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VOLATILITY-SPILLOVER EFFECTS IN EUROPEAN STOCK MARKETS

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Supervisor: Professor João Carlos Henrique da Costa Nicolau

Jury:

President: Professor João Luís Correia Duque

Vowels: Professor José Joaquim Dias Curto

Professor João Carlos Henrique da Costa Nicolau

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RESUMO

Durante as últimas décadas, temos visto como diferentes crises financeiras, que tiveram a sua origem em determinadas regiões ou países, se estenderam depois geograficamente, daí que, entender a volatilidade nos diversos mercados de acções se tenha tornado bastante importante para aqueles que têm que tomar as correctas decisões sobre a alocação de activos.

É analisada a transmissão de volatilidade dos EUA e da Europa para diversos mercados individuais de acções de vários países europeus, utilizando para esse fim um modelo GARCH de transmissão de volatilidades.

Encontrámos uma forte evidência estatística da transmissão de volatilidade dos mercados de acções dos EUA e Europa. Para os países da União Económica e Monetária os efeitos da transmissão volatilidade com origem nos EUA são mais fracos, enquanto que os efeitos da transmissão volatilidade com origem na Europa são mais fortes.

Palavras-chave: GARCH, transmissão, índices de acções, introdução Euro, volatilidade

Classificação JEL: C32; F36; G15

ABSTRACT

During the last decades, we have seen how different financial crisis, originated in particular regions and countries, have extended geographically, therefore, understanding volatility in stock markets has taken a very important place in determining the correct asset allocation decisions.

Volatility spillover from the US and European stock markets into individual European stock markets using a GARCH volatility-spillover model is analyzed.

We find strong statistical evidence of volatility spillover from the US and Europe stock markets. For Economic and Monetary Union countries, the US volatility-spillover effects are rather weak whereas the European volatility-spillover effects are strong.

Keywords: euro introduction, GARCH, spillover, stock indexes, volatility

JEL classifications: C32; F36; G15

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1. INTRODUCTION

In the last three years, stock markets had consistent earnings, with indexes recovering from the heavy loss of the beginning of the decade. But, recently, stock markets witness a strong period of correction, the longest one in five years, with the nervousness falling again upon the investors.

This anxiety in the markets has origin in the volatility, which measures the deviation of the returns from its historical behaviour. Volatility turns the assets more risky, pulling the investor away. But, this turbulence that has rocked risky asset markets (equities, commodities, some emerging markets, and so forth) over the past months have multiple and often interlinked causes.

Uncertainty about developments in monetary policy has induced investors to remain cautious. As a result, financial markets witnessed widespread profit-taking at a time when valuations had hit their highest levels in several years. The rise in long-term interest rates since the beginning of the year, as a result of the upturn in growth, the tightening in monetary policies and the increase in inflation expectations in the wake of the reappearance of upward pressures on energy prices, has also played a role. In addition, there have been forerunning signs of a slowdown in late 2006. Lastly, the turmoil that has broken out in some major emerging countries has fuelled concern. As long as the uncertainty clouding the next monetary policy decisions to be taken by the major central banks subsists, the jitters in financial markets might persist. For, under these conditions, volatility is likely to remain high and this will probably dampen investors' appetite for risk, as they have been used in the very last few years to abundant liquidity and stability in asset markets. The situation should stabilise, however. On the one hand, inflationary pressures remain in check in the

United States, as well as Japan and the euro zone: unit labour costs are rising at a slow pace and the pressure exerted by factory products manufactured in low-wage countries persists. On the other hand, the financial situation of companies remains solid overall.

Furthermore, during the last decades, we have seen how different financial crisis, originated in particular regions and countries, have extended geographically. In fact, the interrelation among different countries has been a topic extensively analysed by academics and professionals for a long time. As far as international markets are becoming more and more integrated, information generated in one country can, without any doubt, affect other markets.

Before we finish this introduction, and to better understand the importance of volatility in the stock markets, we present a list of notable recessions, financial crises, depressions and downturns. All dates are approximate as the recessions began and ended in different parts of the world at different times. Also note that before detailed economic statistics began to be gathered in the nineteenth century it was very difficult to tell when recessions occurred, but prior to industrialization economic downturns usually were caused by external actions on the economic system like wars and variations of the weather.

- Great Depression (1929 to late 1930s), stock market crash, banking collapse in the United States sparks a global downturn, including a second but not heavy downturn in the U.S., the Recession of 1937.
- Post-Korean War Recession (1953 - 1954) - The Recession of 1953 was a demand-driven recession due to poor government policies and high interest rates.
- 1973 oil crisis - a quadrupling of oil prices by OPEC coupled with high government spending due to the Vietnam War leads to stagflation in the United States.

- 1979 energy crisis - 1979 until 1980, the Iranian Revolution sharply increases the price of oil
- Early 1980s recession - 1982 and 1983, caused by tight monetary policy in the U.S. to control inflation and sharp correction to overproduction of the previous decade which had been masked by inflation
- Great Commodities Depression - 1980 to 2000, general recession in commodity prices
- Late 1980s recession - 1988 to 1992, collapse of junk bonds and a sharp stock crash in the United States leads to a recession in much of the West
- Japanese recession - 1991 to present, collapse of a real estate bubble and more fundamental problems halts Japan's once astronomical growth
- Asian financial crisis - 1997, a collapse of the Thai currency inflicts damage on many of the economies of Asia
- Early 2000s recession - 2001 to 2003: the collapse of the Dot Com Bubble, September 11th attacks and accounting scandals contribute to a relatively mild contraction in the North American economy.
- October 27, 1997 mini-crash: The Asian financial crisis came to a head in this crash
- Russian financial crisis, 1998
- Dot-com bubble crash - March 2000
- post-9/11 crash - September 2001
- Stock market downturn of 2002 - October 2002
- The Chinese Correction (Chinese market drop) - February 27, 2007: The SSE Composite Index of the Shanghai Stock Exchange tumbles 9% from unexpected sell-

offs, the largest drop in 10 years, triggering major drops in worldwide stock markets - February 27, 2007.

- After the major Chinese market drop, the Dow Jones Industrial Average in the United States drops 416 points amid fears for growth prospects, the biggest one-day slide since the September 11, 2001 terrorist attacks. It was the 7th largest drop in the history of the Dow Jones. Sell orders are made so fast that a second analysis computer has to be used, causing an instantaneous 200-point drop at one point.

For this facts, and as long as world capital markets have become increasingly integrated, information originating from one market is likely to become more important to other markets. So, understanding the behaviour and sources of volatility is critical for pricing domestic securities, for implementing global hedging strategies and asset allocation decisions, risk sharing, economy policy and for evaluating regulatory proposals to restrict international capital flows.

In this paper we will empirically investigate the influence of the US and Europe stock markets on European individual markets returns. Specifically, we will try to estimate the magnitude of volatility-spillover effects in fourteen individual stock markets (EMU and non-EMU).

The aim is, hence, to study the linkages between each individual stock market and the world benchmark markets (namely a US index and a European aggregated index). In particular, we are interested in finding the way in which volatility in each individual market has evolved and to what extent this was influenced by volatility in the US and European markets.

2. A Brief Survey of Literature

One approach widely used to quantify the magnitude of international integration has focused on estimates of volatility-spillover effects. For this purpose, ARCH/GARCH models are used by economists, which in particular, give us an estimate of a time series for the conditional variance of the relevant variables and allows for time-varying second moments.

The autoregressive conditional heteroskedastic (ARCH) model was introduced by Engle (1982) and generalized by Bollerslev (1986, 1987) and Engle, Lilien and Robins (1987), among many others.

The ARCH model, Engle (1982), was developed to capture the effect of changing volatility in a time series, where the conditional variance is a linear function of past square errors as well as possible exogenous variables.

The conditional variance at time *t* is a positive function of the square of last period's error, this in a ARCH(1), which is the simplest representation of this model.

The generalization of the ARCH model, Bollerslev (1986), was by allowing the conditional variance to be a function not only of last period's error squared but also of its conditional variance. The GARCH formulation can also be extended to include squared errors from prior periods.

Engle *et al* (1987) introduced the ARCH-M model, which extends the ARCH model to allow the conditional variance to affect the mean. In this way changing conditional variances directly affect the expected return on a portfolio. In other words they allow the conditional mean to be a function of the conditional variance.

Volatility-spillover effects are present when the unexpected shock of a given variable is driven by the innovation in a different variable. Since it is observed that time series data, and financial variables in particular, have time-varying volatility, the use of an ARCH/GARCH process to model the conditional variance turns out to be very useful. In fact, this point is crucial here, since it allows us to estimate how these effects have evolved through time.

The inclusion of the unexpected shock of a given asset return, estimated in this fashion, as the regressor of a different asset return, allows then to test for the presence of volatility-spillover effects from the first to the second asset.

This methodology has been widely employed with respect to equity markets and has generally concluded that spillover effects have increased in recent years, leading to a loss of diversification gains, in particular in periods of bear markets, which is recognized by using an asymmetric GARCH structure.

The GARCH model has been extensively applied in studies analysing relations between financial markets. This methodology allows differentiating the effects described by Engle *et al.* (1990) as heat waves and meteor showers. The hypothesis of heat waves is consistent with the idea that most of the volatility sources are country specific. On the contrary, the meteor shower hypothesis is consistent with the idea of shock transmission between different markets, countries or regions.

Hamao *et al.* (1990) was the first study that applied the univariate GARCH methodology to analyse relations between international markets. In that study, daily volatility transmission among the New York, London and Tokyo stock markets is analysed, using a two stages approach. In particular, they find volatility spillovers from New York to

London and Tokyo and from London to Tokyo, being the related coefficients significant and positive.

Other studies that have used univariate GARCH specifications in two stages to analyse volatility transmission between financial markets are Engle *et al.* (1990) or Wang, Rui and Firth (2002).

Wang *et al.* (2002) provides empirical evidence that Hong Kong stocks are priced to reflect information from the London market as well as the Hong Kong market. First, the contemporaneous returns and volatility spillovers are bidirectional: there is strong evidence of returns and volatility spillovers from the SEHK (Stock Exchange of Hong Kong) to the LSE (London Stock Exchange) and from the LSE to the SEHK. However, the spillover effect from the SEHK to the LSE is stronger than that from the LSE to the SEHK.

Along literature, several types of GARCH models are used, for example a GARCH in mean model (GARCH-M) is used by Lin *et al.* (1994), and Hsin (2004).

Lin, Engle and Ito (1994) investigate the volatility spillover between the US and Japanese stock markets. Evidence of volatility-spillover effects is found. They used a two-stage approach that is asymptotically equivalent to a multivariate procedure if the conditional mean equations are correctly specified and if the shocks in the innovation and responding markets are mutually uncorrelated.

Hsin (2004) purposed in his article to study stock market comovements among G-7 and major Asia-Pacific developed markets in a total of 10 markets. Firstly, he used a basic aggregate shock model following the aggregate shock model proposed by Lin *et al.* (1994). By taking account of possible asymmetry in volatility, persistence of volatility, and the prevailing risk-return relationships, the paper uses the threshold AR(1)-GARCH(p,q)-in-mean model representing the return generating functions of equity index returns. A similar framework is also adopted by Bekaert and Harvey (1997). Lastly, an extended aggregate shock model with macroeconomic common factors is implemented. The use of the aggregate shock model proposed provide empirical results provide evidence of significant international transmission effects among these major world markets, in terms of both returns and volatility, mostly in a positive direction. The U.S. market, as expected, is the leading market in the sense that it has the most pervasive and significant impact on all markets across continents. Meanwhile, the U.S. market seems to have a different relationship with European from Asian markets. In fact, their evidence indicates that there are strong regional transmission effects.

But the most commonly used specifications in the univariate analysis of volatility transmission among markets has been the GJR - The basic model was originally proposed by Glosten, Jagannathan, and Runkle (1989) (GJR) to capture the leverage effect of volatility in stock returns - which has introduced asymmetries by means of dummy variables, see Wang *et al.* (2002) and Eom *et al.* (2002) and the EGARCH model, see Kim (2004) and Lee *et al.* (2004).

Kim (2004) investigates the nature of the stock market linkages in the advanced Asia-Pacific stock markets with the U.S and the information leadership of the U.S. and Japan in the region. Kim (2004) highlights the relevance of the variable trade volume as explicative variable for the conditional variance. The study suggest that its introduction can reduce persistency in volatility or, what is the same, that it can be an important source of conditional heteroscedasticity. It has been found that both the contemporaneous return and volatility linkages were significant and tended to be more intense after the 1997 Asian crisis period. However, the investigation of the dynamic information spillover effects in terms of returns, volatility and trading volume from the U.S. and Japan did not produce such timevarying influence. In general, significant dynamic information spillover effects from the U.S. were found in all the Asia-Pacific markets, but the Japanese information flows were relatively weak and the effects were country specific.

Lee *et al.* (2004) uses a two-stage procedure to investigate the information transmission from the NASDAQ to the Asian second board markets. Lee *et al.* (2004) first found was that, there is strong evidence of lagged returns and volatility spillovers from the NASDAQ market to the Asian second board markets when they exclude contemporaneous main board market returns. Second, there is strong evidence of contemporaneous and lagged returns and volatility spillovers from the local main board markets to the corresponding second board markets.

Edwards and Susmel (2003) suggest that an almost integrated behaviour of volatility could be due to the existence of structural changes. Edwards and Susmel (2001) also apply a bivariate SWARCH model and conclude that high volatility states tend to be related to international crisis. Their results find evidence of interdependency rather than contagion.

Bekaert and Harvey (1997), Ng (2000), Bekaert, Harvey and Ng (2005), and Baele (2005) investigate volatility-spillover effects on various equity markets using similar volatility-spillover models. They all find evidence of volatility spillover effects.

Bekaert and Harvey (1997) included Portugal in their analyses of emerging stock markets, with the following results: Portugal have returns that average above 25%, once the emerging markets return are characterized by high volatility, Portugal also had one higher than 33% (one of the highest of the study). The autocorrelation measures the persistence (or predictability) of the market returns based on past market returns. This persistence could be driven by market imperfections, such as infrequent trading of the component securities, or by some fundamental forces, such as predictable changes in sensitivities to world risk factors. In the MSCI sample, Portugal was one of eight countries with autocorrelations above 20%. Not only in Portugal was the estimation ill-behaved. Also, global optima may not have been found. Portugal, was one of two countries were the estimation of the extended model failed. The test on the variance disturbances shows evidence against the specification in only Portugal. It is possible that these residual diagnostic tests lack power.

The results suggest that only a small amount of variance is being driven by world factors. In 16 of the 19 countries, the average proportion of variance being driven by world factors is less than 10%. Portugal is one of the countries that are most affected by world factors.

The evidence also suggests that volatility decreases after liberalizations, a particularly dramatic decrease was found for Portugal.

Ng (2000) finds evidence of volatility-spillover effects to various Pacific Basin stock markets from Japan (regional effects) and the US (global effects). Baele (2005) investigates the volatility-spillover effects from the US (global effects) and aggregate European (regional effects) stock markets into various individual European stock markets. Bekaert and Harvey (1997) investigate the volatility of emerging stock markets. They distinguish between global and local shocks.

Also, Bekaert, Harvey and Ng (2005), included Portugal in their study. They find that U.S. trade impacts the conditional betas in eight of ten European countries (exceptions are Austria and Portugal), and that, Portugal was one of two countries that adhering the world CAPM at a level of 10%.

Baele (2005) propose four different bivariate models to explain stock market returns in Europe and USA and concludes that the model that best describes data is a bivariate Normal model with regime changes.

Related literature considers integration (in contrast to segmentation) of asset markets, cf. e.g. Bekaert and Harvey (1995) and Karolyi and Stulz (1996).

An important question in the two stages estimation of univariate models is to determine which and how regressors are included in the mean and variance equations to represent contagion or movement transmission between markets. Several studies use squared residuals as a proxy for the volatility of the influential market (see, for example, Hamao et al. (1990), Lin et al. (1994), Pyun et al. (2000), Wang et al. (2002) or Lee et al. (2004), among others). Other studies prefer to use the directly as a regressor estimated conditional variance series (Hamao *et al.* (1990) and Kim (2004)).

Finally, among the empirical literature using GARCH methodology, there exist several studies that, based on the world factor model of Bekaert and Harvey (1997), analyze the influence of global, regional and local factors on domestic volatilities (see Aggarwal *et al.* (1999), Ng (2000) or Hsin (2004)).

The studies about transmission of volatility effects are not only about indices and equities, take for instance the article from Eom *et al.* (2002) who's study takes us to another perspective one looks at the transmission of credit risk between two of the world's largest swap markets, and they find that yen swap spreads are highly correlated with the interest rate differentials between the two markets, while dollar swap spreads have virtually zero correlation with interest rate differentials. Furthermore they get evidence that credit risk factor in the swap markets is country-specific, rather than global in nature. These findings also show a strong transmission of volatility from the dollar swap spread and the interest rate differential to the yen swap spread, as well as an asymmetric volatility effect of dollar swap spreads on yen swap spreads. Contrary to the results for the yen swap spreads, we find weak volatility spillover effects, if any, from other markets to dollar swap spreads, and strong asymmetric effects of the own lagged shock in the dollar swap spreads.

Another example is the paper from Engle *et al.* (1990), that initiate the volatility-spillover analysis, and that seeks to explain the causes of volatility clustering in exchange rates throw a two test hypotheses of, the already mentioned, heat waves and meteor showers. Using the GARCH model (methodology that allows to differentiate the effects described) to specify the heteroskedasticity across intra-daily market segments they find that the empirical evidence is generally against the heat wave hypothesis, or that the volatility as only country-specific autocorrelation.

Lastly, several studies highlight the relevance of the variable trade volume as explicative variable for the conditional variance, see Pyun et al. (2000) and Kim (2004). They suggest that its introduction can reduce persistency in volatility or, what is the same, that it can be an important source of conditional heteroskedasticity.

More, Wongswan (2003), analyses the effect of foreign countries macroeconomic announcements over conditional variance and trade volume. Unlike most previous studies, which only investigate information transmission through the impact on return volatility, this paper makes a first attempt to model the transmission through intraday volume. The results show strong and significant evidence of information transmission through this channel as well.

Other studies, for example, Karolyi (1995) and Booth *et al.* (1997), use multivariate GARCH models.

Karolyi (1995) examines the short-run dependence in price movements for stocks traded on the Toronto Stock Exchange (TSE) and the New York Stock Exchange (NYSE). The main finding was that inferences about the magnitude and persistence of return innovations that originate in either market and that transmit to the other market depend importantly on how the cross-market dynamics in volatility are modelled.

Booth *et a.l* (1997) uses a multivariate EGARCH model to investigate the asymmetric impact of good news and bad news on the volatility transmission among four Scandinavian countries.

Other studies use both univariate and multivariate ARCH models, one Engle and Susmel (1993), investigate whether international stock markets have the same volatility process, they test for a time-varying volatility process in international stock markets and the relationship between these markets within and outside each region.

With the univariate ARCH model the authors observed some similarities in the studied markets. They also observed that second moments might be related for some countries. With the multivariate ARCH the authors find two groups of countries with similar time-varying volatility.

French, Schwert and Stambaugh (1987), examine the relation between stock returns and stock market volatility uses two statistical approaches to investigate the relation between expected stock returns and volatility. In the first, they use daily returns to compute estimates of monthly volatility. There is a strong negative relation, however, between excess holding period returns and the unpredictable component of volatility. This can be interpreted as indirect evidence of a positive ex ante relation. Daily returns were also used to estimate ex ante measures of volatility with a generalized autoregressive conditional heteroskedasticity (GARCH) model. The GARCH-in-mean model of Engle, Lilien and Robins (1987) is used to estimate the ex ante relation between risk premiums and volatility. They found evidence that the expected market risk premium (the expected return on a stock portfolio minus the Treasury bill yield) is positively related to the predictable volatility of stock returns.

Cohen *et al.* (1980) follow a microstructure approach, to show that six interrelated empirical phenomena reported in literature can be attributed to friction in the trading process causing a bid-ask-spread and price-adjustment delays that differ systematically across securities.

There are also, several studies about days of the week effect. Gibbons and Hess (1981) document negative mean returns for U.S. stocks on Mondays, while Fama (1965) documents higher return variance for U.S. stocks on Mondays.

3. METHODOLOGY

A volatility-spillover model will be applied to separate the shock to the selected European market returns in three effects:

- Local (own country)
- Regional (European Index)
- Global (USA Index)

We will use the framework proposed by Charlotte Christiansen, 2005, Volatility Spillover Effects in European Bond Markets, European Financial Management, forthcoming, which was applied successfully to European bond markets. Instead, we propose to investigate volatility spillover effects in stock markets.

This estimation process is equivalent to one used by Bekaert, Harvey and Ng (2005) which represents only practical differences to the two-step estimation procedure applied by Ng (2000) and Baele (2005).

This three-step procedure model will allow us to distinguish world from regional effects, using univariate GARCH regressions as the estimation procedures.

We will model the returns of the US and European Indices. The returns on the local markets are assumed to follow AR-GARCH processes that are extended to include volatility-spillover effects. The conditional volatility of the unexpected return is divided into the proportion caused by US, European and own country effects.

We will support through Granger causality tests with four lags, cf. Granger (1969), that causality goes from the US market to the European market, that is, moving from world to regional effects and not in the opposite direction. The European return fails to Granger cause the US return, whereas the US return Granger causes the European return.

US Returns

The first step consists in estimating a univariate GARCH (1,1), for the US market.

The conditional return on the US index is assumed to evolve according an AR(1) process,

$$R_{US,t} = c_{0,US} + c_{1,US} R_{US,t-1} + e_{US,t} \tag{1}$$

where, $e_{US,t} \mid I_{t-1} \sim N(0, \sigma^2_{US,t})$ the idiosyncratic shock, is normally distributed with mean 0 and the conditional variance follows the GARCH (1,1) specification.

$$E(e^2_{us,t} \mid I_{t-1}) = \sigma^2_{US,t} = \omega_{US} + \alpha_{US} e^2_{US,t-1} + \beta_{US} \sigma^2_{US,t-1} \tag{2}$$

Where $\omega_{US} > 0$ and $\alpha_{US}, \beta_{US} \geq 0$ to make sure the variance is positive, and $\alpha_{US} + \beta_{US} \leq 1$ and $\left| c_{1,US} \right| < 1$ to ensure stationarity.

Equation (1) defines the mean-return of the US market as a simple auto-regressive process of order one.

European Returns

We follow the assumption that the shocks on the return of the European market is driven by the idiosyncratic shock of the US market's return. The difference for the US market lies in the assumption that there are spillover effects from the world market to the European market. These may be captured, both from the inclusion of the lag of the US

Index in the mean-return equation, and from the assumption that the shock on the return of the European market is driven by the idiosyncratic shock of the US market's return.

Hence, the European market is described by the following three equations, where $\varepsilon_{E,t}$ represents the total unexpected shock on the return, and $e_{E,t}$ the idiosyncratic shock, therefore, the return on the European Index is assumed to be described by the following extended AR (1) specification:

$$R_{E,t} = c_{0,E} + c_{1,E} R_{E,t-1} + \gamma_{\mathrm{E},t-1} R_{US,t-1} + \phi_{E,t-1} e_{US,t} + e_{E,t} \tag{3}$$

$$\varepsilon_{E,t} = \phi_{E,t-1} e_{US,t} + e_{E,t} \tag{4}$$

where, just like before, $e_{E,t} \mid I_{t-1} \sim N(0, \sigma^2_{E,t})$ the idiosyncratic shock, is normally distributed with mean 0 and the conditional variance follows the GARCH (1,1) specification.

The conditional mean of the European return depends on its own lagged return as well as the lagged US return. The mean spillover effects are introduced by the lagged US return, $R_{US,t-1}$. The volatility spillover from the US to Europe takes place via the penultimate term, $e_{US,t}$. Thus, the European return depends on the US idiosyncratic shock.

In the practical estimation, the residual from equation (1) is used in place of $e_{US,t}$.

The idiosyncratic shock, $e_{E,t}$, has mean 0 and conditional variance:

$$E(e^2_{E,t} \mid I_{t-1}) = \sigma^2_{E,t} = \omega_E + \alpha_E e^2_{E,t-1} + \beta_E \sigma^2_{E,t-1} \tag{5}$$

Country *i* Returns

The last step consists of providing a model for the individual country returns. The mean specification for the European return in equation (3) is extended even further.

$$R_{i,t} = c_{0,i} + c_{1,i} R_{i,t-1} + \gamma_{i,t-1} R_{US,t-1} + \delta_{i,t-1} R_{E,t-1} + \phi_{i,t-1} e_{US,t} + \psi_{i,t-1} e_{E,t} + e_{i,t} \qquad (6)$$

Again, $e_{i,t} \mid I_{t-1} \sim N(0, \sigma^2_{i,t})$ the idiosyncratic shock, is normally distributed with mean 0 and the conditional variance follows the GARCH (1,1) specification.

The conditional country i mean return depends on the lagged US, European and own return. This specification allows mean spillover effects from both the US and European returns to the individual countries by the lagged returns $R_{US,t-1}$ and $R_{E,t-1}$.

Volatility spillover effects from the US and Europe to the individual countries are introduced by the idiosyncratic US and Europe shocks, $e_{US,t}$ and $e_{E,t}$.

In the estimation, the residuals from equation (1) and (3) are applied as explanatory variables.

The idiosyncratic country shocks have the same distributional assumptions as the one before, therefore $e_{i,t}$ has mean 0 and conditional volatilities follow the GARCH (1,1) specification:

$$E(e^2_{i,t} \mid I_{t-1}) = \sigma^2_{i,t} = \omega_i + \alpha_i e^2_{i,t-1} + \beta_i \sigma^2_{i,t-1} \qquad (7)$$

Notice that the non-negative and stationarity conditions that were required for coefficients of equation (2), should apply to the coefficients of equations (5) e (7).

Variance Ratios

We assume the idiosyncratic shocks $e_{US,t}$, $e_{E,t}$ and $e_{i,t}$ (for *i*= 1,…,N) to be independent. However, this will not be applied to the unexpected returns:

$$\varepsilon_{US,t} = e_{US,t} \tag{8}$$

$$\varepsilon_{E,t} = \phi_{E,t-1} e_{US,t} + e_{E,t} \tag{9}$$

$$\varepsilon_{i,t} = \phi_{i,t-1} e_{US,t} + \psi_{i,t-1} e_{E,t} + e_{i,t} \tag{10}$$

Following this identity we are assuming, from (8) that for the US no other market has any influence on their market[1].

It follows from (10) that the conditional variance of the unexpected return of country i based on the information available at time $t-1$ (I_{t-1}) is given by:

$$E(\varepsilon_{i,t}^2 \mid I_{t-1}) = h_{it} = \phi_{i,t-1}^2 \sigma_{US,t}^2 + \psi_{i,t-1}^2 \sigma_{E,t}^2 + \sigma_{i,t}^2 \tag{11}$$

The conditional variance of the unexpected return for country i depends on the variance of the US, European, and own idiosyncratic shocks.

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[1] Using this approach, we are discarding the hypothesis of having spillover effects form the European market to the US market, and from each of the individual markets to both the European and US markets. Apart from the intuitive appeal of moving from world to regional effects, the fact that we include spillover effects from the US to Europe and not the contrary should be proved by standard Granger causuality tests, cf. Granger (1969).

When for example the US idiosyncratic volatility is large, the volatility of the unexpected returns for country i also tends to be large if $\phi_{i,t-1}$ is significant.

This is what is denoted by volatility spillover effects.

So the significance of the parameters $\phi_{i,t-1}$ and $\psi_{i,t-1}$ determine whether volatility spillover effects from the US and Europe, respectively, are presented in country i.

The conditional variance of the European unexpected return depends only on the US and its own idiosyncratic volatility, as shown in equation (9). So, there is volatility spillover from the US to the aggregate European stock market. The conditional variance of the US unexpected return is equal to the variance of the US idiosyncratic shock, also seen in equation (8).

Equation (11) also show us that the return volatility of market i is positively related to the conditional variances of the US and European market. Under this specification, we can investigate whether potential asymmetric effect in the US and /or regional markets induce asymmetry in the conditional return volatility of any equity market.

We measure the proportion of the variance of the unexpected return of country i, that is caused by the US and European volatility spillover effects, respectively, as given by equation (11). To this end, we define the following variance ratios:

$$VR_{i,t}^{US} = \frac{\phi_{i,t-1}^2 \sigma_{US,t}^2}{h_{i,t}} \qquad (12)$$

Equation (12) gives us the proportion of the total of the unexpected return that is directly explained by the variance of the US market.

$$VR_{i,t}^{E} = \frac{\psi_{i,t-1}^{2}\sigma_{E,t}^{2}}{h_{i,t}} \tag{13}$$

Equation (13) gives us the proportion justified by the European market's volatility.

The variance ratios take on values between 0 and 1.

The remaining part of the variance of the unexpected return for country i is caused by pure local effects;

$$VR_{i,t}^{i} = 1 - VR_{i,t}^{US} - VR_{i,t}^{E} = \frac{\sigma_{i,t}^{2}}{h_{it}} \tag{14}$$

The above equation retrieves the weight of the local shock.

The variance ratios provide a measure of the impact of global, regional, and local effects on the local variance.

We find evidence in favour of presence of volatility spillover effects when the coefficients $\phi_{E,t-1}$, $\phi_{i,t-1}$ and $\psi_{i,t-1}$ are statistically significant.

The specification of the functions for the spillover parameters, γ_t, δ_t, ϕ_t, and ψ_t, differentiates the volatility-spillover models. We, just like Charlotte Christiansen (2005), use three different specifications.

First, the spillover parameters are assumed to be constant throughout the entire sample period; the *constant spillover model*:

$$\gamma_{i,t} = \gamma_i \forall t$$

$$\delta_{i,t} = \delta_i \forall t$$

$$\phi_{i,t} = \phi_i \forall t$$

$$\psi_{i,t} = \psi_i \forall t \quad (15)$$

Second, the spillover parameters are assumed to be constant before and after the introduction of the euro; the *euro spillover model*:

$$\gamma_{i,t} = \gamma_{0,i} + \gamma_{1,i} D_t$$

$$\delta_{i,t} = \delta_{0,i} + \delta_{1,i} D_t$$

$$\phi_{i,t} = \phi_{0,i} + \phi_{1,i} D_t$$

$$\psi_{i,t} = \psi_{0,i} + \psi_{1,i} D_t \quad (16)$$

The dummy variable D_t equals 0 before 1 January 1999 (i.e. before the introduction of the euro) and 1 after 1 January 1999. Using a dummy variable is the simplest way to capture the changes produced by the introduction of the euro. We contribute to the general volatility spillover modelling literature by introducing the euro spillover model.

Third, the spillover parameters undergo a gradual transition by taking on a different value each year in the sample, the *trend spillover model*:

$$\gamma_{i,t} = \gamma_{0,i} + \gamma_{1,i} DT_t$$

$$\delta_{i,t} = \delta_{0,i} + \delta_{1,i} DT_t$$

$$\phi_{i,t} = \phi_{0,i} + \phi_{1,i} DT_t$$

$$\psi_{i,t} = \psi_{0,i} + \psi_{1,i} DT_t \qquad (17)$$

The function DT_t equals 1 for the observations of year 1988, 2 for the observations of year 1989, 3 for the observations of year 1990, etc.

4. DATA

On January 1, 1999, starts stage three of the EMU the euro becomes the single currency of the member states of the EMU, with the irrevocability of the conversion rates between the different former national currencies of the participating member states and the euro. From that day, the responsibility for the definition and execution of the monetary policies was delivered to the European System of Central Banks. A single monetary policy started to be conducted in euros, and the monetary markets of all the member states started to work in euros. Public Debt in the member states started to be issued in the new currency. All financial operations processed throw the banking system, which do not involved coins and motes, could be done either in national currency or in euros. This situation last for three years.

On January 1, 2002, starts the euro cash changeover with the introduction of euro banknotes and coins. The new currency becomes the sole legal tender in the euro area by the end of February 2002.

In their study of emerging markets, which included Portugal, the data used by Bekaert and Harvey (1997), ends on December 1992.

Furthermore, Bekaert, Harvey and Ng (2005), whose paper includes in their analyses the Portuguese and Spanish cases the data period ranges from January 1980/January 1986 to December 1998.

We use daily data from January 1 1990 to September 31 2006. This range has two purposes, the first one is the study of volatility transmission in European stock markets, and the second is to investigate if the introduction of the single currency provides us with some changes in the volatility behaviour as stated before.

We use financial time series of fourteen European Index, for which corresponds the same number of countries, namely Austria - ATX Index, Belgium - BEL 20, Denmark - KFX Index (OMX Copenhagen 20), England - FTSE 100, Finland - HEX Index (OMX Helsinki 25), France - CAC 40, Germany - DAX Index, Ireland - ISEQ Index, Italy - MIB 30, Netherlands - AEX Index, Portugal - PSI 20, Spain - IBEX 35, Sweden - OMX Index (OMX Stockholm 30), Swiss - SMI Index.

For the US market effect, we use the S&P 500, which is an index containing the stocks of 500 Large-Cap corporations, most of which are American. All of the stocks in the index are those of large publicly held companies and trade on the two largest US stock markets, the New York Stock Exchange and Nasdaq. The S&P 500 is one of the most widely watched index of large-cap US stocks. It is considered to be a bellwether for the US economy and is a component of the Index of Leading Indicators The index is the most notable of the many indices owned and maintained by Standard & Poor's.

For the regional market effect and as a European Index we will use the Dow Jones Euro STOXX 50 Index, which is a capitalization-weighted index of 50 European blue-chips stocks from those countries participating in the EMU. It has the stated objective to provide a blue-chip representation of Supersector leaders in the Eurozone. Covers Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. As a unique aspect, we can state that this index captures approximately 60% of the free float market capitalisation of the Dow Jones EURO STOXX Total Market Index, which in turn covers approximately 95% of the free float market capitalisation of the represented countries.

In Figure 1 to 3 we present the prices, returns and squared returns for the 16 stock market indexes used in this analysis. All the data was collected from Bloomberg.

Figure 1: Stock Markets Indexes

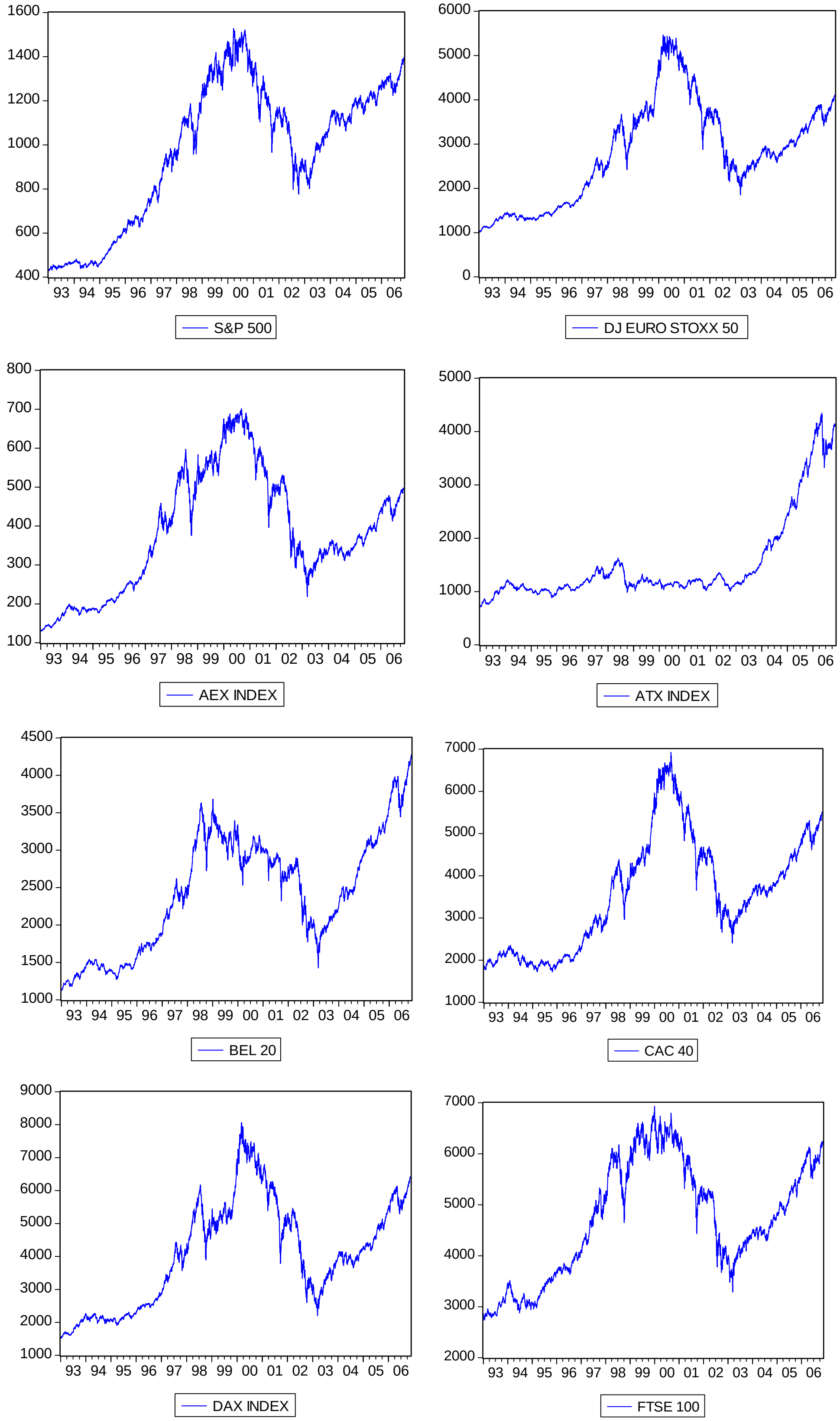


Figure 1: Stock Markets Indexes **(continued)**

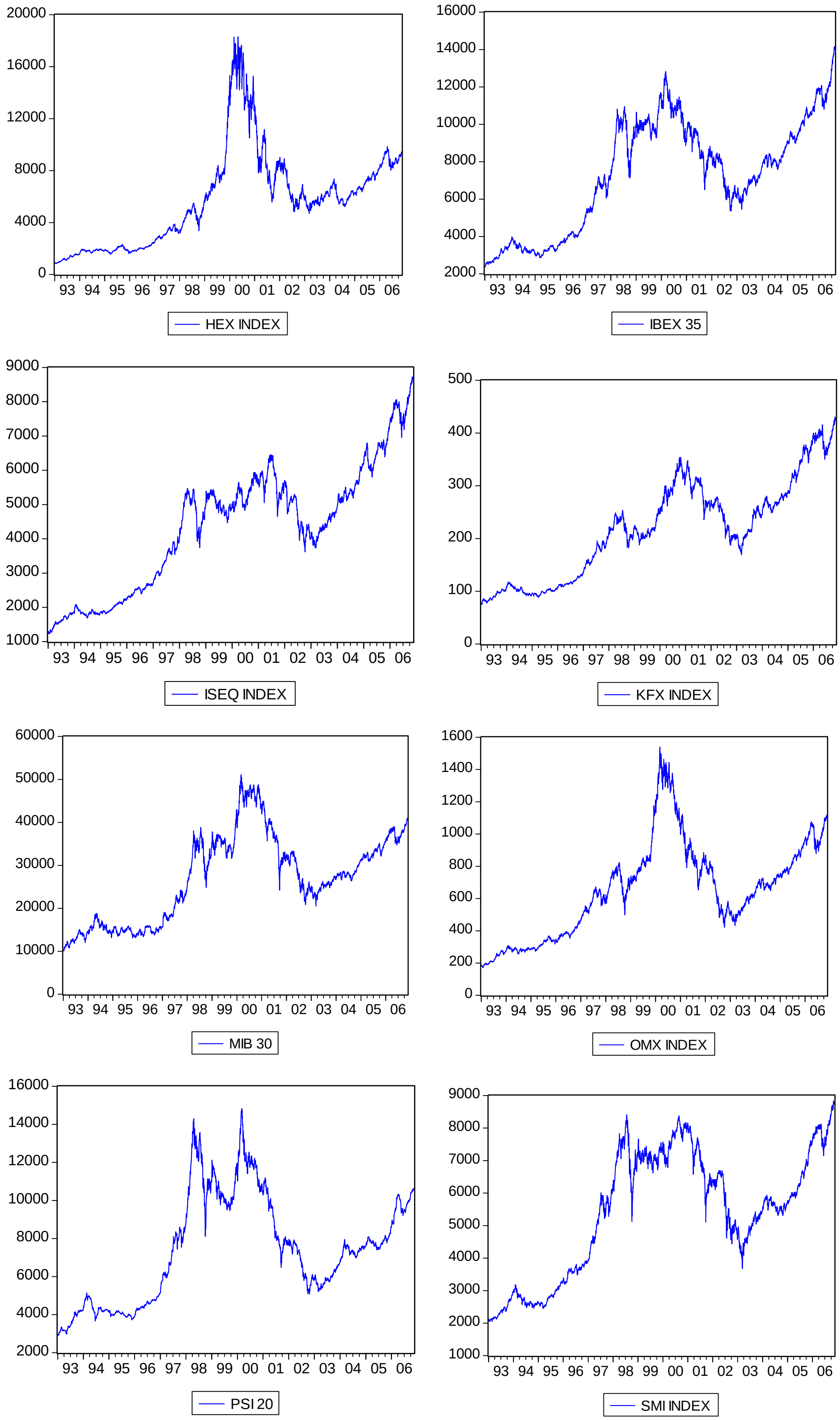


Figure 2: Returns of the Stock Markets Indexes

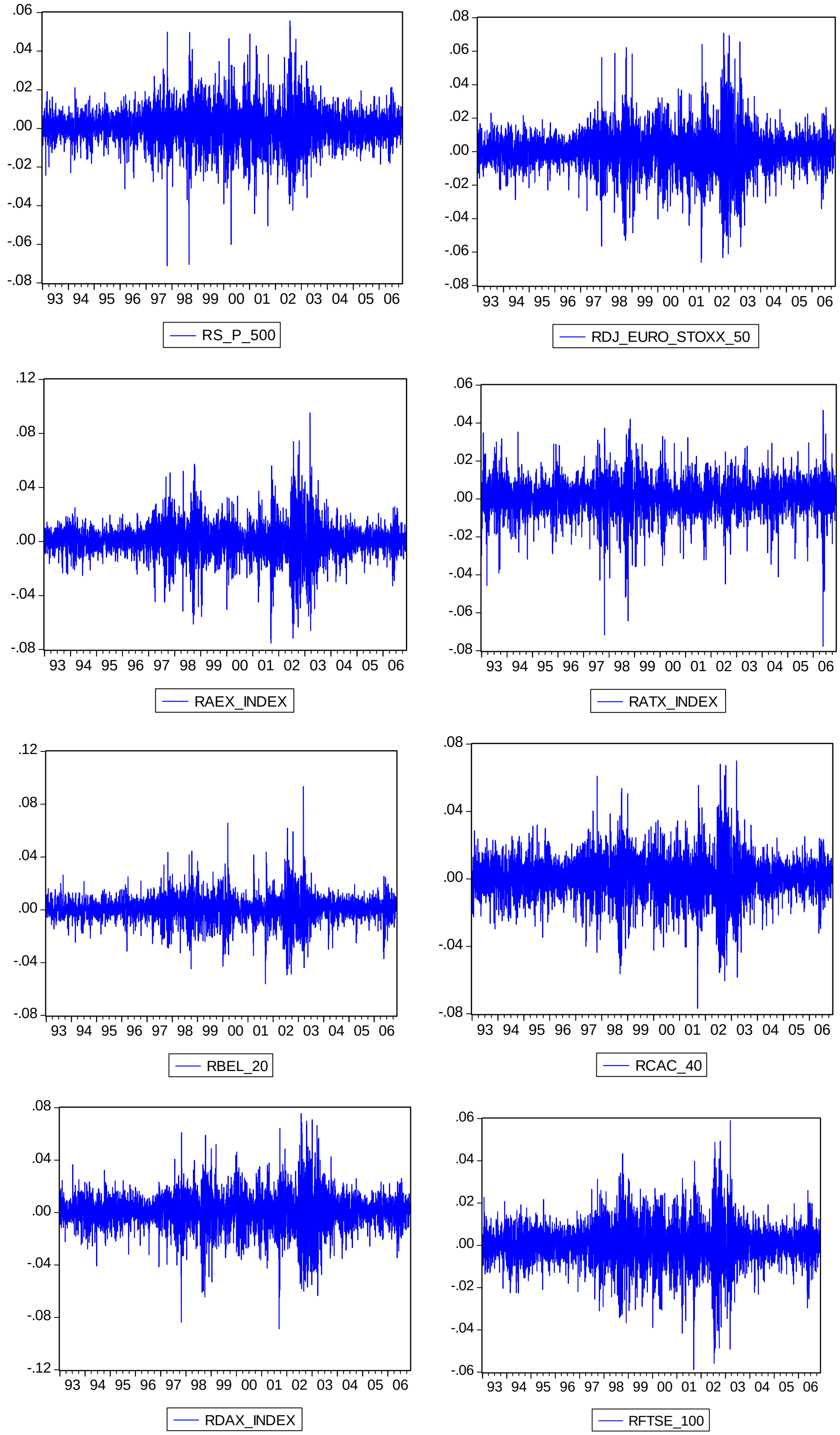


Figure 2: Returns of the Stock Markets Indexes (continued)

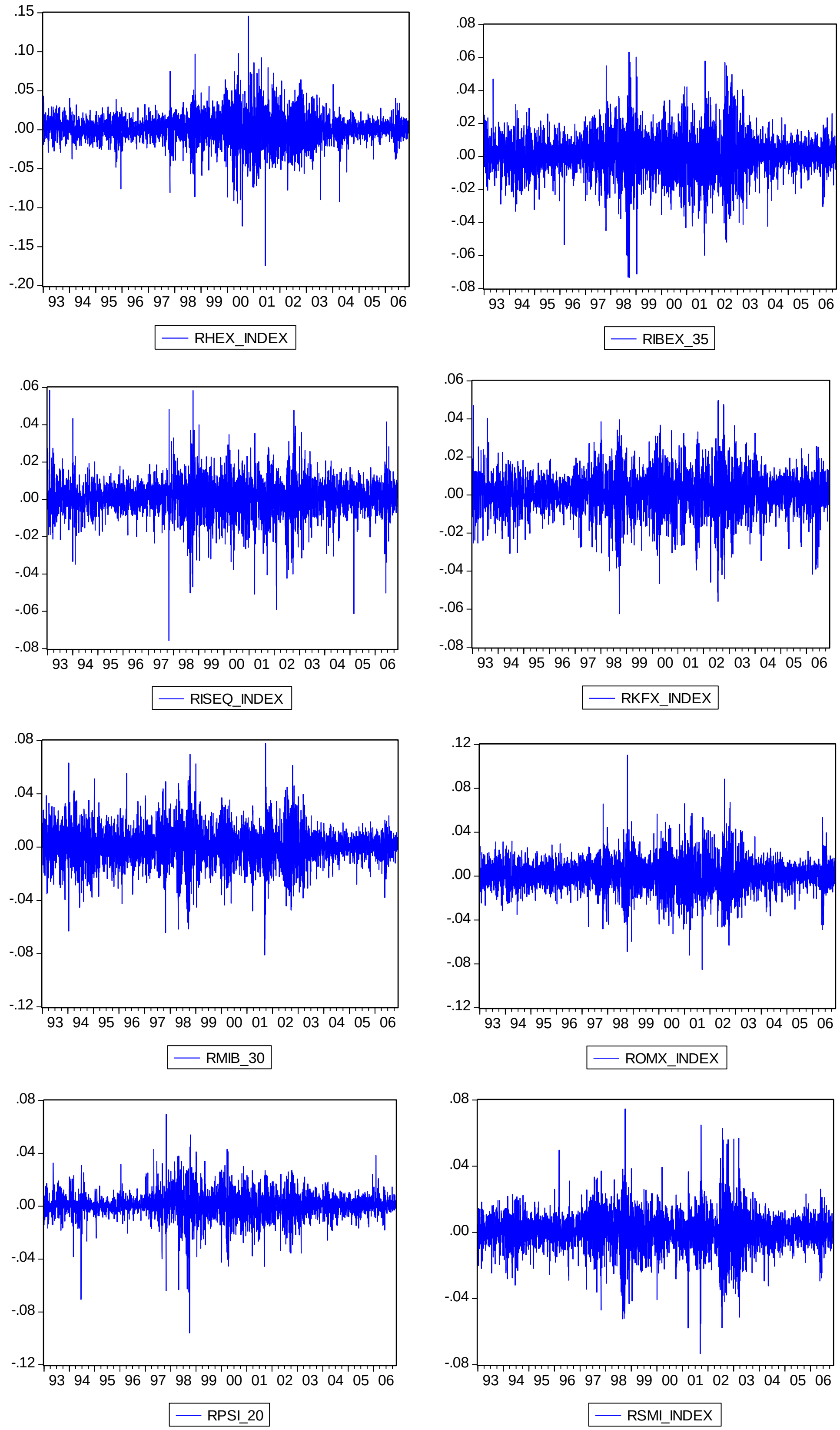


Figure 3: Squared Returns of the Stock Markets Indexes

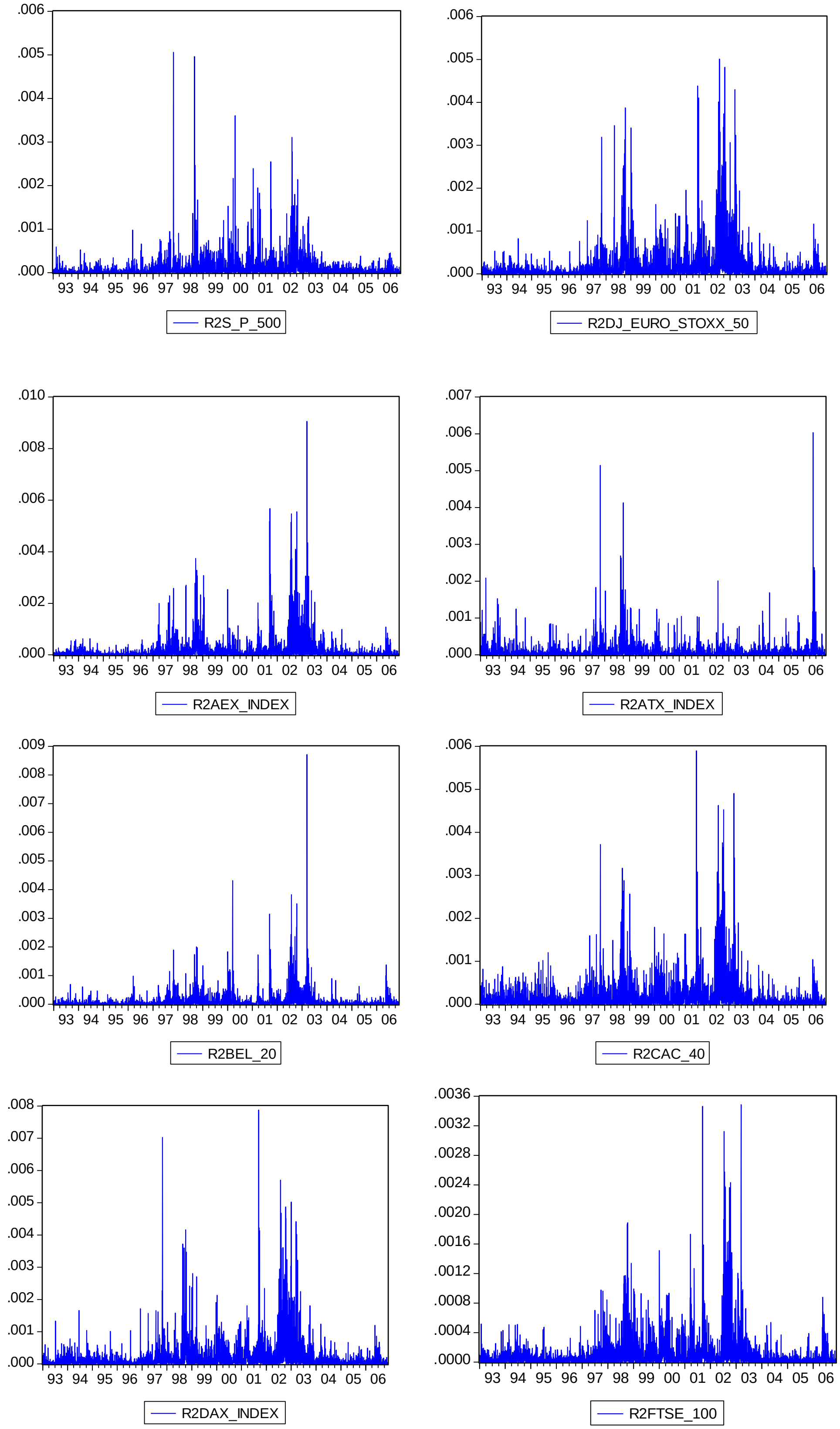
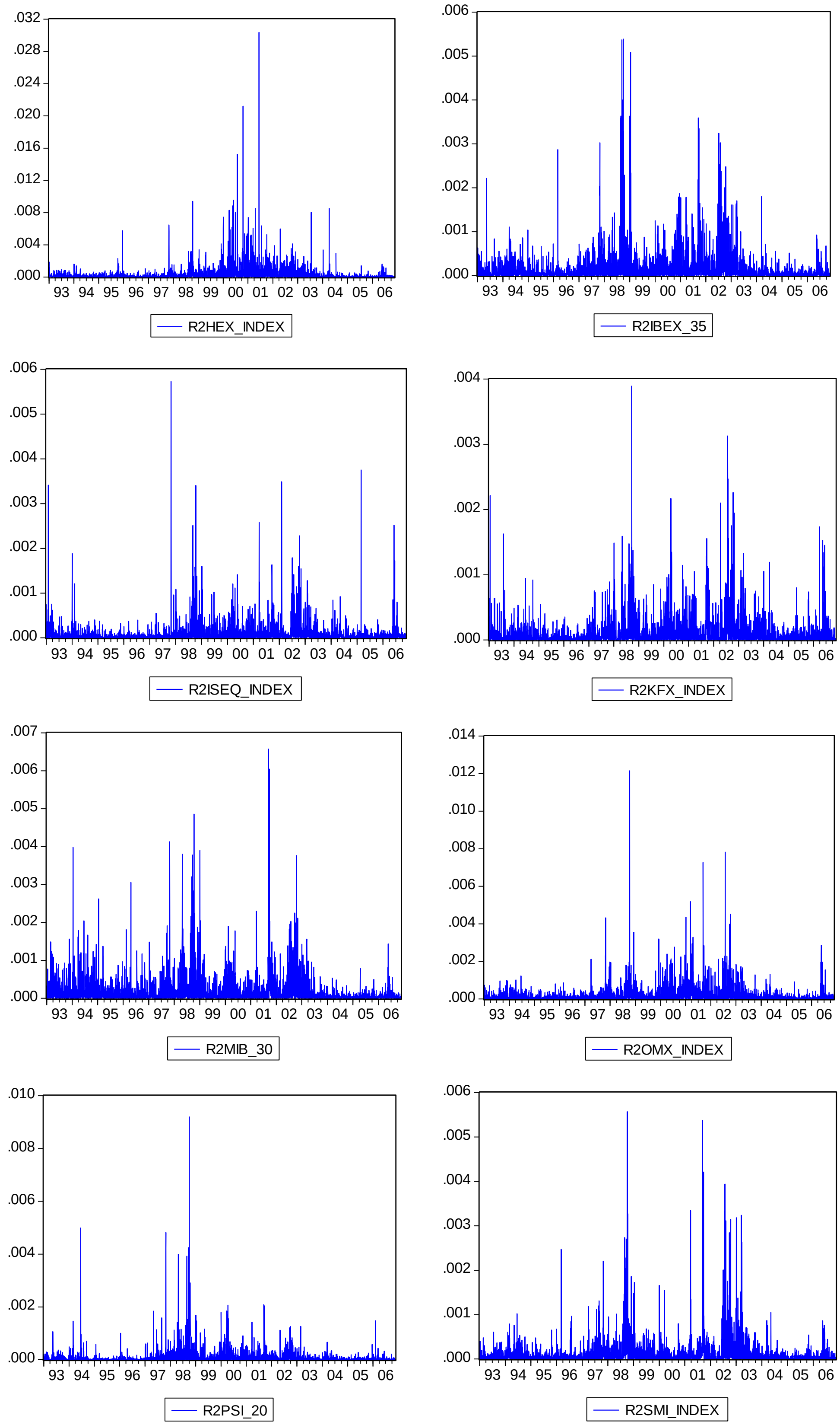


Figure 3: Squared Returns of the Stock Markets Indexes **(continued)**



5. RESULTS

We estimate the model using the E-views ARCH – Autoregressive Conditional Heteroskedasticity method with heteroskedasticity consistent covariance (Bollerslev-Wolldridge) option.

But before, we have estimated our model without the ARCH effect in order to realize a Lagrange multiplier test, an ARCH-LM test.

The results indicate the presence of heteroskedasticity, in other words there is a strong evidence of the presence of ARCH effect, what justify the model through the use of ARCH effects.

Constant Spillover Model

Table 2 reports the results from estimating the constant spillover model. The US results are shown in the first row of Table 2. The AR(1) parameter $\hat{c}_{1,US}$ (0.002772) is small, positive, and insignificant, which implies no (or weak negative) first-order autocorrelation, consistent with the summary statistics reported in Table 1.

Table 1: Individual returns descriptive statistics

	S_P_500	DJ_EURO_STOXX_50	AEX_INDEX	ATX_INDEX	BEL_20	CAC_40	DAX_INDEX	FTSE_100
Mean	0.000322	0.000381	0.000371	0.000471	0.000368	0.0003	0.000394	0.000217
Std. Dev.	0.010088	0.012845	0.013244	0.009991	0.010272	0.01311	0.014309	0.010213
Skewness	-0.109395	-0.123233	-0.146997	-0.711736	0.187818	-0.098236	-0.256856	-0.195656
Kurtosis	7.240339	6.930415	8.012655	7.700101	9.230212	5.871337	6.584973	6.30697
Jarque-Bera	2718.525	2338.614	3801.933	3636.676	5874.337	1249.034	1977.773	1672.155
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	3619	3619	3619	3619	3619	3619	3619	3619

	HEX_INDEX	IBEX_35	ISEQ_INDEX	KFX_INDEX	MIB_30	OMX_INDEX	PSI_20	SMI_INDEX
Mean	0.000672	0.000497	0.000542	0.000481	0.00039	0.000506	0.000349	0.000394
Std. Dev.	0.01881	0.012782	0.009686	0.010471	0.013797	0.014244	0.009771	0.011337
Skewness	-0.353184	-0.201535	-0.459242	-0.306728	-0.1006	0.065787	-0.61686	-0.189297
Kurtosis	9.559798	6.048451	8.339604	5.645314	5.57024	6.558304	11.42771	7.694348
Jarque-Bera	6563.948	1425.813	4426.488	1111.94	1002.254	1911.864	10939.69	3344.595
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	3619	3619	3619	3619	3619	3619	3619	3619

Table 2: Constant spillover model

The table reports the results from estimating the constant spillover model. Estimated parameters and standard errors below - *, §, #, indicates that the value is significant at a 1%, 5% or 10% level of significance, respectively.

	$c_{0,i}$	$c_{1,i}$	γ_t	δ_t	ϕ_t	ψ_t	$100\omega_i$	α_i	β_i
USA - S&P 500	**0,000526** *	**0,002772**					**0,000051** *	**0,059655** *	**0,936453** *
	0,000126	0,001704					0,000000	0,009437	0,009009
Europe - DJ EURO STOXX 50	**0,000528** *	**-0,152494** *	**0,460649** *		**0,460744** *		**0,000053** *	**0,058781** *	**0,936601** *
	0,000130	0,015798	0,203510		0,017875		0,000015	0,010498	0,009940
Austria - ATX INDEX	**0,000573** *	**0,089716** *	**0,233552** *	**-0,042135** *	**-0,015181**	**0,308103** *	**0,000320** *	**0,084527** *	**0,872979** *
	0,000125	0,018420	0,017008	0,014402	0,020663	0,014472	0,000001	0,016237	0,022273
Belgium - BEL 20	**0,000613** *	**0,063105** *	**0,253553** *	**-0,061152** *	**0,048149** *	**0,561646** *	**0,000031** *	**0,063973** *	**0,930157** *
	0,000090	0,018536	0,013171	0,015206	0,012970	0,010899	0,000000	0,009887	0,008197
Denmark - KFX INDEX (OMX Copenhagen 20)	**0,000531** *	**0,066155** *	**0,275540** *	**-0,061299** *	**0,002869**	**0,457630** *	**0,000029** *	**0,033714** *	**0,962417** *
	0,000125	0,018594	0,017722	0,019996	0,020004	0,014547	0,000000	0,006324	0,006340
England - FTSE 100	**0,000364** *	**-0,058053** *	**0,299017** *	**-0,065458** *	**0,082766** *	**0,586081** *	**0,000007**	**0,033495** *	**0,964734** *
	0,000083	0,018269	0,011338	0,014816	0,012187	0,011672	0,000000	0,005663	0,005730
Finland - HEX INDEX (OMX Helsinki 25)	**0,000719** *	**0,035001** #	**0,568210** *	**-0,138494** *	**0,053089** #	**0,802301** *	**0,000022**	**0,023301** *	**0,975190** *
	0,000164	0,020199	0,021661	0,024899	0,028302	0,019854	0,000000	0,004730	0,004749
France - CAC 40	**0,000512** *	**-0,113509** *	**0,373844** *	**-0,003126**	**0,001636**	**0,934283** *	**0,000001**	**0,035872** *	**0,964371** *
	0,000059	0,018316	0,007600	0,018889	0,008423	0,007789	0,000000	0,006248	0,005544
Germany - DAX INDEX	**0,000637** *	**-0,193301** *	**0,410208** *	**0,087680** *	**0,050716** *	**0,997297** *	**0,000005**	**0,070383** *	**0,932738** *
	0,000070	0,018552	0,009963	0,021362	0,011923	0,010785	0,000000	0,010796	0,008688
Ireland - ISEQ INDEX	**0,000554** *	**0,053885** *	**0,351119** *	**-0,022721**	**0,022495**	**0,358826** *	**0,000074** *	**0,062412** *	**0,927095** *
	0,000110	0,018745	0,020474	0,015818	0,018426	0,014564	0,000000	0,011978	0,011877
Italy - MIB 30	**0,000548** *	**-0,008117**	**0,209298** *	**-0,059700** *	**0,015465**	**0,757792** *	**0,000008**	**0,051723** *	**0,948790** *
	0,000088	0,018672	0,012196	0,017463	0,013984	0,011217	0,000000	0,007977	0,007346
Netherlands - AEX INDEX	**0,000548** *	**-0,047197** §	**0,378846** *	**-0,061712** *	**0,020363** #	**0,879320** *	**0,000013** #	**0,082096** *	**0,918286** *
	0,000068	0,019196	0,009705	0,019980	0,011070	0,008883	0,000000	0,013217	0,010181
Portugal - PSI 20	**0,000389** *	**0,140339** *	**0,159584** *	**-0,036487** *	**-0,014768**	**0,350271** *	**0,000172** *	**0,122962** *	**0,856284** *
	0,000100	0,020332	0,015293	0,013214	0,020154	0,013994	0,000000	0,019317	0,019482
Spain - IBEX 35	**0,000677** *	**0,045226** §	**0,302244** *	**-0,124856** *	**0,032533** §	**0,786922** *	**0,000018** #	**0,068518** *	**0,931862** *
	0,000091	0,019941	0,012346	0,019012	0,013243	0,011155	0,000000	0,009858	0,008223
Sweden - OMX INDEX (OMX Stockholm 30)	**0,000763** *	**-0,039593** §	**0,418922** *	**-0,084903** *	**0,064599** *	**0,767493** *	**0,000085** *	**0,077111** *	**0,915038** *
	0,000128	0,018427	0,018535	0,019114	0,019287	0,016895	0,000000	0,011212	0,010712
Swiss - SMI INDEX	**0,000596** *	**0,007436**	**0,288773** *	**-0,080822** *	**0,031517** §	**0,655216** *	**0,000042** *	**0,065619** *	**0,927329** *
	0,000098	0,018222	0,013979	0,017249	0,013779	0,012526	0,000000	0,010464	0,009990

The volatility process is highly persistent in that $\hat{\alpha}_{US} + \hat{\beta}_{US}$ equals 0.996. The second row of Table 2 reports the results for the European index. Own lagged and US lagged returns have contradictory importance to the conditional mean; $\hat{c}_{1,E}$ (-0.152494) and $\hat{\gamma}_{\mathrm{E}}$ (0,460649) since they are both small, but significant, despite one is positive and the other negative as showed above. In addiction, the contemporaneous US residual is also significant in explaining the current mean value, $\hat{\phi}_{E}$ is significant. Thus, there is evidence of volatility spillover from the US to the European stock market and evidence of mean spillover.

The robust joint Wald test for no US-spillover effects at all, $H_0 : \gamma_{\mathrm{E}} = \phi_E = 0$, is strongly rejected. The volatility process is highly persistent ($\hat{\alpha}_{E} + \hat{\beta}_{E}$ = 0.99).

Lastly, the models for the individual countries are estimated. The models include mean and volatility-spillover effects from both the US and Europe. The bottom rows of Table 2 provide the results. For all countries, the returns show negative or no first-order autocorrelation. The conditional volatility processes are highly persistent. In fact, in some cases the restriction that $\hat{\alpha}_{i} + \hat{\beta}_{i} < 1$ is required (the exceptions are France, Germany, Italy, Netherlands and Spain). This has the repercussion that some of the conditional variances evolve according to Integrated GARCH processes. Still, the conditional volatilities are not very high, since they roughly rise above 1.

The US mean-spillover parameter, $\hat{\gamma}_{i}$, is significant in all individual countries equations.

Only for German Index, the European mean-spillover effects, i.e. $\hat{\delta}_i$ is positive and significant, for France and Ireland the coefficient is not significant, for the rest of the scope of our analyses the evidence of European mean-spillover effects, is negative and significant.

The robust Wald test for the joint hypothesis of no mean-spillover effects $H_0: \gamma_i = \delta_i = 0$ changes part of our conclusion, since we reject H_0 in all occasions meaning that there are significant mean-spillover effects.

For all the countries there are significant volatility-spillover effects from Europe, i.e. $\hat{\psi}_i$ is individually significant, additionally there also exist volatility-spillover, i.e. $\hat{\phi}_i$, is individually significant in Belgium, England, Finland, Ireland, Netherlands, Spain, Sweden and Swiss stock market indexes, which is slightly more than half of the countries that we are studying.

The robust Wald tests for the joint hypothesis of no volatility-spillover effects, $H_0: \phi_i = \psi_i = 0$, is rejected for all countries. The results also lead us to reject the null hypotheses of no US-spillover effects ($H_0: \gamma_i = \phi_i = 0$) as well as no European-spillover effects ($H_0: \delta_i = \psi_i = 0$) for all countries. Finally, the null hypothesis of no spillover effects at all is rejected in all cases: $H_0: \gamma_i = \delta_i = \phi_i = \psi_i = 0$. All the results we achieve in the Wald tests for the stock markets are in line with the one from the Bond markets in the Charlotte Christiansen (2005) results**.** To summarise, there are indications of volatility-spillover effects from both the S&P 500 and DJ EURO STOXX 50 stock markets into all the individual stock markets, less strong indications of mean-spillover effects from the US and European markets.

So far, we have only discussed the significance of the spillover parameters. The relative size of the parameters is not particularly relevant for evaluating the quantitative influence of the US and European stock markets on the individual stock markets. To assess the importance of the US and European volatility-spillover effects on the variance of the unexpected return of country *i*, the time series of the variance ratios $VR_{i,t}^{US}$, $VR_{i,t}^{E}$, $VR_{i,t}^{i}$ from equations (12)-(14) are calculated. Table 3 reports the mean of the variance ratios for each country.

Table 3: Variance ratios – constant spillover model

The table reports the mean and standard deviation of the US, European, and own variance ratios for the constant spillover model:

	US		Europe		Own Country	
	Mean	Stdev.	Mean	Stdev.	Mean	Stdev.
Austria - ATX INDEX	0,0003	0,0002	0,1193	0,8805	0,0806	0,0807
Belgium - BEL 20	0,0031	0,0013	0,4235	0,1287	0,5734	0,1290
Denmark - KFX INDEX (OMX Copenhagen 20)	0,0000	0,0000	0,2247	0,0914	0,7753	0,0914
England - FTSE 100	0,0095	0,0043	0,4748	0,1251	0,5157	0,1258
Finland - HEX INDEX (OMX Helsinki 25)	0,0013	0,0008	0,3081	0,1488	0,6905	0,1492
France - CAC 40	0,0000	0,0000	0,7311	0,1880	0,2689	0,1880
Germany - DAX INDEX	0,0019	0,0009	0,7030	0,1241	0,2951	0,1243
Ireland - ISEQ INDEX	0,0007	0,0003	0,1818	0,0795	0,8175	0,0796
Italy - MIB 30	0,0002	0,0001	0,4762	0,2496	0,5236	0,2497
Netherlands - AEX INDEX	0,0004	0,0002	0,7026	0,1231	0,2970	0,1231
Portugal - PSI 20	0,0003	0,0002	0,1806	0,0951	0,8191	0,0952
Spain - IBEX 35	0,0009	0,0005	0,5361	0,1738	0,4629	0,1740
Sweden - OMX INDEX (OMX Stockholm 30)	0,0029	0,0014	0,4079	0,1406	0,5892	0,1410
Swiss - SMI INDEX	0,0011	0,0005	0,4550	0,1294	0,5439	0,1295

Over the period, on average, the US volatility-spillover effects make up between 0% and 0.95% of the conditional variance of the unexpected return of country i. For most countries the mean of the US variance ratio is around 0.16%, only in one case it is considerably higher; England with a 0.95%. It is remarkable that the US volatility spillover effects are particularly weak comparable the European volatility spillover as we are going to show. The average European variance ratios range between 12% and 73% for the EMU-member countries plus Denmark, whereas the European variance ratios for the Non-EMU countries (England, Denmark and Sweden) and the Non- EU, Swiss, are at the average of the results achieved. Finally, the purely local volatility effects are larger for Austria, Ireland and Portugal (means of 81.75%, 81.91% and 88%, respectively) than for the other countries (the means range between 27% and 78%). To all purposes of our study all the Non-EMU countries and the Non-EU country behave like EMU-member countries, which give an idea of how integrated the euro countries are. Figures 4 to 7 show the time series evolution of the variance ratios for Germany, UK (representing the non-EMU countries), Portugal and Spain. We chose these countries because Germany and the UK are a wide representation of the European stock markets, and the most liquid ones; and Portugal and Spain because of the interest that those two indexes bring to our study once we are in their financial space. The European variance ratio generally increases over the sample period for all countries except (again) Sweden and the UK, for which it appears to be stable.

Figure 4: Variance ratios - Germany - constant spillover model

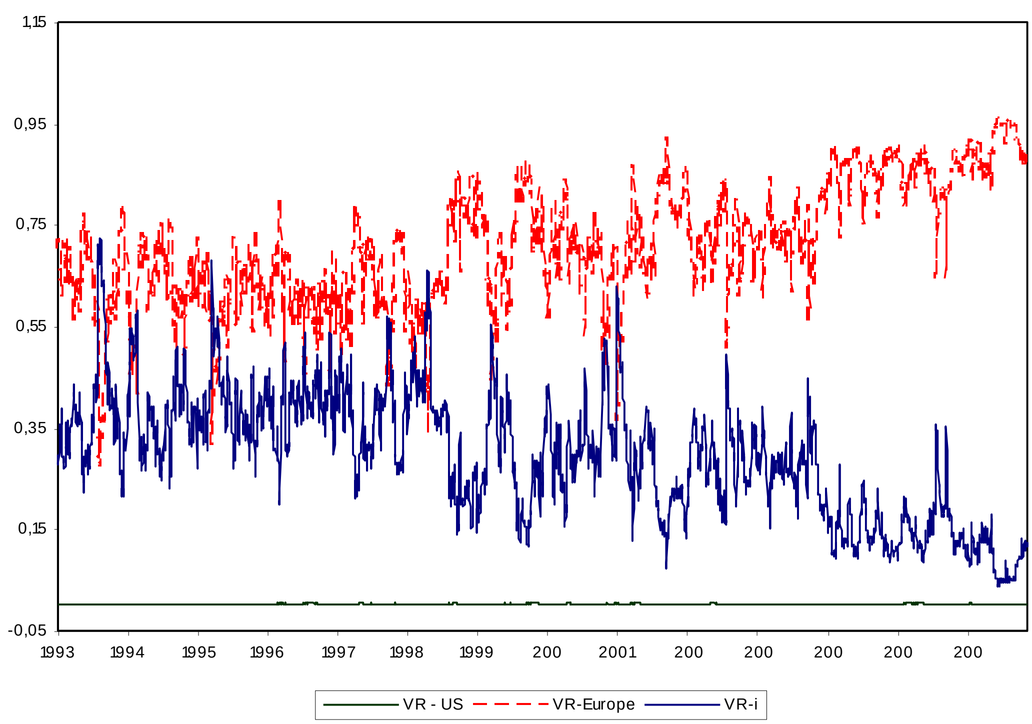


Figure 5: Variance ratios - UK - constant spillover model

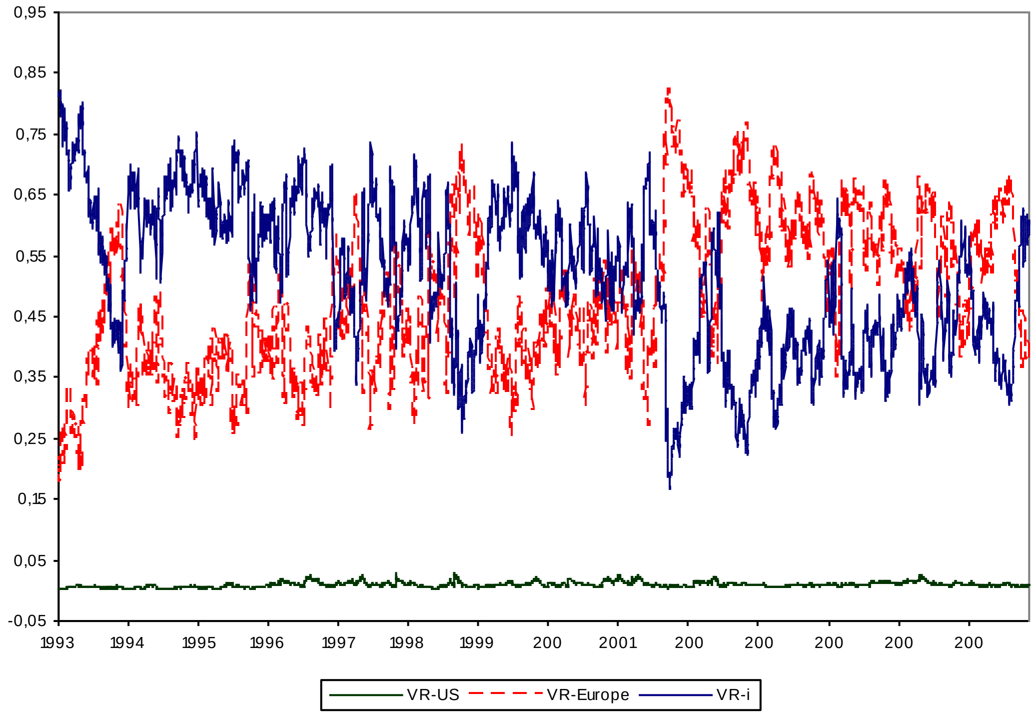


Figure 6: Variance ratios - Portugal - constant spillover model

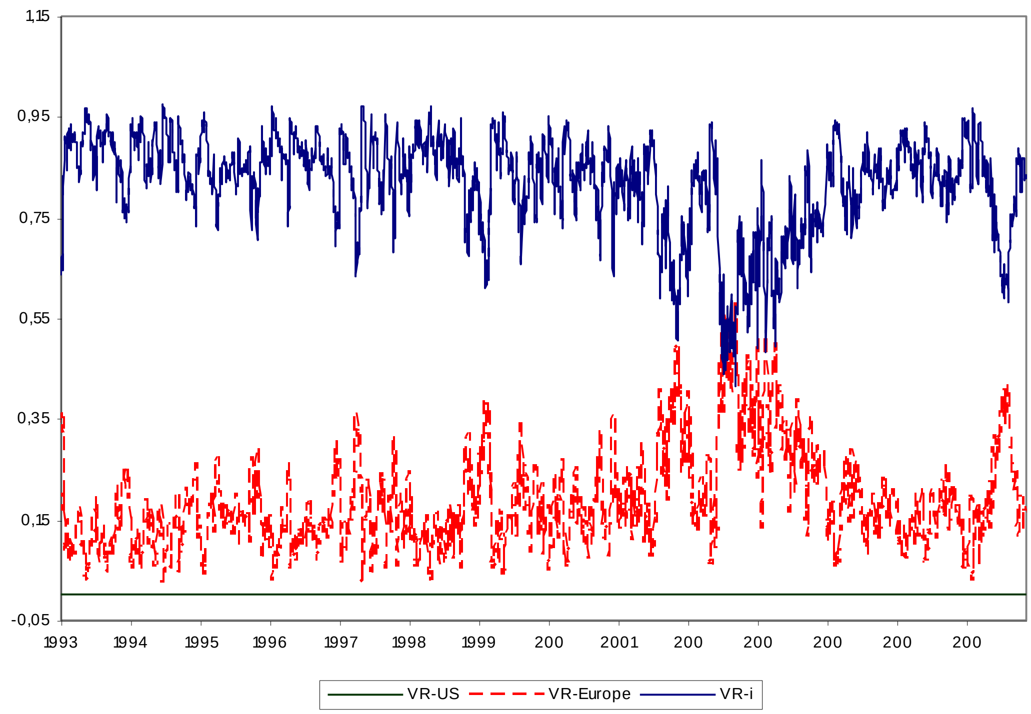
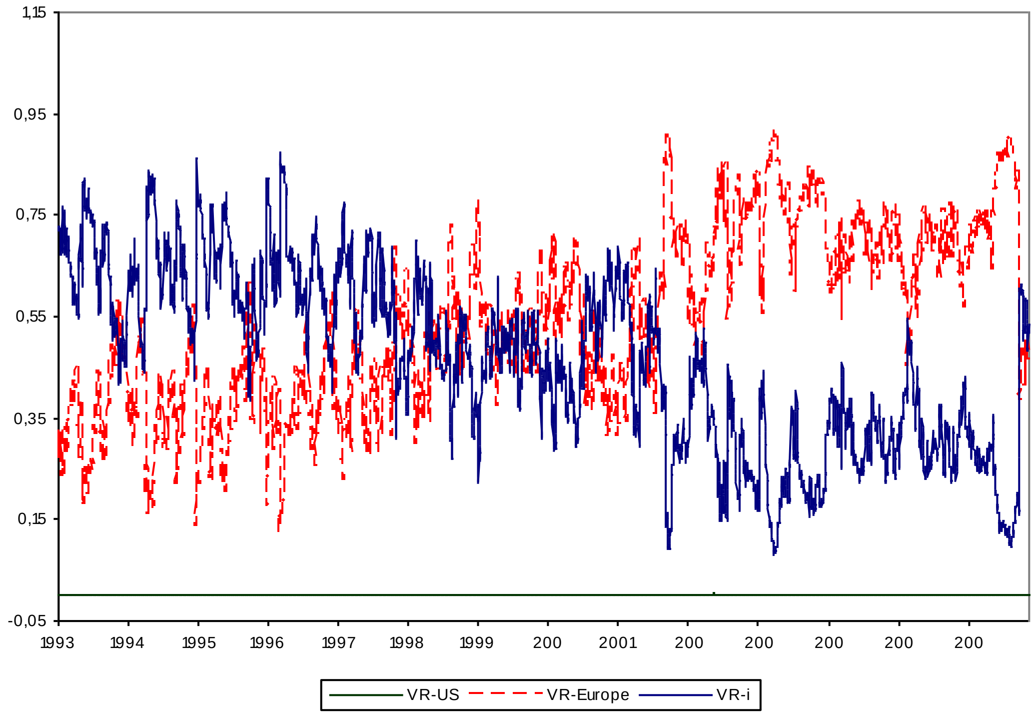


Figure 7: Variance ratios - Spain - constant spillover model



Regarding Portuguese and Spanish stock markets (Figures 6 and 7) we detect that they have dissimilar behaviours that we believe come from the different size of the stock markets and their consequent liquidity. Notice that from the Portuguese PSI 20, a small index for a small open economy (Portugal) was expected that de European Variance Ratio had a greater influence over the PSI 20 volatility, instead is the own country effect that has that prevalence. In opposition, in the IBEX 30, a more liquid stock market we can observe a behaviour, more in line with the expected, with a greater weight of the European variance ratio and a downgrading own country effect, this reversion of effects takes places around 1999. Please remember that the Euro, the 'single currency' of the European Monetary Union, was adopted on January 1, 1999 by 11 Member States.

The results regarding the relative size of volatility-spillover effects are in line with results from Baele (2005). Our conclusions are contrary to the ones from Ilmanen (1995) who states that world factors are more important than local factors.

Europe Spillover Model

Continuing with the framework proposed by Charlotte Christiansen (2005), we will now report the results from estimating the euro spillover model, which tries to make a register of the changes brought by the introduction of the European single currency. This effect is achieved by the introduction of a dummy variable, i.e. by letting the spillover parameters take on different values before and after the introduction of the euro, cf. equation (16).

To do so we keep the US returns specifications equal to the constant spillover model, $R_{US,t} = c_{0,US} + c_{1,US} R_{US,t-1} + e_{US,t}$ where $e_{US,t}$ has mean 0 and conditional variance, $\sigma^2_{US,t} = \omega_{US} + \alpha_{US} e^2_{US,t-1} + \beta_{US} \sigma^2_{US,t-1}$. But now we will change the European return in order to be described by the following extended AR(1), $R_{E,t} = c_{0,E} + c_{1,E} R_{E,t-1} + (\gamma_{0,E} + \gamma_{1,\mathrm{E}} D_t) R_{US,t-1} + (\phi_{0,E} + \phi_{1,E} D_t) e_{US,t} + e_{E,t}$ where $e_{E,t}$ has mean 0 and conditional variance, $\sigma^2_{E,t} = \omega_E + \alpha_E e^2_{E,t-1} + \beta_E \sigma^2_{E,t-1}$. On the other hand the Country *i* returns assume the following specification for country *i* (*i*=1,…,N), $R_{i,t} = c_{0,i} + c_{1,i} R_{i,t-1} + (\gamma_{0,i} + \gamma_{1,i} D_t) R_{US,t-1} + (\delta_{0,i} + \delta_{1,i} D_t) R_{E,t-1} + (\phi_{0,i} + \phi_{1,i} D_t) e_{US,t} + (\psi_{0,i} + \psi_{1,i} D_t) e_{E,t} + e_{i,t}$ where $e_{i,t}$ has mean 0 and conditional variance: $\sigma^2_{i,t} = \omega_i + \alpha_i e^2_{i,t-1} + \beta_i \sigma^2_{i,t-1}$. D_t equals 0 before January 1, 1999 and 1 hereafter.

At this point we also going to report the results about the mean and standard deviation of the US, European, and own variance ratios for the euro spillover model, $VR_{i,t}^{US} = \frac{(\phi_{0,i} + \phi_{1,i} D_t)^2 \sigma_{US,t}^2}{h_{i,t}}$, $VR_{i,t}^{E} = \frac{(\psi_{0,i} + \psi_{1,i} D_t)^2 \sigma_{E,t}^2}{h_{i,t}}$, and $VR_{i,t}^{i} = 1 - VR_{i,t}^{US} - VR_{i,t}^{E}$., where $\sigma_{US,t}$ and $\sigma_{E,t}$ are the conditional volatility of the US and European idiosyncratic shock, respectively and $h_{i,t}$ is the conditional variance of the unexpected return of country *i*. Table 4 contains the results from estimating the euro spillover model.

Table 4: Euro spillover model

The table reports the results from estimating the euro spillover model. Estimated parameters and standard errors below - *, §, #, indicates that the value is significant at a 1%, 5% or 10% level of significance, respectively.

	$c_{0,i}$	$c_{1,i}$	$\gamma_{0,i}$	$\gamma_{1,i}$	$\delta_{0,i}$	$\delta_{1,i}$	$\phi_{0,i}$	$\phi_{1,i}$	$\psi_{0,i}$	$\psi_{1,i}$
USA - S&P 500	**0,000526** *	**0,002772**								
	0,000126	0,001704								
Europe - DJ EURO STOXX 50	**0,000526** *	**-0,147940** *	**0,509626** *	**-0,087977** §			**0,309643** *	**0,260583** *		
	0,000129	0,015695	0,029559	0,037391			0,027421	0,036137		
Austria - ATX INDEX	**0,000513** *	**0,071980** *	**0,411022** *	**-0,214712** *	**-0,046319** #	**0,002696**	**0,123853** *	**0,008494**	**0,548738** *	**-0,321433** *
	0,000124	0,018683	0,033834	0,038931	0,026243	0,029113	0,031826	0,037364	0,028332	0,033152
Belgium - BEL 20	**0,000609** *	**0,065905** *	**0,312367** *	**-0,034174**	**-0,052343** §	**-0,040435** #	**0,242061** *	**0,107631** *	**0,535006** *	**0,055753** §
	0,000090	0,018631	0,020750	0,026629	0,020855	0,024002	0,017698	0,022739	0,019092	0,023495
Denmark - KFX INDEX (OMX Copenhagen 20)	**0,000533** *	**0,066760** *	**0,320643** *	**-0,001136**	**-0,070356** §	**-0,015581**	**0,178900** *	**0,058390** #	**0,535950** *	**-0,106883** *
	0,000124	0,018684	0,025838	0,035496	0,028631	0,034041	0,021908	0,033191	0,024911	0,031289
England - FTSE 100	**0,000376** *	**-0,057500** *	**0,308399** *	**0,043697** #	**-0,061389** *	**-0,030489**	**0,319619** *	**0,073191** *	**0,559919** *	**0,053882** §
	0,000082	0,017972	0,019716	0,024259	0,019607	0,020062	0,018637	0,022277	0,019557	0,022980
Finland - HEX INDEX (OMX Helsinki 25)	**0,000731** *	**0,037927** #	**0,645006** *	**-0,019095**	**-0,129480** *	**-0,047658**	**0,283467** *	**0,228997** *	**0,713582** *	**0,166984** *
	0,000163	0,020112	0,036271	0,047277	0,034147	0,039322	0,044020	0,054625	0,032840	0,041991
France - CAC 40	**0,000534** *	**-0,127928** *	**0,440579** *	**-0,014503**	**-0,046984** #	**0,035011**	**0,379352** *	**0,141641** *	**0,980417** *	**-0,029236**
	0,000052	0,017781	0,022006	0,023300	0,027485	0,021689	0,019633	0,020762	0,017766	0,019466
Germany - DAX INDEX	**0,000652** *	**-0,173307** *	**0,600488** *	**-0,213532** *	**0,079876** *	**-0,050401** #	**0,242154** *	**0,406137** *	**0,961667** *	**0,051140** §
	0,000066	0,017223	0,020118	0,023136	0,029422	0,026407	0,023144	0,025412	0,021511	0,023951
Ireland - ISEQ INDEX	**0,000527** *	**0,046620** §	**0,438553** *	**-0,101338** §	**0,018434**	**-0,070919** *	**0,134538** *	**0,082676** *	**0,352732** *	**0,013292**
	0,000110	0,018870	0,032244	0,040244	0,021540	0,027211	0,021692	0,031695	0,024023	0,030813
Italy - MIB 30	**0,000542** *	**-0,019243**	**0,435509** *	**-0,196006** *	**-0,115107** *	**0,046488**	**0,316572** *	**0,117705** *	**0,987333** *	**-0,238374** *
	0,000088	0,018455	0,035956	0,038392	0,036358	0,033334	0,039347	0,040876	0,030514	0,032866
Netherlands - AEX INDEX	**0,000559** *	**-0,042421** §	**0,478068** *	**-0,065968** *	**-0,126608** *	**0,046469** §	**0,329700** *	**0,177410** *	**0,840322** *	**0,070137** *
	0,000066	0,018512	0,017620	0,021005	0,026289	0,022193	0,018238	0,021056	0,018006	0,020377
Portugal - PSI 20	**0,000368** *	**0,142479** *	**0,152165** *	**0,049621**	**0,032640**	**-0,110377** *	**0,046055**	**0,157954** *	**0,325365** *	**0,023515**
	0,000100	0,020448	0,027595	0,033173	0,026058	0,029265	0,039156	0,042137	0,024194	0,029782
Spain - IBEX 35	**0,000692** *	**0,034473** #	**0,382700** *	**-0,046838**	**-0,141956** *	**0,000434**	**0,367331** *	**0,086985** *	**0,886624** *	**-0,095916** *
	0,000088	0,020228	0,025944	0,029532	0,029861	0,026938	0,026112	0,029068	0,034970	0,036873
Sweden - OMX INDEX (OMX Stockholm 30)	**0,000781** *	**-0,040394** §	**0,490405** *	**-0,020546**	**-0,131068** *	**0,030709**	**0,356465** *	**0,111420** *	**0,774169** *	**0,020978**
	0,000127	0,018167	0,031778	0,039593	0,027339	0,029141	0,027203	0,033954	0,027401	0,034770
Swiss - SMI INDEX	**0,000604** *	**0,012556**	**0,377603** *	**-0,061143** §	**-0,123026** *	**0,025211**	**0,289885** *	**0,082708** *	**0,742399** *	**-0,095949** *
	0,000096	0,018091	0,023455	0,028882	0,024409	0,024600	0,022739	0,027336	0,020757	0,026179

The estimates of the GARCH parameters (ω_i, α_i, and β_i) are not reported because they are similar to the results of the constant spillover model. The univariate model for the US return is identical to that of the constant spillover model; for convenience the results are repeated in the first row of Table 4.

The second step of the estimation concerns the return of the DJ EURO STOXX 50, cf. the second row of Table 4. The joint hypothesis of no spillover changes after the euro is strongly rejected; the robust Wald test for the hypothesis $H_0 : \gamma_{1,\mathrm{E}} = \phi_{1,E} = 0$ results in a p-value equal to 0%.

The subsequent results are robust to including or excluding euro changes in the spillover parameters. Thus, we continue with the dummy variable in the specification for the European return.

In the third step of the estimation, we investigate the effect of the euro on the mean-spillover effects and the volatility-spillover effects from the US and European stock markets to the European stock markets cf. the bottom rows of Table 4. As for the constant spillover model, we only find spotted evidence of mean spillover effects. For the period before the euro there are only mean-spillover effects for a few countries, $\hat{\gamma}_{0,i}$ and $\hat{\delta}_{0,i}$ are only significantly positive for a few countries, Germans DAX Index, and Portuguese PSI 20. Moreover, there is no evidence that the mean-spillover effects are different after the euro; for the indexes CAC 40, FTSE 100, IBEX 35, KFX Index, HEX Index and OMX Index we don't reject the hypothesis $H_0 : \gamma_{1,i} = \delta_{1,i} = 0$. After the euro, there are strong signs of mean-spillover effects; we reject $H_0 : \gamma_{0,i} = \gamma_{1,i} = \delta_{0,i} = \delta_{1,i} = 0$ for all *i*.

There are strong indications of both US and European volatility-spillover effects. For the period before the euro the US volatility-spillover effects as well as the European volatility-spillover effects are significant, i.e. $\phi_{0,i}$ and $\psi_{0,i}$ are significant, the only parameter that is not significant at this point is the Portuguese PSI 20's US volatility spillover. In addition, the volatility-spillover effects are significantly different after the euro; the robust Wald test for the hypothesis $H_0 : \phi_{1,i} = \psi_{1,i} = 0$ is rejected for all countries. There are also significant volatility spillover effects after the euro; $H_0 : \phi_{0,i} = \phi_{1,i} = \psi_{0,i} = \psi_{1,i} = 0$ is rejected for all *i*.

We tried to demonstrate how the introduction of the euro has significantly changed the volatility spillover effects into European stock markets.

The following commonalities are observed in our study. The US volatility-spillover effects before the euro are found to be stronger than the effects estimated by the constant spillover model, i.e. $\hat{\phi}_{0,i} > \hat{\phi}_i$. The US volatility-spillover effects weaken by the euro ($\hat{\phi}_{1,i} < \hat{\phi}_{0,i}$) and are stronger than estimated by the constant spillover model, $\hat{\phi}_{0,i} + \hat{\phi}_{1,i} > \hat{\phi}_i$.

In contrast, the European volatility-spillover effects before the euro are found to be weaker than estimated by the constant spillover model, for half of the counties under our scope, $\hat{\psi}_{0,i} < \hat{\psi}_i$. After the euro, the effects of European volatility spillover are strengthened ($\hat{\psi}_{1,i} > 0$) and are stronger than estimated by the constant spillover model, $\hat{\psi}_{0,i} + \hat{\psi}_{1,i} > \hat{\psi}_i$ (exceptions are Austria, Denmark, Italy, Portugal and Swiss).

Table 5 presents the mean of the variance ratios. In the first sub period the average US variance ratios are smaller than in the second sub period. Compared to the constant spillover model, the mean of the US variance ratio has increased from 0-1% to 2-16%, because the sample period before the euro is longer than the sample period after the euro.

Table 5: Variance ratios – euro spillover model

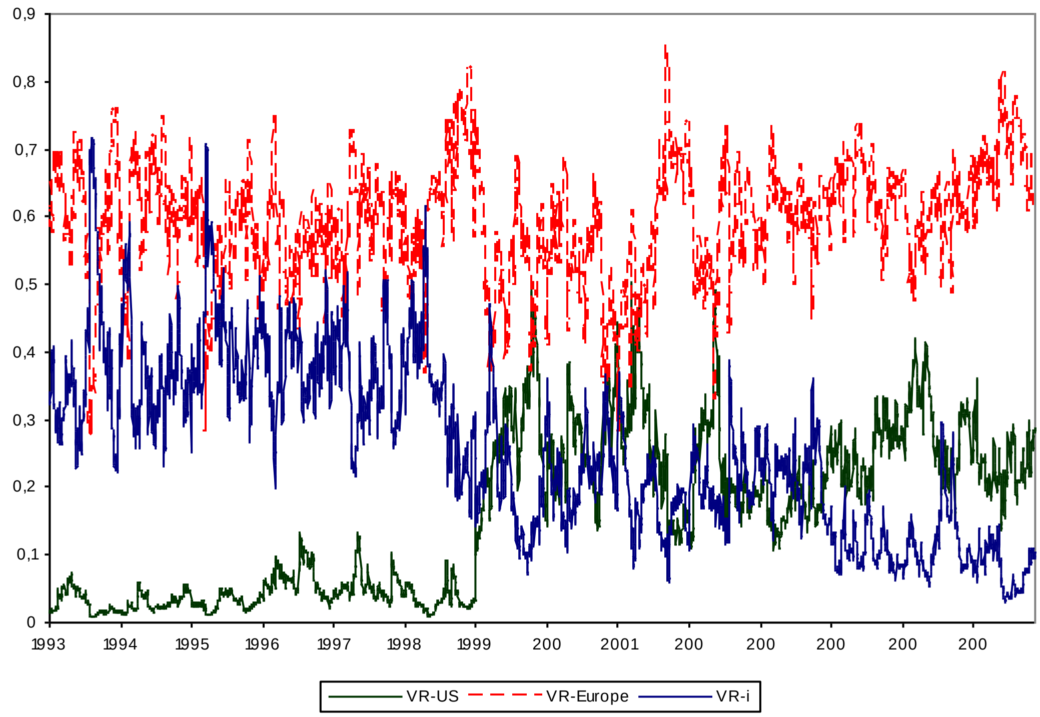
The table reports the mean and standard deviation of the US, European, and own variance ratios for the euro spillover model:

	US		Europe		Own Country	
	Mean	Stdev.	Mean	Stdev.	Mean	Stdev.
Austria - ATX INDEX	0,0213	0,0170	0,1488	0,1071	0,8299	0,1080
Belgium - BEL 20	0,1097	0,0502	0,3769	0,1151	0,5134	0,1323
Denmark - KFX INDEX (OMX Copenhagen 20)	0,0479	0,0286	0,2220	0,0890	0,7301	0,0969
England - FTSE 100	0,1544	0,0644	0,4033	0,1115	0,4423	0,1340
Finland - HEX INDEX (OMX Helsinki 25)	0,0761	0,0483	0,2812	0,1337	0,6427	0,1652
France - CAC 40	0,1561	0,0857	0,6166	0,1320	0,2273	0,1736
Germany - DAX INDEX	0,1568	0,1166	0,5853	0,0895	0,2578	0,1301
Ireland - ISEQ INDEX	0,0460	0,0281	0,1728	0,0737	0,7812	0,0877
Italy - MIB 30	0,1183	0,0849	0,4411	0,1724	0,4405	0,2284
Netherlands - AEX INDEX	0,1508	0,0786	0,5882	0,1038	0,2610	0,1299
Portugal - PSI 20	0,0380	0,0371	0,1626	0,0855	0,7994	0,1109
Spain - IBEX 35	0,1323	0,0686	0,4809	0,1272	0,3868	0,1575
Sweden - OMX INDEX (OMX Stockholm 30)	0,1094	0,0532	0,3680	0,1223	0,5226	0,1477
Swiss - SMI INDEX	0,1099	0,0569	0,4205	0,1046	0,4696	0,1184

The average European variance ratios are smaller in the last sub period than in the first sub period. Therefore, the means of the European variance ratios tend to be smaller in the euro spillover model than in the constant spillover model. The purely local volatility effects are, in general, smaller after the introduction of the euro. The average local variance ratio has decreased from 57% to 52%. The tendencies are also seen in the plots of the variance ratios for the example country Germany in Figure 8. Thus, after the introduction of the euro there is much more sensitivity from the own stock markets to the changes that come in from the European stock market and less room for local effects.

Our results are in line with Allen and Song (2005) find that the euro has helped to integrate the financial services industry in Europe.

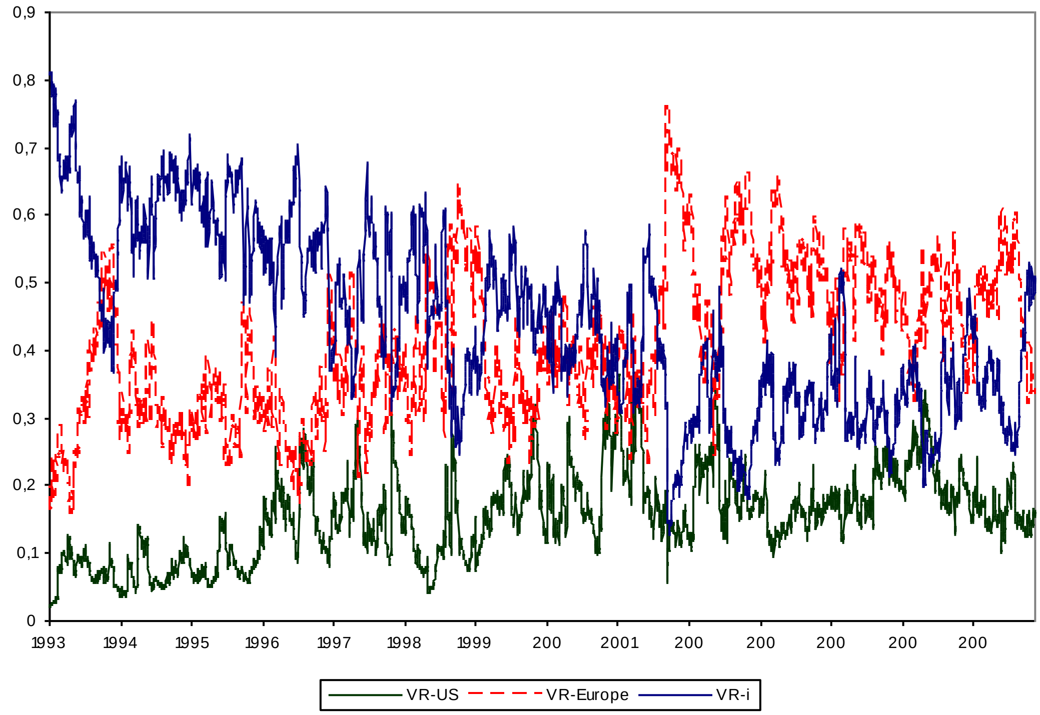
Figure 8: Variance ratios - Germany - europe spillover model



For the non-EMU countries and Swiss (non-EU), there has been an increase of the mean of the US variance ratios. This is not surprising given that the euro appears to be an insignificant event for the spillover processes for these non-EMU countries.

The tendencies are also seen in the plots of the variance ratios for the UK in Figure 9.

Figure 9: Variance ratios - UK - europe spillover model



Portuguese and Spanish stock markets (Figures 9 and 10) show a behaviour which is in line with the constant spillover model. Again, for the Portuguese PSI 20, the own country effect is the dominating one. In opposition, in the IBEX 30, we can observe a behaviour with a greater weight of the European variance ratio and a downgrading own country effect.

Figure 10: Variance ratios - Portugal - europe spillover model

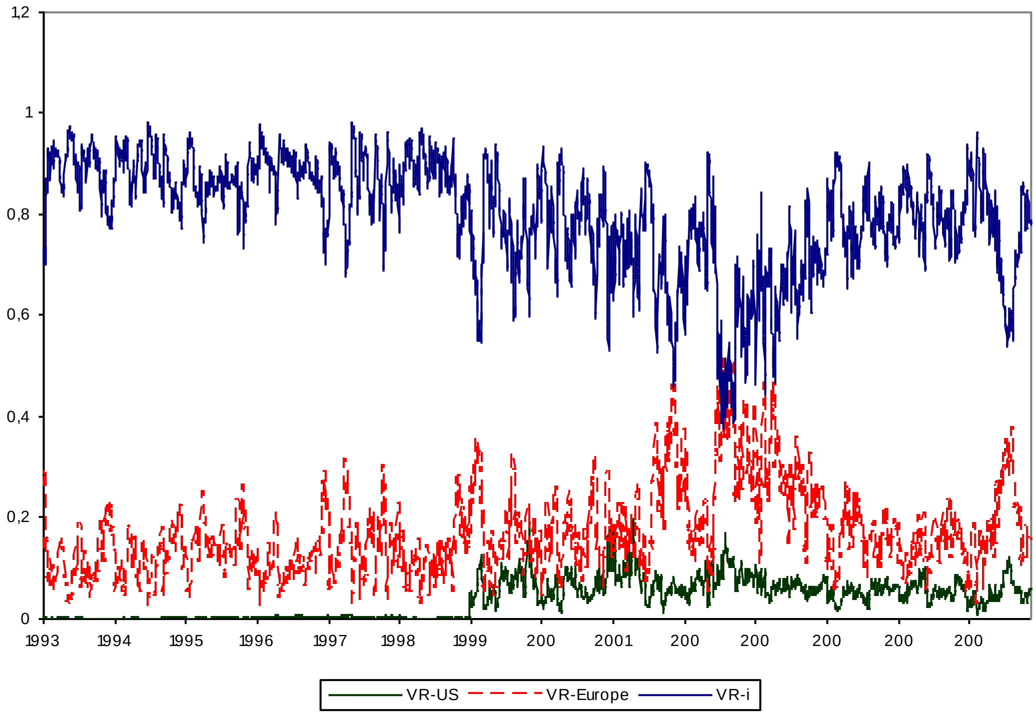
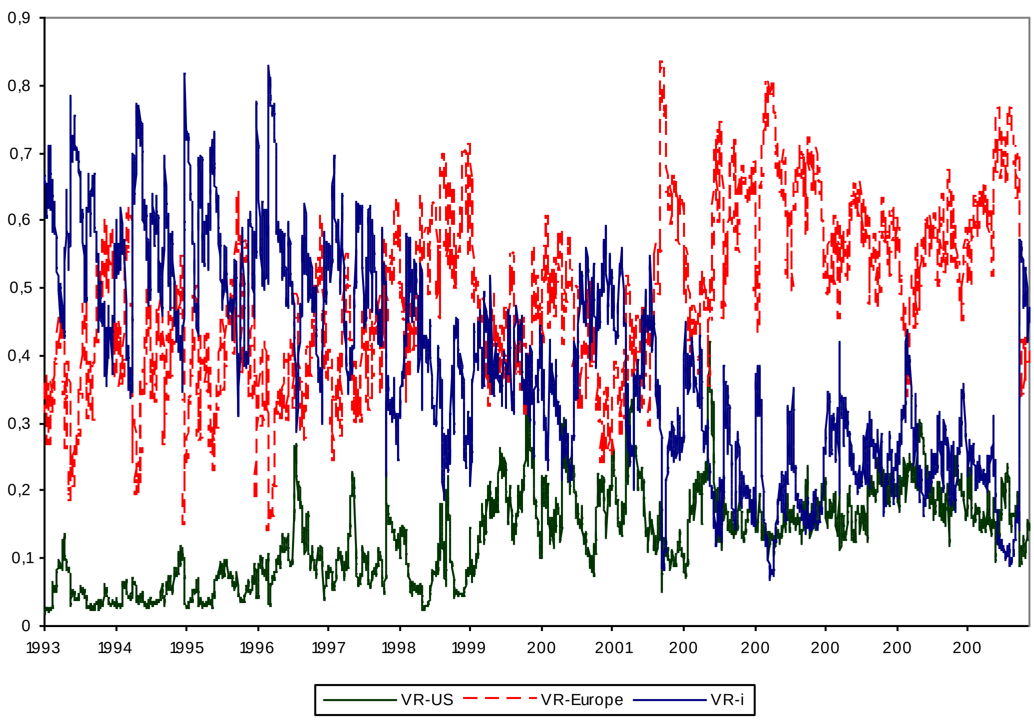


Figure 11: Variance ratios - Spain - europe spillover model



Trend Spillover Model

We will now report on the results from estimating the trend spillover model. This model as we said above is novel to the literature and was introduced by Charlotte Christiansen (2005), so once again we'll continuing with the framework proposed by this author.

As before, the US returns specifications is equal to the one in the constant spillover model, $R_{US,t} = c_{0,US} + c_{1,US} R_{US,t-1} + e_{US,t}$ where $e_{US,t}$ has mean 0 and conditional variance, $\sigma_{US,t}^2 = \omega_{US} + \alpha_{US} e_{US,t-1}^2 + \beta_{US} \sigma_{US,t-1}^2$.

In this trend spillover model we will allow that the spillover parameters to increase or decrease with a constant value each year, cf. equation (17). Thus, the spillover parameters may change gradually during the sample period.

By this time the European return will have the following specification $R_{E,t} = c_{0,E} + c_{1,E} R_{E,t-1} + \gamma_{0,E} R_{US,t-1} + (\phi_{0,E} + \phi_{1,E} DT_t) e_{US,t} + e_{E,t}$ where $e_{E,t}$ has mean 0 and conditional variance, $\sigma_{E,t}^2 = \omega_E + \alpha_E e_{E,t-1}^2 + \beta_E \sigma_{E,t-1}^2$.

Country i returns assume the following specification for country i (i= 1,…,N), $R_{i,t} = c_{0,i} + c_{1,i} R_{i,t-1} + (\gamma_{0,i} + \gamma_{1,i} DT_t) R_{US,t-1} + (\delta_{0,i} + \delta_{1,i} DT_t) R_{E,t-1} + (\phi_{0,i} + \phi_{1,i} DT_t) e_{US,t} + (\psi_{0,i} + \psi_{1,i} DT_t) e_{E,t} + e_{i,t}$ where $e_{i,t}$ has mean 0 and conditional variance: $\sigma_{i,t}^2 = \omega_i + \alpha_i e_{i,t-1}^2 + \beta_i \sigma_{i,t-1}^2$. DT_t equals 1 for 1998 observations, 2 for 1999 observations, etc.

Table 6 shows the results arising from estimating the trend spillover model. Table 6 is structured like Table 4.

Table 6: Trend spillover model

The table reports the results from estimating the trend spillover model. Estimated parameters and standard errors below - *, §, #, indicates that the value is significant at a 1%, 5% or 10% level of significance, respectively.

	$c_{0,i}$	$c_{1,i}$	$\gamma_{0,i}$	$\gamma_{1,i}$	$\delta_{0,i}$	$\delta_{1,i}$	$\phi_{0,i}$	$\phi_{1,i}$	$\psi_{0,i}$	$\psi_{1,i}$
USA - S&P 500	**0,000526** *	**0,002772**								
	0,000126	0,001704								
Europe - DJ EURO STOXX 50	**0,000535** *	**-0,153291** *	**0,463389** *				**0,328556** *	**0,043950** *		
	0,000129	0,015507	0,019628				0,025680	0,006006		
Austria - ATX INDEX	**0,000539** *	**0,080902** *	**0,329044** *	**-0,020440** *	**-0,052599** §	**0,001356**	**0,110792** *	**0,004673**	**0,470128** *	**-0,044268** *
	0,000123	0,018574	0,029254	0,007066	0,024043	0,005325	0,029992	0,006947	0,025599	0,005718
Belgium - BEL 20	**0,000610** *	**0,067570** *	**0,277230** *	**0,006481**	**-0,042211** §	**-0,010232** *	**0,229711** *	**0,025423** *	**0,484132** *	**0,023537** *
	0,000089	0,018619	0,019182	0,003948	0,019800	0,003797	0,016392	0,003479	0,017888	0,003712
Denmark - KFX INDEX (OMX Copenhagen 20)	**0,000542** *	**0,066861** *	**0,285100** *	**0,013066** §	**-0,068587** *	**-0,004449**	**0,166764** *	**0,014858** *	**0,495087** *	**-0,008302**
	0,000125	0,018591	0,023736	0,006395	0,026438	0,005322	0,020922	0,005559	0,022671	0,005322
England - FTSE 100	**0,000376** *	**-0,058164** *	**0,307137** *	**0,010256** *	**-0,069700** *	**-0,003452**	**0,311233** *	**0,016914** *	**0,550907** *	**0,011125** *
	0,000082	0,018043	0,017476	0,003490	0,018339	0,002950	0,016311	0,003222	0,020023	0,003574
Finland - HEX INDEX (OMX Helsinki 25)	**0,000730** *	**0,037613** #	**0,644905** *	**-0,002353**	**-0,178069** *	**0,003897**	**0,308197** *	**0,036460** *	**0,767618** *	**0,012990** §
	0,000162	0,019905	0,033291	0,006769	0,032870	0,006070	0,040188	0,007560	0,032013	0,006543
France - CAC 40	**0,000535** *	**-0,125308** *	**0,409793** *	**0,008985** *	**-0,030497**	**0,001582**	**0,346064** *	**0,034067** *	**0,922551** *	**0,005407** §
	0,000052	0,017718	0,016824	0,002714	0,022264	0,002375	0,015095	0,002437	0,015407	0,002459
Germany - DAX INDEX	**0,000664** *	**-0,176093** *	**0,490719** *	**-0,007260** §	**0,055481** §	**-0,003196**	**0,317809** *	**0,055955** *	**0,948656** *	**0,011654** *
	0,000066	0,017503	0,017783	0,002911	0,025849	0,003110	0,018481	0,003035	0,019095	0,003001
Ireland - ISEQ INDEX	**0,000545** *	**0,048627** *	**0,401540** *	**-0,005353**	**0,020772**	**-0,014718** *	**0,116493** *	**0,022881** *	**0,328603** *	**0,009367** #
	0,000109	0,018812	0,031477	0,007361	0,020887	0,004684	0,021309	0,006913	0,022979	0,005562
Italy - MIB 30	**0,000571** *	**-0,020612**	**0,309386** *	**-0,004867**	**-0,066259** §	**-0,001946**	**0,317743** *	**0,021500** *	**0,899672** *	**-0,024369** *
	0,000089	0,018370	0,027164	0,004764	0,028992	0,004148	0,028227	0,004910	0,026415	0,004289
Netherlands - AEX INDEX	**0,000556** *	**-0,044264** §	**0,445867** *	**0,000260**	**-0,118339** *	**0,005552** §	**0,312567** *	**0,037406** *	**0,821121** *	**0,015145** *
	0,000066	0,018492	0,015603	0,002893	0,022908	0,002759	0,015582	0,002834	0,015893	0,002717
Portugal - PSI 20	**0,000384** *	**0,144499** *	**0,158894** *	**0,009000** #	**-0,017853**	**-0,008665** §	**0,103557** *	**0,014320** §	**0,378877** *	**-0,006787**
	0,000100	0,020482	0,024608	0,005249	0,022408	0,004154	0,034917	0,006589	0,022552	0,004487
Spain - IBEX 35	**0,000704** *	**0,037485** #	**0,320984** *	**0,009183** §	**-0,139312** *	**-0,002133**	**0,336859** *	**0,024307** *	**0,870150** *	**-0,012339** *
	0,000088	0,020068	0,022069	0,003938	0,027332	0,003481	0,021712	0,003796	0,027037	0,004475
Sweden - OMX INDEX (OMX Stockholm 30)	**0,000780** *	**-0,039732** §	**0,455609** *	**0,008302**	**-0,131327** *	**0,004528**	**0,348521** *	**0,024213** *	**0,761456** *	**0,006693**
	0,000127	0,018163	0,028244	0,005874	0,025465	0,004509	0,024668	0,005153	0,025840	0,004930
Swiss - SMI INDEX	**0,000607** *	**0,011530**	**0,318907** *	**0,007631** #	**-0,132689** *	**0,005960** #	**0,292529** *	**0,015749** *	**0,679051** *	**-0,000469**
	0,000096	0,017900	0,021752	0,004322	0,021632	0,003530	0,020339	0,004249	0,019446	0,004069

Table 7 will disclose the results from the mean and standard deviation of the US, European, and own variance ratios for the trend spillover model, $VR_{i,t}^{US} = \frac{(\phi_{0,i} + \phi_{1,i} DT_t)^2 \sigma_{US,t}^2}{h_{i,t}}$, $VR_{i,t}^{E} = \frac{(\psi_{0,i} + \psi_{1,i} DT_t)^2 \sigma_{E,t}^2}{h_{i,t}}$, and $VR_{i,t}^{i} = 1 - VR_{i,t}^{US} - VR_{i,t}^{E}$, where $\sigma_{US,t}$ and $\sigma_{E,t}$ are the conditional volatility of the US and European idiosyncratic shock, respectively and $h_{i,t}$ is the conditional variance of the unexpected return of country i.

Table 7: Variance ratios – trend spillover model

The table reports the mean and standard deviation of the US, European, and own variance ratios for the trend spillover model:

	US		Europe		Own Country	
	Mean	Stdev.	Mean	Stdev.	Mean	Stdev.
Austria - ATX INDEX	0,0197	0,0149	0,1366	0,0919	0,8437	0,0965
Belgium - BEL 20	0,1141	0,0569	0,3684	0,1270	0,5174	0,1594
Denmark - KFX INDEX (OMX Copenhagen 20)	0,0475	0,0265	0,2186	0,0872	0,7338	0,0961
England - FTSE 100	0,1578	0,0687	0,3978	0,1118	0,4444	0,1436
Finland - HEX INDEX (OMX Helsinki 25)	0,0815	0,0576	0,2794	0,1318	0,6391	0,1705
France - CAC 40	0,1568	0,0932	0,6028	0,1378	0,2404	0,1947
Germany - DAX INDEX	0,1594	0,1055	0,5737	0,0835	0,2669	0,1345
Ireland - ISEQ INDEX	0,0499	0,0349	0,1700	0,0739	0,7800	0,0948
Italy - MIB 30	0,1201	0,0887	0,4286	0,1792	0,4513	0,2424
Netherlands - AEX INDEX	0,1522	0,0840	0,5806	0,1008	0,2672	0,1391
Portugal - PSI 20	0,0349	0,0268	0,1746	0,0843	0,7906	0,0981
Spain - IBEX 35	0,1343	0,0808	0,4775	0,1202	0,3882	0,1660
Sweden - OMX INDEX (OMX Stockholm 30)	0,1123	0,0562	0,3651	0,1219	0,5226	0,1525
Swiss - SMI INDEX	0,1114	0,0539	0,4142	0,1102	0,4744	0,1336

As in both the constant and the euro spillover model the US as well as the European mean spillover effects are fairly weak. Again, only in about half of the countries the mean spillover parameters are significant.

There are strong US and European volatility-spillover effects at play. In order to have significant volatility spillover from the US stock market either $\phi_{0,i}$ or $\phi_{1,i}$ should be significant. We find that this is the case for all countries except Austria where $\phi_{1,i}$ is not significant, equal to the euro spillover model. Moreover, for most countries we reject that the US volatility-spillover parameter is constant (the Wald test hypothesis that $\phi_{1,i}$ = 0 is rejected with the exception of Austria).

Only for the Portuguese PSI-20 the results are different from those in the euro spillover model, with the $\phi_{0,i}$ being significant in the trend spillover model

In the trend spillover model, we find only weak signs of time variation in US volatility-spillover effects, whereas in the euro spillover model we find evidence of changes.

The European volatility-spillover effects are significant for most countries without exception; either $\psi_{0,i}$, $\psi_{1,i}$ or both are significant for all countries. Only for Danish OMX Copenhagen 20, Portuguese PSI-20, Sweden OMX Stockholm 30 and Swiss SMI Index the $\psi_{1,i}$ parameter is not significant. Which is similar to the result in the euro spillover model where this also happen to French CAC 40, Irish ISEQ Index, Portuguese PSI-20 and Sweden OMX Stockholm 30. For Sweden and Portugal, the European volatility-spillover effects seem to be constant during the sample period, $\psi_{1,i}$ is insignificant.

In general the European volatility-spillover effects decrease during the sample period $\psi_{1,i}$ is significantly positive, with the exception of French CAC 40 that become positive and significant, and Irish ISEQ Index that become significant. For Spain and Italy the point estimates are negative and significant which might indicate a slight tendency to be decreasing over time. The European volatility-spillover results complement those from the euro spillover model.

Table 7 shows the average variance ratios. Compared to the constant spillover model, the average US effects have become much stronger, the average European effects and the local effects become weaker.

The most interesting information from the trend spillover model is shown in the graphs of the time series of the variance ratios, Figures 12 and 13 concern the example countries Germany and the UK.

Figure 12: Variance ratios - Germany - trend spillover model

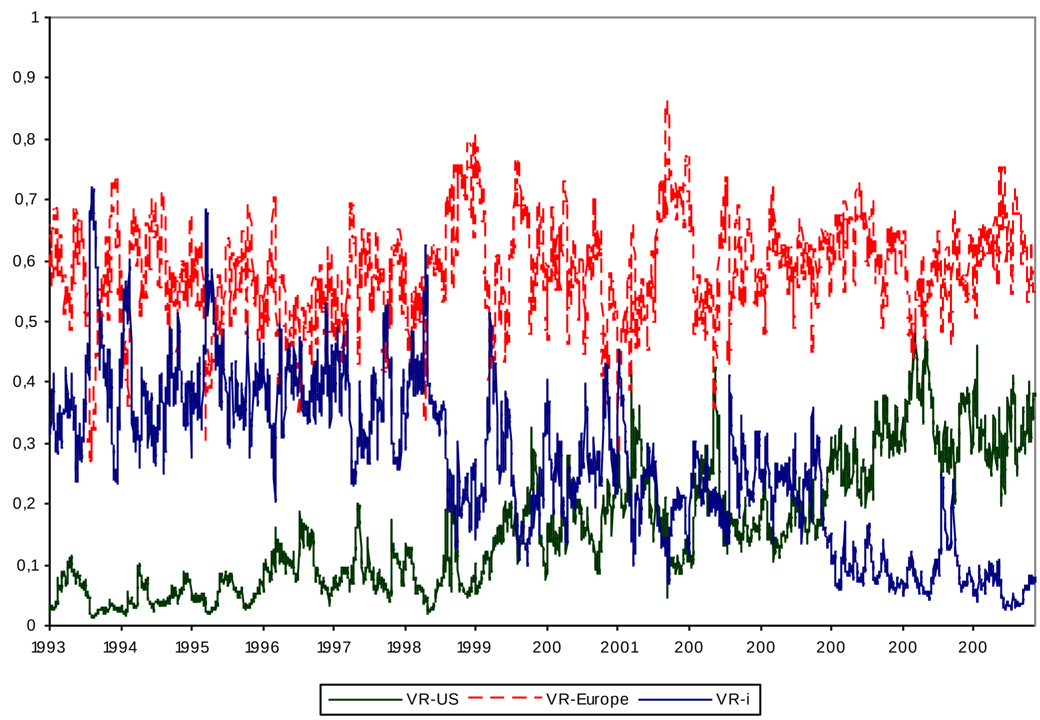
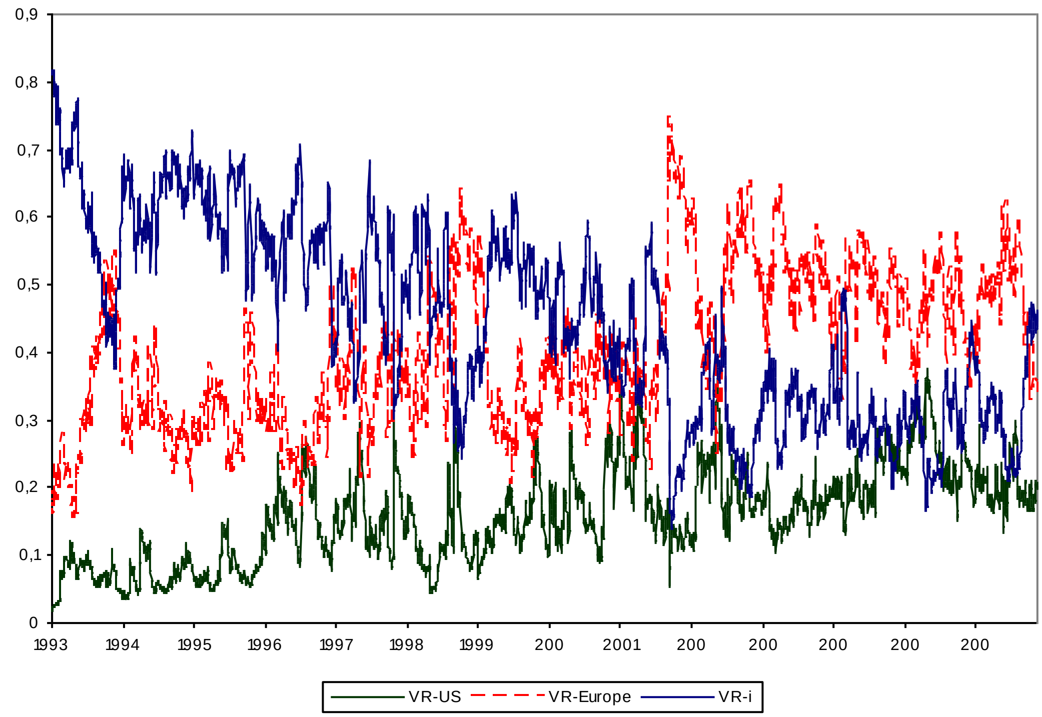


Figure 13: Variance ratios - UK - trend spillover model



For fully integrated stock markets the European variance ratio should tend to one, and the local and global variance ratios should tend to zero. We expect EMU countries to be, if not fully integrated, then on their way to becoming integrated. In other words, we expect the European variance ratios to be increasing during the sample period and to be very large at the end of the sample period. For non-EMU countries we do not expect full integration with the European stock markets.

For Germany we see that the European variance ratio is more or less constant with some increases over time. Starting around 0.6 in the beginning of the sample period it increases so much that it is around 0.9 in 2002, time of the begging of the circulations of EURO coins and notes. At the end of the sample period, it returns to levels similar to ones in the begging of the sample period. The US effects are comparatively low throughout and diminishing trough time. The local effects decrease over time and in 2006 the local variance ratio is around 0.05. The graphs of the variance ratios document that EMU countries are becoming more and more integrated during the sample period; European effects increase in importance and local effects decrease in importance. For the last six months of the sample, the average European variance ratio for the EMU countries equals 0.43. The corresponding average US variance ratio equals 0.18 and the average local variance ratio equals 0.39. So, although EMU countries are not yet fully integrated they are well on their way to becoming so. In Figure 13, we can observe that for the UK stock market the US effects increase over time to a level of about 0.2. The local effects decrease, to half of the value observed in the beginning of the sample period, but nevertheless to a much higher level than for Germany. In 2002 the local variance ratio equals around 0.35. The European effect has gain some importance but still hasn't a well defined trend. As expected, the non-EMU countries have not become so integrated with other European stock markets as the EMU countries.

For Portugal (Figure 14), we can observe that the Portuguese stock market, unlike the Spanish market (Figure 15), and probably due to its lack of dimension, continues to present a far from expected behaviour for a EMU member, but consistent with the previous results from the constant and euro spillover models. Overall, the graphs of the time series of the variance ratios corroborate and strengthen the conclusions from the euro spillover model.

Figure 14: Variance ratios - Portugal - trend spillover model

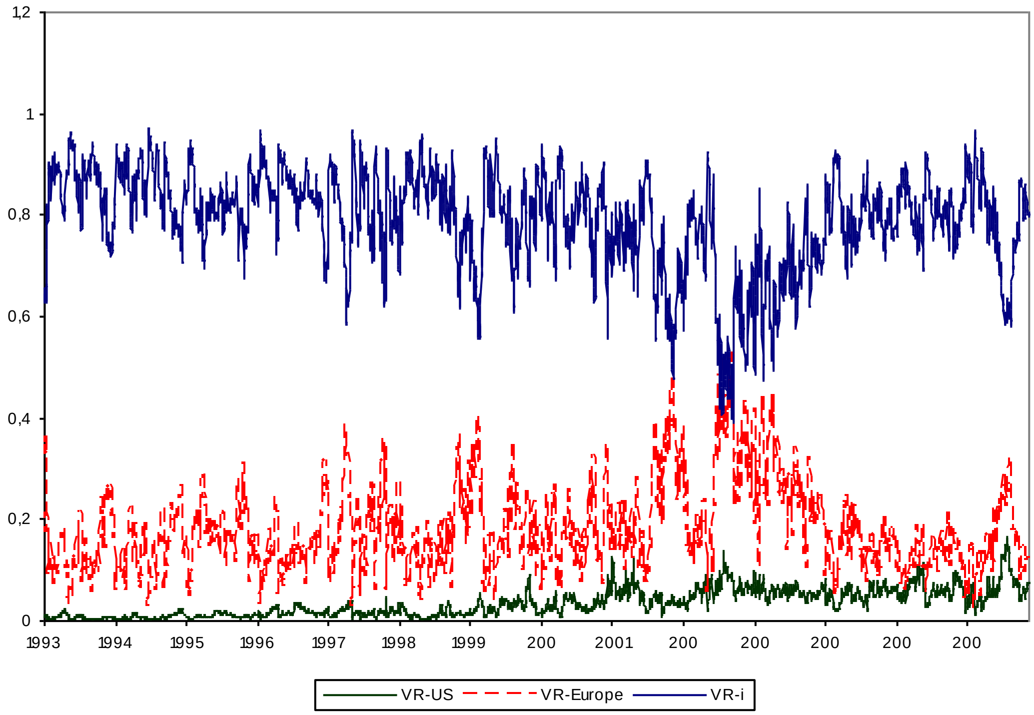
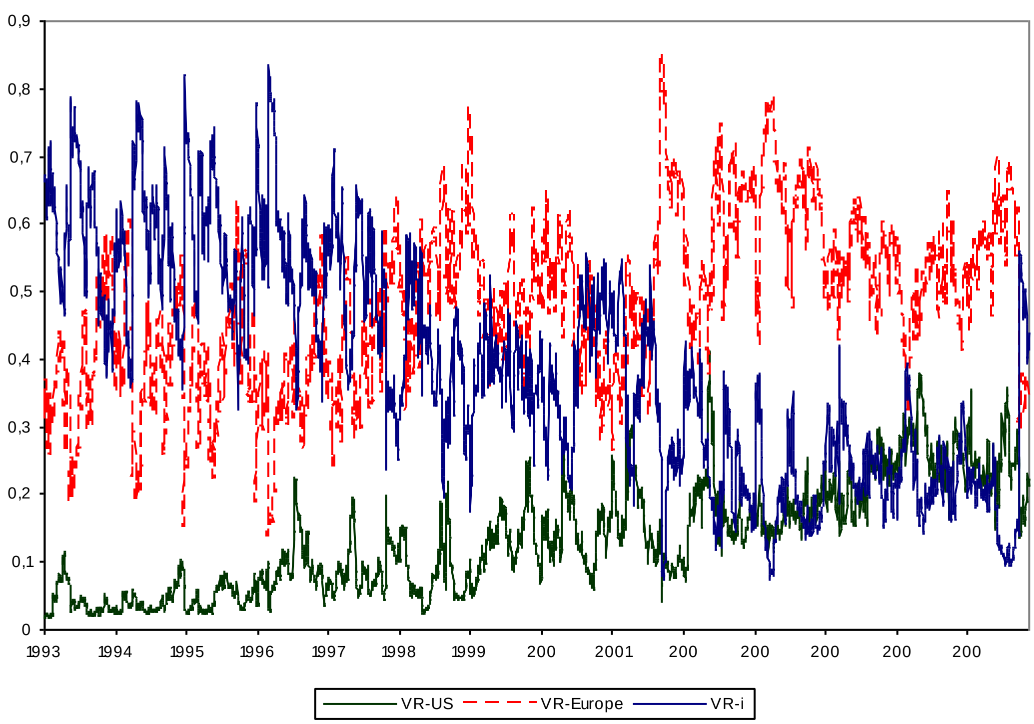


Figure 15: Variance ratios - Spain - trend spillover model



6. CONCLUSION

In this work we intend to provide some findings about how volatility in fourteen individual stock market indexes is affected by volatility in the US (through S&P 500) and European stock markets (through DJ EURO STOXX 50). We distinguish between global, regional, and local volatility effects. We apply an approach developed by Charlotte Christiansen (2005) that is supported in a GARCH-type model that allows for both mean and volatility spillover from the US and European stock markets into the individual countries.

Mean-spillover effects are almost negligible, whereas volatility-spillover effects are essential. For EMU countries regional effects are most important, followed by local effects. Global effects are almost inconsequential. For non-EMU countries own country effects are stronger, European effects smaller, and US effects larger. EMU countries have become much more integrated after the introduction of the euro.

We find evidence of substantial differences between the nature of the volatility of the stock markets of EMU-member countries and of non-EMU member countries.

For Portugal and Spain stock markets we find that although they are in the same financial environment, same geographical region, that both enter the EMU in the same opening phase, there is a difference in their volatility structure, with Portugal being much more sensible to the own country effect. In opposition Spain presents a much more consistent results to the expected results, a growing importance of the European effect in detriment of the own country effect, mainly from the begging of the Euro (around 1999). We explain this fact by the lack of liquidity that is a inherent characteristic of the Portuguese PSI 20.

One interesting exercise to the future would be, at the same time that we can update data, develop the same model but considering the new EU countries, and compare those to the countries of the first phase of the EMU. However this seems not yet possible to conclude since only now these new countries are developing their stock exchange markets.

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