	0.424623	0.748055	-6.802
	(0.5677)*	(0.0001)	(0.00)	(0.0195)	(0.0295)	
Portugal	1.19 E-05	0.44240	0.451998	-0.108629	1.873105	-7.859
	(0.7360)*	(0.00)	(0.00)	(0.1688)*	(0.0008)	
Spain	0.000384	0.131668	0.843723	0.23851	1.113458	-6.235
	(0.4728)*	(0.00)	(0.00)	(0.0808)*	(0.00)	
Luxembourg	4.23 E-05	0.096442	0.8853883	0.113771	1.412629	-7.223
	(0.6683)*	(0.0056)	(0.00)	(0.4450)*	(0.0017	
France	0.000675	0.068697	0.907922	0.872419	0.930716	-6.106
	(0.4755)*	(0.0026)	(0.00)	(0.0014)	(0.0008)	

Note: This table reports the volatility equation estimates for the APARCH model, Equation (4) in the text. p-values are contained in parentheses below each estimate and insignificant cases are denoted by *.

Table 2. **Period 1 Estimation of the TARCH (1,1) Model**

Country	ω	α	β	γ	SIC
Germany	3.88 E-06	0.065086	0.864883	0.093123	-6.362
	(0.0057)	(0.0494)	(0.00)	(0.0355)	
Ireland	1.60 E-06	0.095209	0.882206	0.033551	-6.734
	(0.0660)*	(0.0054)	(0.00)	(0.3845)*	
Austria	1.22 E-05	0.107606	0.766345	0.171754	-5.943
	(0.0018)	(0.0227)	(0.00)	(0.0138)	
Belgium	3.01 E-06	0.111686	0.825541	0.086875	-7.021
	(0.0042)	(0.0141)	(0.00)	(0.1306)*	
Finland	1.24 E-06	0.055347	0.934646	0.006165	-6.319
	(0.0770)	(0.0058)	(0.00)	(0.7744)*	
Greece	2.42 E-05	0.428419	0.613232	-0.087574	-5.404
	(0.0010)	(0.00)	(0.00)	(0.3826)*	
Italy	4.30 E-06	0.018905	0.921290	0.072366	-5.824
	(0.0655)*	(0.4210)*	(0.00)	(0.0149)	
Netherlands	2.63 E-06	0.027648	0.908103	0.055692	-6.799
	(0.0149)	(0.2433)*	(0.00)	(0.0415)	
Portugal	6.15 E-06	0.557190	0.436193	-0.196401	-7.867
	(0.00)	(0.0001)	(0.00)	(0.1850)*	
Spain	1.16 E-05	0.101385	0.767681	0.103357	-6.237
	(0.0025)	(0.0215)	(0.00)	(0.0799)*	
Luxembourg	2.42 E-06	0.066807	0.886714	0.015656	-7.229
	(0.0153)	(0.0580)*	(0.00)	(0.6549)*	
France	1.08 E-05	0.023933	0.835997	0.131857	-6.105
	(0.0107)	(0.3825)*	(0.00)	(0.0045)	

Note: This table reports the volatility equation estimates for the TARCH model, Equation (3) in the text. p-values are contained in parentheses below each estimate and insignificant cases are denoted by *.

Tables 1 and 2 present the results for the conditional volatility equation for the time period July 1990 to December 1993 for the APARCH (1,1) and TARCH(1,1) models, respectively. None of the α or β coefficients are insignificant for the APARCH model whereas four of the TARCH α estimates are insignificant. Jayasuriya *et al* (2009) found that emerging markets tend to have larger α and smaller β coefficients compared to developed markets. This period displays similar results with Portugal and Greece in particular displaying high α and comparatively low β estimates for both models. In contrast to this; the more developed markets such as France and Germany display low α's (less than 0.1) and high β's (greater than 0.8) in both models. The γ coefficient is of particular interest to this study. Five countries (Ireland, Belgium, Portugal, Spain and Luxembourg) display insignificant γ in the APARCH model estimates. The same five countries along with Greece and Finland have insignificant γ coefficients for the TARCH model.

The discussion in Section 2 showed that integration of the EU economies was low for period 1 owing to the uncertainty that surrounded markets around the time of the EMS crisis. The first tentative step had just been taken towards monetary and fiscal union within the EU but speculative attacks upon European currencies threatened to derail these efforts. The evidence would suggest that low integration resulted in low asymmetric volatility levels. Markets were less integrated at this time and hence shocks in one area of Europe were less likely to reverberate in other European locations. The TARCH model, with 7 of the 12 countries having insignificant γ coefficients illustrates this point well.

3.2. Period 2 Results

Table 3. **Period 2 Estimation of the APARCH (1,1) Model**

Country	ω	α	β	γ	d	SIC
Germany	0.000629	0.100999	0.901334	0.36877	0.779404	-6.155
	(0.4081)*	(0.00)	(0.00)	(0.0032)	(0.0012)	
Ireland	1.49 E-05	0.061082	0.933601	0.29889	1.423582	-6.981
	(0.4254)*	(0.0001)	(0.00)	(0.0354)	(0.00)	
Austria	6.25 E-05	0.11577	0.863697	0.218751	1.402801	-6.448
	(0.6094)*	(0.00)	(0.00)	(0.0554)*	(0.0005)	
Belgium	9.74 E-05	0.094485	0.908840	0.242778	1.085036	-6.867
	(0.6049)*	(0.00)	(0.00)	(0.0259)	(0.0061)	
Finland	4.60 E-06	0.108959	0.805062	0.280444	2.195884	-5.907
	(0.7107)*	(0.0004)	(0.00)	(0.0226)	(0.0003)	
Greece	6.62 E-05	0.222509	0.777943	0.105134	1.529003	-5.780
	(0.5579)*	(0.00)	(0.00)	(0.0986)*	(0.0001)	
Italy	2.47 E-06	0.120676	0.794718	0.122198	2.436204	-5.595
	(0.7739)*	(0.0006)	(0.00)	(0.0597)*	(0.0032)	
Netherlands	9.97 E-07	0.092663	0.889704	0.188836	2.097249	-6.408
	(0.7060)*	(0.0001)	(0.00)	(0.0366)	(0.0001)	
Portugal	0.000528	0.186736	0.844742	0.084866	0.769433	-7.220
	(0.3430)*	(0.00)	(0.00)	(0.2726)*	(0.0002)	

Country	ω	α	β	γ	d	SIC
Spain	2.12 E-05	0.106959	0.878843	0.224014	1.60740	-6.096
	(0.6370)*	(0.00)	(0.00)	(0.0204)	(0.0006)	
Luxembourg	2.18 E-05	0.085114	0.920959	0.129685	1.284523	-7.035
	(0.6618)*	(0.00)	(0.00)	(0.1971)*	(0.0054)	
France	2.26 E-06	0.04093	0.929596	0.493731	2.053615	-6.038
	(0.6640)*	(0.0287)	(0.00)	(0.0299)	(0.0001)	

Note: This table reports the volatility equation estimates for the APARCH model, Equation (4) in the text. p-values are contained in parentheses below each estimate and insignificant cases are denoted by *.

Table 4. **Period 2 Estimation of the TARCH (1,1) Model**

Country	ω	α	β	γ	SIC
Germany	2.93 E-06	0.072395	0.879607	0.056655	-6.150
	(0.0106)	(0.0075)	(0.00)	(0.0696)*	
Ireland	1.05 E-06	0.025767	0.929160	0.052269	-6.985
	(0.0044)	(0.1212)*	(0.00)	(0.0089)	
Austria	3.87 E-06	0.075166	0.860326	0.054882	-6.452
	(0.0018)	(0.0093)	(0.00)	(0.0997)*	
Belgium	1.36 E-06	0.068652	0.889775	0.049779	-6.870
	(0.0116)	(0.0025)	(0.00)	(0.0640)*	
Finland	1.06 E-05	0.059602	0.810236	0.131583	-5.913
	(0.0002)	(0.0414)	(0.00)	(0.0006)	
Greece	8.92 E-06	0.178480	0.756176	0.096621	-5.785
	(0.0002)	(0.00)	(0.00)	(0.0729)*	
Italy	1.45 E-05	0.097359	0.812116	0.063808	-5.600
	(0.0036)	(0.0003)	(0.00)	(0.0831)*	
Netherlands	1.59 E-06	0.061253	0.890836	0.074231	-6.413
	(0.0066)	(0.0080)	(0.00)	(0.0087)	
Portugal	2.03 E-06	0.268298	0.718792	0.106066	-7.211
	(0.0004)	(0.00)	(0.00)	(0.1341)*	
Spain	3.91 E-06	0.068568	0.867040	0.068568	-6.101
	(0.0041)	(0.0091)	(0.00)	(0.0091)	
Luxembourg	7.47 E-07	0.065402	0.910575	0.027641	-7.039
	(0.0203)	(0.0034)	(0.00)	(0.2525)*	
France	2.86 E-06	0.010619	0.930008	0.083508	-6.044
	(0.0072)	(0.4082)*	(0.00)	(0.00)	

Note: This table reports the volatility equation estimates for the TARCH model, Equation (3) in the text. p-values are contained in parentheses below each estimate and insignificant cases are denoted by *.

Tables 3 and 4 show the parameter estimates for the period January 1994 to December 1998 of the APARCH (1,1) and TARCH (1,1) models, respectively. Again the emerging markets such as Portugal, Italy and Greece display a higher α but lower β coefficients than their more developed European counterparts such as Germany, France and Netherlands. While these differing coefficients can be seen in both models, it is interesting to note that the differences are slightly more distinct when examining the TARCH model. The estimated d parameter in the APARCH model is obviously allowing the estimates of the developed and emerging markets to be closer together when compared to the TARCH estimates.

Based on a 5% significance level, there are a number of insignificant γ coefficients for both models, 5 for the APARCH model and 7 for the TARCH model. However, there are a number of cases on the borderline of the 5% significance level and if we relax the rejection criteria to a 10% significance level we find that 10 of the 12 countries have significant γ coefficients using either method. The two countries (Portugal and Luxembourg) that exhibit insignificant γ's at any recognised rejection level are the same for both models. This is an interesting finding given that both displayed significant negative skewness.

Previous European stock market volatility studies, as discussed in Section 2, conducted on this period revealed that integration among European stock markets increased notably from 1996 onwards. With 10 of the 12 countries now showing significant γ coefficients at the 10% significance level; we conclude that asymmetric volatility appears to be following a similar path to European stock market integration.

3.3. Period 3 Results

Table 5. **Period 3 Estimation of the APARCH (1,1) Model**

Country	ω	α	β	γ	d	SIC
Germany	8.36 E-05	0.071178	0.876284	0.617870	1.529880	-5.539
	(0.7106)*	(0.0306)	(0.00)	(0.0303)	(0.0102)	
Ireland	1.11 E-06	0.018496	0.778115	0.914436	2.618627	-6.153
	(0.8712)*	(0.9753)*	(0.00)	(0.9689)*	(0.0609)*	
Austria	8.19 E-06	0.061480	0.906524	0.396556	1.780432	-6.473
	(0.7906)*	(0.0441)	(0.00)	(0.1326)*	(0.00319)	
Belgium	9.47 E-06	0.151779	0.825365	0.315142	1.758177	-6.367
	(0.7038)*	(0.00)	(0.00)	(0.0089)	(0.0008)	
Finland	0.000135	0.080776	0.904667	0.356918	0.916411	-4.266
	(0.5929)*	(0.0015)	(0.00)	(0.0665)*	(0.0500)	
Greece	1.83 E-06	0.194591	0.596212	0.243840	2.884858	-5.041
	(0.8260)*	(0.0168)	(0.00)	(0.0113)	(0.0113)	
Italy	7.97 E-06	0.122703	0.827708	0.258123	2.006253	-5.755
	(0.7588)*	(0.0016)	(0.00)	(0.0029)	(0.0058)	
Netherlands	2.42 E-06	0.039873	0.882055	0.745053	2.207040	-5.902
	(0.7334)*	(0.6494)*	(0.00)	(0.6285)*	(0.0001)	
Portugal	0.000342	0.153204	0.777542	0.345890	1.236570	-6.248
	(0.6040)*	(0.00)	(0.00)	(0.0157)	(0.0049)	
Spain	0.000488	0.068362	0.908790	0.728458	1.00454	-5.614
	(0.5465)*	(0.0030)	(0.00)	(0.0057)	(0.0089)	

Country	ω	α	β	γ	d	SIC
Luxembourg	2.19 E-07	0.136790	0.815496	0.201235	2.493835	-6.415
	(0.7913)*	(0.0012)	(0.00)	(0.0134)	(0.0009)	
France	6.25 E-05	0.035741	0.912457	0.778721	1.528242	-5.659
	(0.6758)*	(0.9078)*	(0.00)	(0.9273)*	(0.0043)	

Note: This table reports the volatility equation estimates for the APARCH model, Equation (4) in the text. p-values are contained in parentheses below each estimate and insignificant cases are denoted by *.

Table 6. **Period 3 Estimation of the TARCH (1,1) Model**

Country	ω	α	β	γ	SIC
Germany	1.12 E-05	0.009139	0.869501	0.143759	-5.544
	(0.0125)	(0.6636)*	(0.00)	(0.0003)	
Ireland	1.59 E-05	-0.008491	0.811486	0.123580	-6.161
	(0.0124)	(0.7421)*	(0.00)	(0.0004)	
Austria	2.89 E-06	0.024074	0.905338	0.081330	-6.482
	(0.0579)	(0.3560)*	(0.00)	(0.0165)	
Belgium	2.91 E-06	0.076208	0.819728	0.168288	-6.376
	(0.0261)	(0.0192)	(0.00)	(0.0004)	
Finland	2.02 E-06	0.027115	0.980399	-0.017773	-4.266
	(0.4624)*	(0.0107)	(0.00)	(0.2125)*	
Greece	5.95 E-05	0.109302	0.648186	0.246304	-5.049
	(0.0038)	(0.0388)	(0.00)	(0.0059)	
Italy	8.20 E-06	0.067628	0.827774	0.127013	-5.764
	(0.0330)	(0.0095)	(0.00)	(0.0009)	
Netherlands	6.43 E-06	-0.017528	0.891352	0.160715	-5.915
	(0.0019)	(0.5484)*	(0.00)	(0.00)	
Portugal	1.17 E-05	0.084364	0.740900	0.149781	-6.255
	(0.0078)	(0.0466)	(0.00)	(0.0081)	
Spain	7.46 E-06	0.006958	0.891987	0.122458	-5.618
	(0.0094)	(0.7671)*	(0.00)	(0.0003)	
Luxembourg	2.66 E-06	0.086747	0.821818	0.144871	-6.423
	(0.0270)	(0.0086)	(0.00)	(0.0012)	
France	8.26 E-06	-0.014481	0.916232	0.109366	-5.667
	(0.00175)	(0.4757)*	(0.00)	(0.0015)	

Note: This table reports the volatility equation estimates for the TARCH model, Equation (3) in the text. p-values are contained in parentheses below each estimate and insignificant cases are denoted by *.

The parameter estimates for the APARCH and TARCH models for the period January 1999 to December 2001 can be seen in Tables 5 and 6. The α coefficients are of interest for this period. Once again Italy, Portugal and Greece have high α estimates for both models as well as, Luxembourg and Belgium. Ireland, Netherlands and France have insignificant α's for the APARCH model and those same three countries along with Germany, Austria and Spain have insignificant α's for the TARCH model. Once again low (high) α coefficients are matched by comparatively high (low) β coefficients.

In this subperiod some disparity between the models with regard to the γ coefficients appears. The APARCH model shows 5 countries (Ireland, Austria, Finland, Netherlands and France) with insignificant γ coefficients whereas for the TARCH model only Finland has an insignificant γ estimate. This was a particularly volatile time for the Finnish economy as its large electronics industry was deeply affected by the Dot com bubble but this period of high volatility in Finland has not been matched with the presence of asymmetric volatility. Discounting Finland due to its "special" circumstances, all of our countries exhibit asymmetric volatility at a 5% significance level for this period using the TARCH model.

3.4. Period 4 Results

Table 7. **Period 4 Estimation of the APARCH (1,1) Model**

Country	ω	α	β	γ	d	SIC
Germany	9.11 E-05	0.054359	0.936804	0.998105	1.165944	-5.973
	(0.4876)*	(0.0986)*	(0.00)	(0.2241)*	(0.0001)	
Ireland	1.60 E-05	0.068575	0.898341	0.504700	1.589150	-6.715
	(0.5545)*	(0.0006)	(0.00)	(0.0077)	(0.00)	
Austria	6.82 E-05	0.091277	0.834883	0.392576	1.503337	-6.616
	(0.5854)*	(0.0009)	(0.00)	(0.4620)	(0.0003)	
Belgium	3.23 E-05	0.075475	0.910749	0.605988	1.352312	-6.635
	(0.4721)*	(0.0003)	(0.00)	(0.0056)	(0.00)	
Finland	0.000125	0.050048	0.954561	0.454497	0.915909	-5.835
	(0.6080)*	(0.0001)	(0.00)	(0.0524)*	(0.0195)	
Greece	8.96 E-08	0.058147	0.851788	0.233799	2.907897	-6.334
	(0.8116)*	(0.0488)	(0.00)	(0.0012)	(0.0016)	
Italy	0.000201	0.055309	0.943701	1.00000	0.905657	-6.645
	(0.4030)*	(0.00)	(0.00)	(0.00)	(0.0001)	
Netherlands	0.000177	0.058533	0.941681	0.999965	0.967152	-6.198
	(0.4160)*	(0.00)	(0.00)	(0.00)	(0.0001)	
Portugal	6.61 E-05	0.097485	0.894122	0.296789	1.190147	-7.426
	(0.6186)*	(0.00)	(0.00)	(0.0087)	(0.0025)	
Spain	2.35 E-05	0.054163	0.924678	0.855584	1.425499	-6.424
	(0.5759)*	(0.0552)*	(0.00)	(0.0520)*	(0.00)	
Luxembourg	2.62 E-05	0.068708	0.916207	0.632237	1.375717	-6.690
	(0.4508)*	(0.0009)	(0.00)	(0.0138)	(0.00)	
France	0.000183	0.061956	0.934887	1.00	1.005578	-6.231
	(0.3346)*	(0.0001)	(0.00)	(0.0012)	(0.00)	

Note: This table reports the volatility equation estimates for the APARCH model, Equation (4) in the text. p-values are contained in parentheses below each estimate and insignificant cases are denoted by *.

Table 8. **Period 4 Estimation of the TARCH (1,1) Model**

Country	**ω**	**α**	**β**	**γ**	**SIC**
Germany	1.60 E-06	-0.013973	0.932420	0.144420	-5.975
	(0.0002)	(0.3083)*	(0.00)	(0.00)	
Ireland	3.96 E-06	0.033074	0.855615	0.115256	-6.697
	(0.0002)	(0.2096)*	(0.00)	(0.0008)	
Austria	7.26 E-06	0.032436	0.818189	0.111369	-6.621
	(0.0001)	(0.2800)*	(0.00)	(0.0022)	
Belgium	1.52 E-06	0.026760	0.890824	0.121531	-6.639
	(0.0002)	(0.1796)*	(0.00)	(0.00)	
Finland	6.65 E-07	0.035537	0.954820	0.008615	-5.832
	(0.0907)*	(0.0146)	(0.00)	(0.6308)*	
Greece	5.73 E-06	0.033417	0.868330	0.097827	-6.338
	(0.0023)	(0.0334)	(0.00)	(0.0004)	
Italy	9.60 E-07	-0.014614	0.929346	0.133869	-6.641
	(0.0007)	(0.4128)*	(0.00)	(0.00)	
Netherlands	1.17 E-06	-0.018292	0.939137	0.140196	-6.197
	(0.00)	(0.1269)*	(0.00)	(0.00)	
Portugal	9.92 E-07	0.047023	0.888350	0.078054	-7.428
	(0.0029)	(0.0122)	(0.00)	(0.0054)	
Spain	1.40 E-06	0.001610	0.919727	0.123254	-6.427
	(0.0008)	(0.8980)*	(0.00)	(0.00)	
Luxembourg	1.33 E-06	0.025778	0.898383	0.109144	-6.694
	(0.0003)	(0.2018)*	(0.00)	(0.00)	
France	1.70 E-06	-0.017936	0.926852	0.157205	-6.230
	(0.00)	(0.0871)*	(0.00)	(0.00)	

Note: This table reports the volatility equation estimates for the TARCH model, Equation (3) in the text. p-values are contained in parentheses below each estimate and insignificant cases are denoted by *.

Period 4 runs from January 2002 to December 2006 and the parameter estimates for the APARCH (1,1) and TARCH (1,1) models are contained in Tables 7 and 8. The 1st of January 2002 marked the day of the introduction of the euro currency in cash form across all 12 members of the currency union. European stock markets reacted poorly to the euro introduction and for most of 2002 they remained highly volatile. A phase of extremely high volatility was present for all of 2002 and some of 2003, this was followed by relatively low volatility from the end of 2003 onward. The APARCH model was unable to capture the stylised features of the data. The γ estimates for the five return series push right up to the boundary restraints of $|\gamma| \leq 1$. When the sample size was reduced to eliminate the period of high volatility, taking only from late 2003 onward, the results remained unchanged.

This result is not unique, Jayasuriya *et al*. (2009) found when estimating an APARCH model using UK returns for the period 1st of July 1997 to 31st August

2001 that the γ coefficient was also approaching the boundary constraint. The same problem was encountered in period 3 in this study with Irish returns (See Table 5). A potential solution to this problem could be to use the Markov-switching ARCH (SWARCH) model employed by Hamilton and Susmel (1994). Hamilton and Susmel (1994) identified three different volatility regimes (high, medium and low) and assigned a constant to each regime. The idea was that the lagged ARCH (q) variable (ε_{t-q}) was multiplied by the constant depending on the regime in which it occurred. Therefore different parameters were used depending on the volatility regime in effect at the time. The empirical results found that the SWARCH model proved a better fit to a portfolio of stocks traded on the NYSE from 1962 to 1987 than the standard GARCH model.[1]

Examining the TARCH parameter estimates we can see that 9 countries have insignificant α coefficients (Portugal, Greece and Finland). Finland continues to be something of an enigma and Portugal and Greece continue to display the higher α and lower β coefficient estimates which are commonly observed in emerging markets. Note that Portugal may not be considered an emerging market by some in terms of a world scale however in comparison to the other highly developed European markets that are being used in this study; it is reasonable to assume that Portugal is still a developing market. The α and β estimates for Portugal across the 4 sample periods lend weight to this view.

Inspection of the gamma coefficients show that again 11 of the 12 countries display significant γ coefficients and hence asymmetric volatility is in evidence. Finland fails to display a significant γ estimate for either the APARCH or TARCH models and continues to be the outlier from the pack. The period 3 results appear not to have been an aberration; the euro introduction seems to have increased asymmetric volatility among the member states.

3.5. Comparison of asymmetric volatility across countries

Equation 5 gives us the metric formula to facilitate comparison of asymmetric volatility across the different countries. Table 9 contains these calculations based on the estimates from both the APARCH and TARCH models. There are a few extremely large figures calculated for periods 3 and 4 based on the APARCH γ estimates. As already discussed, the APARCH model had some limitations when dealing with the features of the data for period 4. Thus, the extremely large asymmetric volatility metrics calculated from these estimates are somewhat un-interpretable. No such problems were encountered for estimating the TARCH model and therefore those results are considerably easier to interpret. Hence, we focus our main attention on the TARCH model, and only referencing the APARCH model calculations where appropriate.

Table 9. **Asymmetric Volatility Metric Comparison**

	APARCH Models				TARCH Models			
Period	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Germany	2.0705	1.8088	9.0955	3347.03*	1.4529	1.2547*	1.7843	1.7892
Ireland	1.2846*	2.4056	88.168*	5.84648	1.1437*	1.2328	1.6436	1.5890
Austria	2.2704	1.8660*	4.4548*	3.48091	2.0015	1.2458*	1.3855	1.5641
Belgium	1.6036*	1.7119	3.1493	6.68691	1.4168*	1.2205*	1.9731	1.6299
Finland	1.0636	3.4550	1.9824*	2.45527*	1.0250*	1.6979	0.9314*	1.0351*
Greece	0.8132	1.3808*	4.2031	3.99622	0.7039*	1.4736*	2.7344	1.4808
Italy	7.3920	1.8192*	2.8855	508828	1.3364	1.2912*	1.6666	1.7138
Netherlands	1.9704	2.2293	69.770*	39874.7	1.2498	1.3465	1.9126	1.7586
Portugal	0.6646*	1.1399*	2.4406	2.07168	0.4512*	1.5309*	1.8288	1.3673
Spain	1.7187*	2.0805	6.4191	38.0791*	1.5022*	1.3777	1.6361	1.6414
Luxembourg	1.3810	1.3980*	2.7665	7.76935	1.0646*	1.1169*	1.7925	1.5501
France	12.184	9.2252	24.172*	2168587	1.6998	1.3977	1.5515	1.8853

Note: This table reports the asymmetric volatility metrics based on Equation (5) in the text.* denotes an insignificant γ was used in the calculation.

The big four economies (Germany, France, Spain and Italy) all follow the same pattern. They show a decrease in asymmetric volatility from period 1 to period 2, an increase from period 2 to period 3 and then another slight increase from period 3 to period 4. Austria, with strong links to Germany and France, follows the same pattern as these 4 countries.

Another group of 5 countries (Ireland, Greece, Netherlands, Portugal and Luxembourg) with somewhat smaller economies also all follow a similar pattern whereby asymmetric volatility increases from period 1 to period 2, increases again from period 2 to period 3 and then decreases from period 3 to period 4. The only countries not included in either of these two groups are Finland and Belgium who each follow their own unique evolution. Note that all the countries, barring Finland, showed an increase in asymmetric volatility from period 2 to period 3. This would suggest that the introduction of the euro in scriptural form had a significant impact on asymmetric volatility across the euro-zone. Table 10 shows the percentage change in the asymmetric volatility metric calculations from period to period. The patterns for the APARCH model are relatively similar for most countries however the gamma coefficient boundary issues tend to hamper the comparisons. Any of the extremely large percentage changes, for example Germany in period 4 of the APARCH model estimates, are resultant of the γ coefficient closing in on 1. It is evident from the table when examining the (more reliable) TARCH measures that there are significant changes in asymmetric volatility from period 2 to period 3.

Table 10. **Percentage Change in Asymmetric Volatility from Period to Period**

	APARCH Models			TARCH Models		
	Period 1 to 2	Period 2 to 3	Period 3 to 4	Period 1 to 2	Period 2 to 3	Period 3 to 4
Germany	-12.639%	402.852%	36698.8%	-13.646%	42.217%	0.270%
Ireland	87.266%	3565.189%	-93.369%	7.790%	33.321%	-3.321%
Austria	-17.810%	138.732%	-21.861%	-37.758%	11.215%	12.895%
Belgium	6.592%	83.972%	112.861%	-13.758%	61.662%	-17.393%
Finland	233.319%	-44.081%	23.857%	65.656%	-45.146%	11.133%
Greece	69.803%	204.383%	-4.921%	109.361%	85.559%	-45.846%
Italy	-75.390%	58.613%	1.7 E+07%	-3.381%	29.076%	2.829%
Netherlands	13.143%	3029.67%	57051.5%	7.732%	42.050%	-8.055%
Portugal	71.510%	114.109%	-15.115%	239.333%	19.459%	-25.234%
Spain	21.047%	208.542%	493.219%	-8.286%	18.751%	0.324%
Luxembourg	1.230%	97.887%	180.837%	4.913%	60.480%	-13.521%
France	-24.284%	162.023%	8.9 E+06%	-17.775%	11.005%	21.514%

Note: This table reports the perior-to-period change in asymmetric volatility based on the APARCH (Equation (4) in the text) and TARCH (Equation (3) in the text) models.

Table 11. **Asymmetric Volatility Summary Statistics based on TARCH model estimates**

Period	Mean	Standard Deviation
1	1.253974	0.419923
2	1.348845	0.159636
3	1.736695	0.418435
4	1.583706	0.222811

Note: This table reports the cross-country sample mean and standard deviation of the TARCH model estimates of the asymmetric volatility coefficents (Equation (3) in the text).

Table 11, shows the mean and standard deviation of the asymmetric volatility metric over the four periods and the figures revealed are of interest. Period 1 shows a low average asymmetric volatility measure with a high standard deviation. As discussed above, prior studies suggest that integration among European stock markets was low during period 1 and this has been attributed to the turmoil caused by the EMS crisis of 1992-1993. We also noted earlier that period 1 only had 7 of 12 countries displaying significant γ coefficients. The low market integration meant that shocks in one market were less likely to have an effect on other markets and hence average asymmetric volatility was low. The standard deviation was high for the period because the different markets were not behaving consistent with the large amount of shocks that characterized this period.

Period 2 saw an increase in integration amongst EU economies and hence there was an increase in the mean asymmetric volatility and a marked decrease in the standard deviation. European markets began to develop stronger bonds and hence negative shocks in one market became more widely felt across Europe. The standard deviation fell relatively low during period 2 suggesting that negative shocks had a more even effect on all of the countries than during period 1. Given that the mean has increased slightly, this confirms the Chakrabarti *et al*. (2002) findings that European markets experienced an increase in correlations and covariance around the time of the Asian Financial crisis that occurred in 1997. We cannot determine that the Asian financial crisis was a significant event in increasing asymmetric volatility for period 2 but we can espouse that it was believed to have been a contributing factor towards increased integration amongst European markets. From this it can be deduced that this increased integration led to increased asymmetric volatility.

Period 3 sees a significant increase in the average asymmetric volatility measure from 1.35 to 1.74. The literature suggests that European stock market integration increased from 1996 onwards and this significant jump in asymmetric volatility would further suggest that this increased integration held into the late 1990s and early 2000s. With the introduction of the euro in the form of scriptural money European markets became even more closely linked. This was also a period of high volatility as we discovered when examining the standard deviation measures from the summary statistics earlier. The Dot com bubble and the 9/11 terrorist attack were two of the most notable volatility causing events during this period. The results suggest that this period of high volatility clearly increased asymmetric volatility across the euro-zone however it affected different countries to varying degrees, resulting in the high standard deviation figure.

Period 4 sees a small fall in the mean asymmetric volatility measure while the standard deviation approximately halves the measure for period 3. Period 4 begins with a yearlong spell of high volatility. That period was followed by a phase of relative tranquillity in the markets with generally small fluctuations around the mean. With volatility decreasing after the initial phase, there were less large negative shocks and hence there was a decrease in both the mean and the standard deviation. The fall in average asymmetric volatility from period 3 to period 4 appears to be as a result of there being lower volatility during period 4 rather than it being due to markets becoming less integrated.

Overall asymmetric volatility appears to have increased across the Euro-zone with the introduction of the euro. During period 1; asymmetric volatility was low. The EMS crisis caused Europe to be divided for a time and it appeared as though the EMU might disintegrate. The stabilisation measures co-ordinated by policymakers ensured this didn’t happen and integration among European stock markets became stronger from around the middle of period 2 onwards and asymmetric volatility followed the same path of stock market integration. The introduction of the euro as scriptural money in 1999 was a significant event in the strengthening of links between European markets. It was also significant in contributing to the high volatility regime which was evident at that time. Asymmetric volatility was particularly high around this time period and then decreased slightly as markets all over Europe began to settle to lower volatility regimes.

At the beginning in period 1 only Germany, France and Italy (along with Austria and Netherlands, both highly influenced by their near neighbours) exhibited significant asymmetric volatility. Over the course of the various stages of the introduction of the euro, asymmetric volatility has spread into the rest of the euro-zone countries. Owing to the increased links between the members of the currency union, there has been convergence in terms of asymmetric volatility between all 12 member states.

CONCLUSION

The motivation for our study was to see if the creation of the Euro-zone led to a change in asymmetric volatility in overall market returns among the original Euro-zone member states. The theory being that the increased integration in European markets brought about the phases that preceded the introduction of the euro should have led to an increase in the inter-dependence of the markets and hence an increase in asymmetric volatility. Our APARCH and TARCH estimates are consistent with the literature as the emerging markets have shown higher alpha and lower beta coefficient estimates than their more developed market counterparts. The gamma coefficient estimates are also consistent with the literature; with emerging markets showing a slightly greater range in the degree of asymmetric volatility.

The main findings of our paper can be summarized as follows. First, the APARCH model struggles empirically to deal with changing volatility regimes for relatively short sample periods. In period 4; the gamma coefficient estimates push against the boundary restrictions set in place and therefore the model becomes difficult to interpret. It is also of interest to note that removing the troublesome period of high volatility failed to improve the interpretability of the model. Conversely increasing the period length considerably, enabled the APARCH model to adequately deal with the stylized features of the data. Second, significant negative skewness in the data does not necessarily imply a significant gamma coefficient estimate using either a TARCH or APARCH model. This was shown in the period 2 estimates for both the APARCH and TARCH models for Luxembourg and Portugal. Third, for Finland, with its strong links to fellow Scandinavian countries that are not a part of the Euro-zone and its Dot com bubble affected economy, does not display similar volatility patterns to its mainland European counterparts. Finally, there has been definite convergence in terms of asymmetric volatility for the Euro-zone countries. In period 1 only the larger economies Germany, France and Italy, together with Austria and Netherlands, displayed evidence of asymmetric volatility. During period 2, the results showed 10 of the 12 countries exhibiting significant gamma coefficients (at the 10% level). Periods 3 and 4 show 11 countries with significant gamma coefficients, the only exception being the aforementioned Finland.

It has been shown in previous literature how European stock markets have become more integrated from around 1996 onwards. The contribution of our paper is to illustrate that asymmetric stock market return volatility has followed a very similar path to stock market integration. The benefits of increased monetary and financial policy co-operation within Europe are evident, with the economies of countries like Ireland and Portugal progressing from a weak state in the early 1990s to relative prosperity by the turn of the new millennium. This increased integration has also meant that negative shocks in one area of the Euro-zone are more likely to have a significant effect on other areas within the currency union. The implications of this for investors is that risk diversification within the Euro-zone has become problematic since the introduction of the single currency.

REFERENCES

Bollerslev, T. (1986) "Generalized autoregressive conditional heteroskedasticity", *Journal of Econometrics,* vol. 31, no. 3: 307-327

Brooks, R. (2007) "Power arch modelling of the volatility of emerging equity markets", *Emerging Markets Review,* vol. 8.no. 2: 124-133

Brooks, R. D., Faff, R. W., Mckenzie, M. D. & Mitchell, H. (2000) "A multi-country study of power ARCH models and national stock market returns", *Journal of International Money & Finance,* vol. 19, no. 3: 377-397

Bun, M. & Klaassen, F. (2002) "Has the Euro Increased Trade?", *Social Science Research Network* (Working Paper Series), 16

Chakrabarti, R. & Roll, R. (2002) "East Asia and Europe during the 1997 Asian collapse: a clinical study of a financial crisis", *Journal of Financial Markets,* vol. 5, no. 1: 1-30

Ding, Z., Granger, C. W. J. & Engle, R. F. (1993) "A long memory property of stock market returns and a new model", *Journal of Empirical Finance,* vol. 1, no. 1: 83-106

Engle, R. F. (1982) "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation", *Econometrica,* vol. 50, vol. 4: 987-1008

Fratzscher, M. (2002) "Financial market integration in europe: on the effects of emu on stock markets", *International Journal of Finance & Economics,* vol. 7, no. 3: 165-193

Hamilton, J. D. & Susmel, R. (1994) "Autoregressive conditional heteroskedasticity and changes in regime", *Journal of Econometrics,* vol. 64, no. 1–2: 307-333

Hentschel, L. (1995) "All in the family Nesting symmetric and asymmetric GARCH models", *Journal of Financial Economics,* vol. 39: 1: 71-104

Jayasuriya, S. (2005) "Stock market liberalization and volatility in the presence of favorable market characteristics and institutions", *Emerging Markets Review,* vol. 6, no. 2: 170-191

Jayasuriya, S., Shambora, W. & Rossiter, R. (2009) "Asymmetric Volatility in Emerging and Mature Markets", *Journal of Emerging Market Finance,* vol. 8, no. 1: 25-43

Kim, S. J., Moshirian, F. & Wu, E. (2005) "Dynamic stock market integration driven by the European Monetary Union: An empirical analysis", *Journal of Banking & Finance,* vol. 29: 10: 2475-2502

Ofek, E. L. I. & Richardson, M. (2003) "DotCom Mania: The Rise and Fall of Internet Stock Prices", *Journal of Finance,* vol. 58, no. 3: 1113-1137

Talpsepp, T. & Rieger, M. O. (2010) "Explaining asymmetric volatility around the world", *Journal of Empirical Finance,* vol. 17, no. 5: 938-956

Taylor, S. (1986) *Modelling Financial Time Series*, *John Wiley & Sons*

Zakoian, J.-M. (1994) "Threshold heteroskedastic models", *Journal of Economic Dynamics and Control,* vol. 18, no. 5: 931-955

[1] In unreported analysis, we estimate the APARCH model for the sample period as a whole, from January 1990 to December 2006. In this case, the same boundary restriction issue for estimating the gamma coefficient does not arise. Emerging markets continue to display larger α and lower β coefficients than their more developed counterparts for the whole sample period. All of the 12 countries exhibit significant γ coefficients and hence evidence of asymmetric volatility for the whole sample period. Lengthening the period used for estimation has allowed the APARCH model to adequately capture the stylized features of the data. The problem with this is however, that using the sample period as a whole does not facilitate comparisons of asymmetric volatility measures across the various stages of the implementation of the Euro.