# The Evolution of the European Banking System: The EU Effectiveness in Achieving a Common Banking Market

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## Abstract

This paper investigates the level of progress towards integration in the European banking industry and its effects on the stock of banks listed in the European stock exchanges. We estimate the overall effect of progress by comparing the changes on the stock price volatility of listed banks over the last fifteen years. We document that the introduction of the Euro as the common European currency has contributed towards the banking industry integration in Europe. In contrast, the adoption of the CAD-I and CAD-II had little effect on banking integration in Europe. We also find evidence of asymmetric volatility spillovers between the bank stock returns of the groups of countries that have been involved in different ways at the various recent stages of European economic and political integration. Our findings have significant economic and political implication in respect to the assessment of the efficacy of significant EU economic decisions.

**Key words:** European Banking, Euro, Market Integration, GARCH Models.
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## 1. INTRODUCTION

This study investigates the recent developments in the European banking industry, since early 1990s and the progress on achieving a single market in the European banking, following the passing of the Second Banking Directive (1989). It explores how the introduction of Euro as the common European currency and the adoption of the Capital Adequacy Directives CAD-I and CAD-II have contributed in the achievement of this key European Union (EU) target. The level of financial market integration depends on a number of factors and is an evolving process, which may vary across a wide spectrum of states from a completely segmented to a fully integrated market (Bekaert *et all*, 1998). The introduction of Euro was one of the most significant economic events in the recent history of global financial markets and had a significant effect on the integration of the European financial markets (Adjaoute and Danthine, 2003 and Hartman *et al*, 2003).

European banking has experienced significant change over the last fifteen years. The EU has consistently pursued the establishment of a single market in all areas of economic activity across all its member states, including the banking industry. There were also efforts, like the Basel Accords, for international harmonisation of banking practice in key issues like the recognition of credit and operational risks, which had a positive effect on the move towards a more integrated framework in banking practice. Additionally, in the EU, the introduction of the Euro had significant impact on the operational activities of European banks. Following the adoption of Euro, significant part of exchange rate risk has disappeared in the Euro zone, transaction costs were reduced and trade within the member states was further encouraged with significant benefits to investments and employment (Askari and Chatterjee, 2005). Furthermore, the establishment of the European Central Bank (ECB) had a positive effect on interest rates and price stability. These issues are extremely important for the banking industry, investors, market participant, industry regulators and policymakers. However, the progress towards a single European banking industry and its implications has not received proper attention in the academic literature, despite its significant economic and political implications. Previous work has examined financial market integration based on international capital mobility (Lemmen and Eijffinger, 1996; Frankel, 1992; Frankel and MacArthur, 1988; Feldstein and Horioka, 1980), asset pricing models (Hardouvelis et al., 2001; Bekaert and Harvey, 1995; Dumas and Solnik, 1995; Ferson and Harvey, 1991), price and volatility spillovers (Bartram et al., 2005; Fratzscher 2002; Koutmos and Booth, 1995; Richards, 1995; Lin and Ito, 1994; Kasa, 1992) or the development of correlation coefficients over time (Askari and Chatterjee, 2005; Cappiello et al., 2004). This study aims to contribute towards filling this gap and shed new light in the debate of the European banking integration by examining the price and volatility spillovers between banks in countries that have adopted the Euro (Euro-adopters), those that have not adopted the Euro (Non-Adopters), the new members joined the EU in 2004 (New-Members) and countries outside the EU[1] (Non-Members).

The EU has dominated the political and economic developments in Europe and since its creation, almost half a century ago, is playing an increasingly significant role in the international economic life. Despite the recent emergence of China and India as international economic powers, the EU has expanded and in May 2004 strengthened its international position by admitting ten new member states. The significance of the EU for the European economic life and the shaping of its markets suggest that a review of the recent developments in the European banking industry should investigate the effects of the policies and decisions of the EU. One of the fundamental objectives of the EU, as enshrined in the Treaty of Rome (1957), is the free trade of goods and services in all markets across the member states, through the creation of 'single markets' in all areas of economic activity. The 'First Banking Directive' (1977), echoing the Treaty of Rome, called for harmonisation of banking in Europe, without offering specific suggestions as to how this should be achieved. Harmonisation of the relevant parts of legal systems and trading rules across the member states was perceived, initially, as necessary to facilitate integration and progress towards single European banking market. However, that proved an extremely difficult objective and effectively very little was achieved towards full market harmonisation until mid eighties.

The history and developments in the US financial markets provide an appreciation of the enormity of the European endeavour to achieve single markets throughout the member states. The US has a much longer history of striving for market integration, within a framework of a common language and a single country socially and culturally less diverse than Europe. However, in the US, there are still highly fragmented parts of banking and financial services, like retail banking activities and insurance services. Single market was proved an elusive goal for the EU member states and actually very little of this target was achieved over almost the initial thirty years of its life. The Single European Act (1986) recognises that harmonisation is very difficult, if not impossible, to achieve and attempts to provide remedies to problems and offer alternative courses of action. It replaces the

[1] The Euro-Adopters are Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal and Spain. The Non-Adopters are the UK, Sweden and Denmark. The New-Members are Cyprus, Czech Republic, Estonia, Latvia, Slovenia, Malta, Poland, Lithuania, Slovakia and Hungary and the Non-Members are Bulgaria, Croatia, Iceland, Norway, Romania, Russia and Turkey.

harmonisation of markets with the principle of mutual recognition, introduces the qualified majority voting instead of the right to veto and declares the 1st January 1993 as the 'single market day' by which time all sectors, including the banking industry, had to achieve a single internal European market.

In response to the Single European Act, the 'Second Banking Directive' (1989) made specific recommendations for establishing a single banking market throughout the EU. This directive operationalises the mutual recognition principle, which had replaced harmonisation, with the introduction of a 'European business passport' concept. This allows banks and financial institutions recognised in one member state, to be able to operate and offer the same services in any other member state, without the need for additional authorisation from the host member state. Therefore, the initial aim of achieving common set of rules and regulations throughout the member states has been transformed to achieving minimum consensus.

The introduction of the 'Capital Adequacy Directive-I' (CAD-I), which took effect in January 1996, is a significant development in the European banking industry. The importance of this directive is twofold. Firstly, it declares the determination of the European Commission to adopt the Basel Committee's recommendations into the European legal framework of banking and financial services and secondly, it provides a concrete and positive step towards banking integration in Europe.[2] The aim was to set a plain field for estimation of market risk exposure for the banks throughout the European Union. The 1988 Basel Accord (Basel 1) aimed at promoting international financial stability through adoption of capital adequacy standards for international banks. Subsequently, the EU adopted the amended Basel Accord (1996) with the implementation of CAD-II, which in 1998 replaced CAD-I. The amended Basel Accord (1996) addresses earlier criticism by introducing more direct treatment to the off-balance sheet items. The recommendations of Basel Committee aimed at international banks but the EU adopted them for all member states banks.

Another significant development in the European banking industry is the establishment of the ECB as the central bank of all EU member states. In January 1999, EU starts preparing for the introduction of the Euro as the single European currency. Initially 11 countries entered the European Monetary Union (EMU). These countries were Austria, Belgium, Germany, France, Italy, Ireland, Luxembourg, Netherlands, Portugal and Spain. Greece joined the EMU later in 2001. In January 2001, dual pricing at fixed rates, in national

[2] The European Commission has already incorporated the main recommendation of Basel 2 into the new CAD-III. A working document on this directive was published at the end of 2002 and its consultation and comments stage was completed in 2003, with plans to ratify the final version by the European Parliament and member states by the end of 2006.

currencies and in Euros was adopted ahead of the full introduction of the Euro as a single European currency in January 2002. Few months later, all national currencies were withdrawn.

The UK ratified the Maastricht Treaty and joined the Exchange Rate Mechanism (ERM) but after 22 months, in September 1992, exited the ERM and has not yet adopted the Euro. Denmark, who was also allowed to ratify the Maastricht Treaty by referendum, has originally rejected it but eventually, following a second referendum in 1992, ratified the Treaty and joined the ERM but has not yet adopted the Euro. Sweden jointed the EU in 1995 but it has neither entered the ERM nor adopted the Euro. We investigate the effect of the introduction of the Euro as the common European currency on the volatility of bank stocks listed in European stock exchanges within the EU and across Europe. In particular, we investigate the volatility of realised returns on bank stocks listed in the European Union countries that have adopted the Euro in 2002 and those that they have not, i.e. the UK, Denmark and Sweden.

The single European Act (1986) and the Second Banking Directive (1989) signalled the determination of the EU to work towards achieving a single market in the banking and financial services industry. Since then, a number of directives have introduced to facilitate the achievement of this objective. The adoption of Euro as the common European currency is the latest decisive step towards European integration. We investigate the level of the overall progress towards the banking industry integration within the EU by comparing the level of integration in the bank stock returns recently and at the beginning of this process. In particular, we investigate the volatility of realised returns on bank stocks listed in the European Union countries that have adopted the Euro post-2002 and at the start of the process, over the period 1990-1998. The empirical finding of this research are not only useful to investors and market participants but can have significant implications for the work of politicians and regulators in national and EU level. International agencies, like the ECB and IMF, might also gain useful insight on how their recommendations, adopted into EU directives, might affect the European banking industry.

The rest of the paper is organized as follows. In section 2 we provide a brief literature review. In section 3 we describe the data and in section 4 the adopted methodology. In section we 5 present our empirical results and Section 6 concludes the paper.

## 2. LITERATURE REVIEW

The integration of financial markets is an issue that has attracted the interest of practitioners, governments and academics, as it has consequences for identification of barriers and opportunities for international investment strategies, asset pricing and portfolio diversification, as well as social wealthfare implications (Bartram and Dufey, 2001). There are several measures of financial integration (Adam *et al*., 2002), with the most common indicators based on price and return data. Their main advantages are broad availability and a clear-cut interpretation founded in the logic of the law of one price (Reszat, 2003).

A number of studies explore financial market integration employing the CAPM (Hardouvelis *et al*. 2001, Bekaert and Harvey 1995, Dumas and Solnik 1995, Ferson and Harvey 1991). The null hypothesis of full integration requires the local portfolio to be solely priced relative to the global portfolio and finds, in general, empirical support. Thus, the basic intuition of the CAPM is that local returns in a fully integrated market depend only on nondiversifiable international factors (Fratzscher, 2002). In international macroeconomics, financial market integration is examined with the help of interest rate parity conditions (Lemmen and Eijffinger 1996, Frankel 1992, Frankel and MacArthur 1988, Feldstein and Horioka 1980). There is a broad consensus that most of the deviation from uncovered interest rate parity (UIP) in developed markets is due to exchange rate risk premia whereas country premia have become smaller or disappeared over time (Frankel, 1992).

Research on financial integration employs GARCH models in order to take into account the existence of ARCH effects of higher frequency (Fratzscher, 2002). Koutmos and Booth (1995) investigate the dynamic interaction of the New York, Tokyo and London stock exchanges examining price and volatility spillovers with the help of an extended multivariate EGARCH model. They document significant volatility spillovers from New York to London and Tokyo, from London to New York and Tokyo and from Tokyo to London and New York. They also report that since the October 1987 crisis, these stock exchanges have become more integrated and stocks in New York and London have become more sensitive to innovations originating in Tokyo. Lin and Ito (1994) find similar volatility spillovers between the London, Tokyo and New York stock markets. Fratzscher (2002) examines the integration process of European equity markets since the 1980s. He focuses on the role of European Monetary Union (EMU) and the changes in exchange rate volatility on the integration process of the European financial markets. He employs an uncovered interest rate parity condition to measure financial integration using a trivariate GARCH model and provides evidence that the European unification process had raised the degree of integration, in particular among countries that have adopted the Euro (Euro-adopters). The reduction of exchange rate uncertainty and the convergence of monetary policies on interest rates and inflation were identified as the main drives behind the European financial integration.

Bartram *et al.* (2005) investigate the impact of the introduction of the Euro on the integration of equity markets in Europe during the period 1994-2003 using a GJR-GARCH-t model that allows capturing time-varying and non-linear relationships. They explore changes in the time-varying dependencies of European markets within Euro area as well as equity markets between the Euro area and non-Euro area. Their results show that, within Euro area, market dependence increases after the introduction of Euro only for large equity markets such as in France, Germany, Italy, the Netherlands and Spain. Those markets characterized by relatively large equity market capitalization, comprehensive regulations, high liquidity and low transaction and information costs. On the other hand, transaction costs remained important barriers to investment in the smaller markets and thus their integration. Testing for alternative structural breaks in market dependence, Bartram *et al.* (2005) find that the increase in dependence started in late 1997 or early 1998 when Euro membership was determined and announced. However, most of the remaining European countries continued to lack significant integration into the Euro area. The UK and Sweden have not adopted the Euro but their stock market dependence with the Euro area markets had slightly increased since its introduction, indicating possible market anticipation of eventual Euro adoption.

Askari and Chatterjee (2005) investigate the convergence in real and nominal interest rates and stock market index returns between three different groups of countries, namely the Euro-adopters, the non-Euro-adopters and countries outside EU (United States, Japan and Switzerland). Their investigation expands over three different time-periods: Maastricht Treaty discussions (January 1992-December 1995), period of convergence (January 1996-December 1998) and the period following the launch of the Euro (January 1999-June 2003). Their results, although mixed, show that the adoption of the Euro had somewhat enhanced financial market integration. In particular, for the Euro-adopting countries, the introduction of Euro reduced the cost of capital, especially for the less-developed Euro-adopters. It appeared, however, that the three non-Euro-adopting countries had also benefited from a lower cost of capital following the introduction of Euro.

This study investigates the changes on the level of the European banking industry integration following the Second Banking Directive (1989). The EU has clearly stated its intension to achieve a single market in the banking industry as a main drive to a broader economic integration and progress. Over the last fifteen years, a number of significant developments, like the introduction of CAD-I and CAD-II, the introduction of Euro and the accession of new member sates in the EU have changed the economic environment and the operational framework of the European banking. However, there is no evidence on the effect of those changes on the level of integration of European banking and this study aims to provide new evidence on this issue.

## 3. DATA AND SAMPLE CHARACTERISTICS

We use daily stock returns for 261 European banks listed in the stock exchanges of 32 European countries. Our data source is the Datastream International and the sample period extends from January 1990 to December 2005, including 4,168 daily observations. Table 1 provides our sample description and the adopted classification.

Table 1, Panel A, shows the group classification of the 32 European countries, included in our study. We include all European countries with data for their listed banks in Datastream. The largest group, with twelve countries, is the Euro-Adopters, i.e. the EU member-states that have adopted the Euro. Three EU members, i.e. Denmark, Sweden and the UK have not adopted the Euro yet and are classified as the Non-Euro-Adopters group. The second largest group is the New-Members group, which includes the ten new members that joined the EU in May 2004. Finally, the seven European countries currently outside the EU are classified into the Non-Members group.

Table 1 about here

Panel B shows the distribution of countries and banks for our group classification. A total number of 261 banks, with available data in the Datastream are included. The majority of banks in our sample, i.e. 135 banks (52%) are concentrated in the 12 member states of Euro-Adopters. Almost a fifth of our sample (54 banks – 21%) is banks listed in the 10 new member states. In stock exchanges of countries outside the EU, we have 46 banks (18%) and the remaining 26 banks (10%) are listed in the Non-Euro-Adopters group.

Panel C gives a list of major recent developments that have affected the European banking industry. The introduction of CAD-I and CAD-II in 1996 and 1998 respectively, the adoption of the Euro in 1999 and the accession of the ten new member states in 2004 are the most significant of them. The effect of those events in the European banks is expected to reflect in the volatility of banks returns and have a measurable impact on the level of the integration of the industry.

Table 2 reports descriptive statistics of stock returns of bank groups used in our subsequent analysis. We calculate bank stock returns as the difference of log prices and the mean daily return of each group is the average daily returns of the stocks in this group.

Table 2 about here

The New-Members group has the highest mean daily bank stock returns at the expense of higher volatility, with the Non-Euro-Adopters experiencing the lowest returns and volatility. The average stock return series for all four groups, i.e. EUROR, NONEUROR, NMEMBERSR and OUTSIDEEUR, are all stationary.

## 4. METHODOLOGY

### 4.1. Univariate GARCH Approach

We have adopted the univariate GARCH approach in order to examine the level of volatility and error for different periods of investigation from 1990 to 2005. The univariate Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model for the return and variance equation has the following form:[3]

$$R_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i R_{t-n} + \varepsilon_t \tag{1}$$

$$h_t = Var(\varepsilon_t) = \beta_{0(ST)} + \sum_{p=1}^{n} \beta_{p(ST)} ARCH_{t-p} + \sum_{q=1}^{n} \beta_{q(ST)} GARCH_{t-q} \tag{2}$$

The log-likelihood function is:

$$\begin{aligned} \text{Log L} &= -0.5 * (\log(h_t) + \frac{\varepsilon_t * \varepsilon_t}{h_t}) = \\ &- 0.5 * (\log(\beta_{0(ST)} + \sum_{p=1}^{n} \beta_{p(ST)} ARCH_{t-p} + \sum_{q=1}^{n} \beta_{q(ST)} GARCH_{t-q}) \\ &+ \frac{\varepsilon_t * \varepsilon_t}{\beta_{0(ST)} + \sum_{p=1}^{n} \beta_{p(ST)} ARCH_{t-p} + \sum_{q=1}^{n} \beta_{q(ST)} GARCH_{t-q}}) \end{aligned} \tag{3}$$

Maximizing logL is equivalent to maximizing L because the logarithmic transformation is monotonic and increasing. We find the maximum by differentiating the log-likelihood function with respect to each of the three unknown parameters and equate the

[3] See Bollerslev (1986) and Bollerslev *et al.* (1992) for details on the GARCH model. This study utilizes the BHHH method presented by Berndt et al. (1974) for the model estimation.

derivatives to zero. Differentiating Equation (3) partially with respect to $\beta_{0(ST)}, \beta_{p(ST)}$ and $\beta_{q(ST)}$ and setting the derivatives equal to zero:

$$\frac{\partial(\log L)}{\partial\beta_{0(ST)}} = 0 \quad (4); \qquad \frac{\partial(\log L)}{\partial\beta_{p(ST)}} = 0 \quad (5); \qquad \frac{\partial(\log L)}{\partial\beta_{q(ST)}} = 0 \quad (6)$$

The parameter restrictions $\beta_{0(ST)} > 0$, $\beta_{p(ST)} \geq 0$, $\beta_{q(ST)} \geq 0$ and $\beta_{p(ST)} + \beta_{q(ST)} < 1$ ensure that the stochastic process $\{\varepsilon_t\}$ is well-defined (i.e., $h_t > 0 \forall t$) and the covariance is stationary with $E(\varepsilon_t) = 0$, Var($\varepsilon_t$)=h, and Cov ($\varepsilon_t, \varepsilon_s$)=0 $t \neq s$.

**4.2. Bivariate GARCH-BEKK approach**

Among GARCH models, the bivariate GARCH approach is the most widely used in time-varying second moments (covariance) studies. The GARCH-BEKK model successfully overcomes the problems associated with previous approaches, like the requirement of the definite matrix $H_t$ to be positive, which does not always hold. Similarly, previous approaches examining volatility spillovers also impose the restriction for the estimated variance to be greater than zero. In contrast, the GARCH-BEKK parameterisation is specified in such a manner that no restrictions are required to ensure a positive definite $H_t$ matrix.

The multivariate GARCH-BEKK model (Engle and Kroner, 1995) for the return and variance is:

$$R_{t+1} = \alpha_0 + \sum_{i=1}^{n} R_{(t+1)-n} + \varepsilon_{t+1} \tag{7}$$

$$E(\varepsilon_t) = E(R_{t+1} - \mu_{(ST)}) \tag{8}$$

$$H_{t+1} = CC' + B'H_t B + A'\varepsilon_t * \varepsilon_t' A \tag{9}$$

where, $\mu_{(ST)}$ is the long-term drift coefficient for the constant.

Given a sample of T observations of the returns vector, $R_{t+1}$, the parameters of the bivariate systems are estimated by computing the conditional log-likelihood function for each time period as:

$$L_t(\Theta) = -\log 2\pi - \frac{1}{2}\log|H_{t+1}| - \frac{1}{2}E(\varepsilon_t)'(\Theta)H_t^{-1}(\Theta)E(\varepsilon_t)(\Theta)$$

and $L(\Theta) = \sum_{t=1}^{T} L_t(\Theta)$ (10)

where $\Theta$ is the vector of all parameters. Numerical maximization of the log-likelihood function following the Berndt, Hall, Hall, and Hausman (1974) algorithm yields the maximum likelihood estimates and associated asymptotic standard errors.

An expansion of the GARCH-BEKK parameterisation equation for the bivariate GARCH (p, q) model takes the form:

$$\begin{pmatrix} h_{11,t+1} & \\ h_{12,t+1} & h_{22,t+1} \end{pmatrix} = \begin{pmatrix} c_{11(ST)} & c_{12(ST)} \\ c_{12(ST)} & c_{22(ST)} \end{pmatrix} * \begin{pmatrix} c_{11(ST)} & c_{12(ST)} \\ c_{12(ST)} & c_{22(ST)} \end{pmatrix} +$$
$$\begin{pmatrix} b_{11(ST)} & b_{21(ST)} \\ b_{12(ST)} & b_{22(ST)} \end{pmatrix} * \begin{pmatrix} h_{11,t} & \\ h_{12,t} & h_{22,t} \end{pmatrix} * \begin{pmatrix} b_{11(ST)} & b_{12(ST)} \\ b_{21(ST)} & b_{22(ST)} \end{pmatrix} + \tag{11}$$
$$\begin{pmatrix} \alpha_{11(ST)} & \alpha_{21(ST)} \\ \alpha_{12(ST)} & \alpha_{22(ST)} \end{pmatrix} * \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} * \begin{pmatrix} \varepsilon_{1,t} & \varepsilon_{2,t} \end{pmatrix} * \begin{pmatrix} \alpha_{11(ST)} & \alpha_{12(ST)} \\ a_{21(ST)} & \alpha_{22(ST)} \end{pmatrix}$$

where $h_{11,t+1}$ is the volatility for the first series in period t+1; $h_{22,t+1}$ is the variance of the return series in period t+1; $h_{12,t+1}$ is the covariance between the first and the second series in period t+1; $c_{11(ST)}$ is the constant coefficient for the first series in period t; $c_{12(ST)}$ is the constant coefficient for the covariance between the two series in period t, and $c_{22(ST)}$ is the constant coefficient for the second series in period t; $b_{11(ST)}$ is the volatility coefficient for the first series in period t; $b_{21}$ is the volatility spillover coefficient from the first series to the second series in period t; $b_{12(ST)}$ is the volatility spillover coefficient from the second series to the first series in period t; $b_{22(ST)}$ is the volatility coefficient for the second series in period t; $\alpha_{11(ST)}$ is the coefficient of error term for the first series in period t; $\alpha_{21(ST)}$ is the coefficient of error transmission from the first series to the second series in period t; $\alpha_{12(ST)}$ is the coefficient of error transmission from the second series to the first series in period t; $\alpha_{22(ST)}$ is the squared coefficient of error term for the second series in period t; $\varepsilon_{1,t}$ is the error term for the first series in period t, and $\varepsilon_{2,t}$ is the error term for the second series in period t.

Expanding the above equation to find the intercept terms, in particular the coefficients of lagged variance and covariance and the coefficients of lagged squared errors and lagged covariance of squared errors, this provides the following equation:

$$\begin{pmatrix} h_{11,t+1} & \\ h_{12,t+1} & h_{22,t+1} \end{pmatrix} = \begin{pmatrix} c_{11(ST)}^2 + c_{12(st)}^2 & \\ c_{11(ST)}c_{12(ST)} + c_{12(ST)}c_{22(ST)} & c_{22(ST)}^2 + c_{12(ST)}^2 \end{pmatrix} +$$

$$\begin{pmatrix} b_{11(ST)}^2 h_{11,t} + 2b_{11(ST)}b_{21(ST)}h_{12,t} + b_{21(ST)}^2 h_{22,t} & \\ b_{11(ST)}b_{12(ST)}h_{11,t} + (b_{11(ST)}b_{22(ST)} + b_{12(ST)}b_{21(ST)})h_{12,t} + b_{21(ST)}b_{22(ST)}h_{22,t} & b_{22(ST)}^2 h_{22,t} + 2b_{12(ST)}b_{22(ST)}h_{12,t} + b_{12(ST)}^2 h_{11,t} \end{pmatrix} + \tag{12}$$

$$\begin{pmatrix} \alpha_{11(ST)}^2 \varepsilon_{1,t}^2 + 2\alpha_{11(ST)}\alpha_{21(ST)}\varepsilon_{1,t}\varepsilon_{2,t} + \alpha_{21}^2 \varepsilon_{2,t}^2 & \\ \alpha_{11(ST)}\alpha_{12(ST)}\varepsilon_{1,t}^2 + (\alpha_{11(ST)\alpha_{22(ST)}} + \alpha_{12(ST)}\alpha_{21(ST)})\varepsilon_{1,t}\varepsilon_{2,t} + \alpha_{21(ST)}\alpha_{22(ST)}\varepsilon_{2,t}^2 & \alpha_{22(ST)}^2 \varepsilon_{2,t}^2 + 2\alpha_{12(ST)}\alpha_{22(ST)}\varepsilon_{1,t}\varepsilon_{2,t} + \alpha_{12(ST)}^2 \varepsilon_{1,t}^2 \end{pmatrix}$$

Without using matrices, in a bivariate case, the GARCH-BEKK model takes the form:

$$h_{11,t+1} = c^2{}_{11(ST)} + c_{12(ST)}^2 + a_{11(ST)}^2 \varepsilon_{1,t}^2 + 2\alpha_{11(ST)}\alpha_{21(ST)}\varepsilon_{,t1}\varepsilon_{2,t} + \alpha_{21(ST)}^2 \varepsilon_{2,t}^2 + b_{11(ST)}^2 h_{11,t} + 2b_{11(ST)}b_{21(ST)}h_{12,t} + b_{21(ST)}^2 h_{22,t} \tag{13}$$

$$h_{12,t+1} = c_{12(ST)}c_{11(ST)} + c_{12(ST)}c_{22(ST)} + \alpha_{11(ST)}\alpha_{12(ST)}\varepsilon_{1,t}^2 + (\alpha_{21(ST)}\alpha_{12(ST)} + \alpha_{11(ST)}\alpha_{22(ST)})\varepsilon_{1,t}\varepsilon_{2,t} + \alpha_{21(ST)}\alpha_{22(ST)}\varepsilon_{2,t}^2 + b_{11(ST)}b_{12(ST)}h_{11,t} + (b_{12(ST)}b_{21(ST)} + b_{11(ST)}b_{22(ST)})h_{12,t} + b_{21(ST)}b_{22(ST)}h_{22,t} = h_{21,t} \tag{14}$$

$$h_{22,t} = c^2{}_{12(ST)} + c_{22(ST)}^2 + \alpha_{12(ST)}^2 \varepsilon_{1,t}^2 + 2\alpha_{12(ST)}\alpha_{22(ST)}\varepsilon_{1,t}\varepsilon_{2,t} + \alpha_{22(ST)}^2 \varepsilon_{2,t}^2 + b_{12(ST)}^2 h_{11,t} + 2b_{12(ST)}b_{22(ST)}h_{12,t} + b_{22(ST)}^2 h_{22,t} \tag{15}$$

where $\alpha_{11(ST)}$ is the coefficient of noise for the first series of equities; $\alpha_{12(ST)}$ is the coefficient of noise transmission from the second series of equities to the first series of equities; $\alpha_{21(ST)}$ is the coefficient of noise transmission from the first series of equities to the second series of equities; $\alpha_{22(ST)}$ is the coefficient of noise of the second series of equities; $b_{11(ST)}$ is the coefficient of volatility for the first series of equities; $b_{12(ST)}$ is the coefficient of volatility transmission from the second series of equities to the first ; $b_{21(ST)}$ is the coefficient of volatility transmission from the first series of equities to the second; $h_{11}$ is the estimated volatility of the first series of equities; $h_{22}$ is the estimated volatility of the second series of equities; $h_{12}$ is the estimated volatility transmission from the second series of equities to the first series of equities; $\varepsilon_1$ is the error term in the first series of equities; $\varepsilon_2$ is the error term in the second series of equities; $c_{11(ST)}$ is the constant coefficient of covariance for the first series of equities; $c_{12(ST)}$ is the constant coefficient of covariance from the second series of equities to the first series of equities.

This model can be economised by imposing the following restriction on the above equation: $B'H_tB=0$. The main limitation to estimating bivariate GARCH type models is the large number of parameters that have to be estimated when the log-likelihood function is maximised; this number is equal to n*(n+1)/2+(p+q)*n2*(n+1)*2/4. Two possible restrictions are suggested in the literature. The first one is suggested by Bollerslev *et al.* (1988), in particular, they set p=q=1 and make the matrices A and B diagonal, reducing the number of parameters in the log-likelihood function to 3n*(n+1)/2. This restriction eliminates the possibility of capturing any transmission between pricing series with the GARCH-BEKK model. It also provides a means of estimating two univariate GARCH processes where in the second one only conditional covariance estimates are considered. In particular, this model takes the form:

$$h_{11,t+1} = c_{11(ST)}^2 + \alpha_{11(ST)}^2 \varepsilon_{1,t}^2 + b_{11(ST)}^2 h_{11,t} \tag{16}$$

$$h_{22,t} = c_{11(ST)}^2 + c_{22(ST)}^2 + \alpha_{22(ST)}^2 \varepsilon_{2,t}^2 + b_{22(ST)}^2 h_{22,t} \tag{17}$$

$$h_{12,t} = h_{21,t} = c_{11(ST)} c_{22(ST)} + \alpha_{11(ST)} \alpha_{22(ST)} \varepsilon_{1,t} \varepsilon_{2,t} + b_{11(ST)} b_{22(ST)} h_{12,t} \tag{18}$$

$$h_{21,t} = h_{12,t} \tag{19}$$

The second restriction is suggested by Bollerslev (1990) who proposes that the correlation between variables to be time-invariant and, therefore, allows the covariance of equities to change and be equal to:

$$\mathrm{h}_{ij,t} = \mathrm{p}_{ij} (\mathrm{h}_{ii,t} * \mathrm{h}_{jj,t})^{1/2} \tag{20}$$

This could reduce the number of parameters in the log-likelihood function, allowing each individual variance to behave as a univariate GARCH (p, q) process and also resulting in a small number of 3n+n*(n+1)/2 parameters. In this case, the GARCH-BEKK model takes the form:

$$h_{11,t+1} = c_{11(ST)} + \alpha_{11(ST)} \varepsilon_{1,t}^2 + b_{11(ST)} h_{11,t} \tag{21}$$

$$h_{22,t} = c_{22(ST)} + \alpha_{22(ST)} \varepsilon_{2,t}^2 + b_{22(ST)} h_{22,t} \tag{22}$$

$$h_{12,t} = h_{21,t} = c_{12(ST)} \sqrt{h_{11,t} * h_{22,t}} \tag{23}$$

$$h_{21,t} = h_{12,t} \tag{24}$$

where,

$c_{12(ST)} = Q(1,2) / \sqrt{(c_{11(ST)} * c_{22(ST)}}$ and Q(1,2) is the covariance matrix. (25)

The above three models govern a different covariance equation. Hence, it is not clear whether the parameters for $h_{12}$ are just the result of the parameter estimates for $h_{11}$ and $h_{22}$ or if the covariance equation alters the parameters estimates of the variance equations for the above equations. Following Baur (2002), the persistence of volatility and covariance for two series is equal to:

In the first model's equations (13-15), the persistence of shocks to volatility for the two series is different for the first series:

$$\alpha_{ii(ST)} + 2\alpha_{ii(ST)}\alpha_{ji(ST)} + \alpha_{ji(ST)} + b_{ii(ST)} + 2b_{ii(ST)}b_{ji(ST)} + b_{ji(ST)} \tag{26}$$

and for the second series:

$$\alpha_{ij(ST)} + 2\alpha_{ij(ST)}\alpha_{jj(ST)} + \alpha_{jj(ST)} + b_{ij(ST)} + 2b_{ij(ST)}b_{jj(ST)} + b_{jj(ST)} \tag{27}$$

for i=1 and j=2

while the persistence of the covariance is equal to:

$$\begin{aligned}&\alpha_{ii(ST)}\alpha_{jj(ST)} + \alpha_{ji(ST)}\alpha_{ij(ST)} + \alpha_{ii(ST)}\alpha_{jj(ST)} + \alpha_{ji(ST)}\alpha_{jj(ST)} + b_{ii(ST)}b_{ij(ST)} + \\ &b_{ij(ST)}b_{ji(ST)} + b_{ii(ST)}b_{jj(ST)} + b_{ji(ST)}b_{jj(ST)}\end{aligned} \tag{28}$$

For example, in the equations (16-19) the persistence of shocks to volatility can be estimated by

$$\alpha_{ii} + b_{ii} \quad \text{for i=1,2} \tag{29}$$

while the persistence of the covariance can be equal to:

$$\alpha_{ii(ST)}\alpha_{jj(ST)} + b_{ii(ST)}b_{jj(ST)} \quad \text{for i=1 and j=2} \tag{30}$$

The last Equations (21-25) show that the correlations are constant while the covariances are time-variant. The persistence of shocks to volatility is equal to:

$$\alpha_{ii(ST)} + b_{ii(ST)} \quad \text{for i=1,2} \tag{31}$$

where the persistence of the covariance is equal to:

$$c_{ij(ST)} \text{ for i=1 and j=2} \tag{32}$$

The above outlines the main differences of the GARCH-BEKK modelling approach with respect to the persistence of volatility and covariance which someone should consider before investigating volatility spillovers. In the current study, we use the full GARCH-BEKK model (without any of the above restrictions) which considers different variances and a dynamic covariance in order to examine the joint effects of the coefficients for different series.

## 5. EMPIRICAL RESULTS

In this section we present and discuss the findings of our empirical analysis. We employ both univariate and bivariate GARCH models to explore the effect of the adoption of the CAD-I, CAD-II, the introduction of Euro and the accession of new member states into the EU during the May 2004 enlargment, on the level of the banking industry integration.

### 5.1. Results for the effect of CAD-I, CAD-II and Euro on volatility

Table 3, Panel A and B report the results from estimating the univariate R(k)-GARCH (p,q) model in Equations (1-2). We test the null hypothesis of no ARCH and GARCH differences (i.e. one ARCH and GARCH lag) against the alternative of an ARCH or GARCH difference (for example two ARCH or GARCH lags). The null hypothesis is equivalent to low level of heteroscedasticity and thus, to the linear R(k)-GARCH (1,1). The standard Akaike and Schwartz tests are employed to test this hypothesis.

Table 3 about here

In Panels A and B, we report that the log-likelihood value of the R(k)-GARCH (1,1) model is significantly higher (15270.11) than the log-likelihood value of the R(k)-GARCH (1,2) models (10411.06 and 8403.35) and the log-likelihood value of R(k)-GARCH (2,1) model (8507.60) in the period before the introduction of Euro[4]. For the groups of Euro-Adopters, New-Members and Non-Members, the Akaike and Schwartz tests suggest that the null hypothesis is rejected and higher level R(k)-GARCH (p,q) models are favoured over the R(k)-GARCH (1,1) model. In addition, the Akaike and Schwartz criteria favour the R(k)-GARCH (3,2) model for the group of the New-Members in the post-Euro adoption period. Therefore, the two periods of investigation are exhibit a volatility variety considering the ARCH and GARCH differences.

In particular, the ARCH effects (the sum of $\beta_{p(ST)}$ coefficients), for the group of the Euro-Adopters, are higher in the first period (0.221) than the second period (0.094). The same applies for the other groups of the Non-Euro-Adopters (0.082 versus 0.049), the New-Members (0.672 versus 0.228-0.327+0.190). In contrast, for the group of the Non-Members, the ARCH effects in the first period are lower than in the second (0.222-0.106 versus 0.134 respectively). The reverse applies for the GARCH effects (the sum of $\beta_{q(ST)}$ coefficients), which are lower in the first period than the second period for the group of the Euro-Adopters (0.160+0.512 versus 0.864), the Non-Euro-Adopters (0.902 versus 0.948) and the New-Members (0.229+0.375 versus 1.451-0.551) but higher for the Non-Members (0.878 versus 0.795).

The ARCH and GARCH effects (the sum of $\beta_{p(ST)} + \beta_{q(ST)}$) for the Euro-Adopters and the Non-Euro-Adopters are marginally lower in the first period than in the second (0.893 versus 0.958 and 0.984 versus 0.997 respectively). In contrast, for the New-Members and the

[4] The period before the introduction and adoption of Euro by 11 countries covers the years from 1990 to 1998 and includes the introduction of CAD-I and CAD-II.

Non-Members are higher in the first period than the second and the differences are larger (1.276 versus 0.991 and 0.994 versus 0.929 respectively). Overall, the average ARCH and GARCH effects are larger in the first period (1.037) than in the second period (0.969). Subsequently we examine the significance of the difference of average ARCH effects, GARCH effects and ARCH+GARCH effects between the two periods before and after the introduction of the Euro.

The first hypothesis of equality of the overall ARCH effects between the two periods, is rejected (t-stat=5.50 > 2.63, statistically significant at 1% level), in favour of the alternative hypothesis of higher ARCH effects in the first period.

Similarly, the second hypothesis of equality of the overall GARCH effects between the two periods, is also rejected (t-stat=2.27 > 2.20, statistically significant at 5% level), in favour of the alternative hypothesis of higher GARCH effects in the second period.

Finally, the third hypothesis, which considers the equality of the overall ARCH+GARCH effects between the two periods, is also rejected (at 10% level, t-stat=1.66 > 1.65) in favour of the alternative hypothesis of higher ARCH+GARCH effects in the first period.

To predict the value of the long-term average volatility for the two periods and following Engle and Bollerslev (1986), we replace Equation (2) by the following equation:

$$h_t = Var(\varepsilon_t) = \gamma_{LT} V + \sum_{p=1}^{n} \beta_{p(ST)} ARCH_{t-p} + \sum_{q=1}^{n} \beta_{q(ST)} GARCH_{t-q} \tag{33}$$

where V the long-term average volatility, with the restriction that:

$$\gamma_{LT} + \beta_{p(ST)} + \beta_{q(ST)} = 1 \tag{34}$$

However, because the long-term average volatility is unknown, the Equation (33) takes the form of the Equation (2). However, in these two cases it should hold that

$$\beta_0 = \gamma_{LT} V \tag{35}$$

In the first period, the average sum for all the groups (Euro-Adopters, Non-Euro Adopters, New-members and Non-Members) is $\beta_{p(ST)} + \beta_{q(ST)} = 1.037$. Therefore, $\gamma_{LT} + \beta_{p(ST)} + \beta_{q(ST)} = 1 \Rightarrow \gamma_{LT} + 1.037 = 1 \Rightarrow \gamma_{LT} = 1 - 1.037 \Rightarrow \gamma_{LT} = -0.037$.

From equation (35) and given that the average sum of $\beta_0$ for the above four groups is $0.539E^{-6}$, we have the long-term average volatility:

$$\beta_0 = \gamma_{LT} V_1 \Rightarrow V_1 = \frac{\beta_0}{\gamma_{LT}} \Rightarrow V_1 = -\frac{0.539E^{-6}}{0.037} \Rightarrow V_1 = -0.147E^{-4}$$

Similarly, for the second period we find that $V_2$ =0.232E$^{-2}$. Therefore, the difference in the long-term average volatility is $\Delta V = V_2 - V_1$ = 0.247E$^{-3}$. This suggests that the long-term average volatility in the second period is higher by 0.247E$^{-3}$ than the first period, due to the higher persistence of ARCH and GARCH terms in the first period and given that:

$$\begin{aligned}\gamma_{2(LT)} - \gamma_{1(LT)} &= 1 - \beta p_{2(ST)} - \beta q_{2(ST)} - (1 - \beta p_{1(ST)} - \beta q_{1(ST)}) = 1 - \beta p_{2(ST)} - \beta q_{2(ST)} - 1 + \\ \beta p_{1(ST)} + \beta q_{1(ST)} &= (\beta p_{1(ST)} + \beta q_{1(ST)}) - (\beta p_{2(ST)} + \beta q_{2(ST)}) = \gamma_{1(ST)} - \gamma_{2(ST)}\end{aligned} \tag{36}$$

We find that the difference of 0.247E$^{-3}$ in the long-term average volatility is statistically significant, because the difference of the long-term coefficients of ($\gamma_{2(LT)} - \gamma_{1(LT)}$) is equal to the difference of the short-term coefficients of ($\gamma_{1(ST)} - \gamma_{2(ST)}$) which is found previously to be statistically significant at 10% significance level. Therefore, there is some evidence that the first period is a period of 'high' short-term volatility and 'low' long-term volatility. In contrast, the second period is a period of 'low' short-term volatility and 'high' average value of long-term volatility.

### 5.2 The effect of Euro adoption and the expansion of the EU

Subsequently, we investigate the differential impact of the Euro adoption on bank stocks of the Euro-Adopters and Non-Euro-Adopters. This focus within the EU provides evidence on the impact of the decision of the three EU member-states (Denmark, Sweden and the UK) not to joint the Euro on the level of integration of the banking industry within the EU. In similar fashion, we also explore the differential impact of the latest EU enlargement on the banking industry outside the EU, i.e. the area of New-Member states and the countries that have not yet joined the EU.

Following our previous findings that the post-Euro period (1999-2005) has lower ARCH+GARCH effects than the pre-Euro period (1990-1998), we further consider a R(k)-GARCH-BEKK model to measure the level of integration of the bank stock returns in the group of Euro-Adopters and Non-Euro-Adopters, post-Euro adoption and before the EU expansion in May 2004. We also employ a similar analysis for the bank stock returns of New-Members and Non-Members, in order to measure the level of integration for this period followed the latest expansion of EU. In particular, we consider the period from the beginning of May 2004 to the end of 2005. Then, we test the difference on the measures of the level of integration between these events considering the volatility and noise transmission between Euro-Adopters and Non-Euro-Adopters and between New-Members and Non-Members.

Finally, we examine if there is a difference in the overall covariance persistence between these two periods.

Table 4, Panel A reports the results for the R(k)-GARCH-BEKK model for the period of the circulation of Euro for the groups of Euro-Adopters and Non-Euro-Adopters. The null hypothesis of no volatility dependence is rejected in favour of the alternative of volatility dependence on the basis of the significantly unilateral transmission of volatility from Non-Euro-Adopters to Euro-Adopters (-0.003) and the significantly unilateral transmission of noise from Non-Euro-Adopters to Euro-Adopters (0.012). The LR (likelihood ratio test) further supports this result. Thus, the period of circulation of Euro is jointly characterized by partly volatility dependence (partly integration), which is well captured by the R(k)-GARCH-BEKK technique.

Table 4 about here

The results for testing for volatility spillovers between New-Members and Non-Members are reported in Panel B. The null hypothesis of no volatility dependence is rejected. We also find that the volatility is transmitted from New-Members to Non-Members (0.102) in the period following the accession of New-Members to the EU, in May 2004. Comparing this result with the volatility spillovers following the previous period of the circulation of Euro, we observe that in the second, post-enlargement period, a different level of dependence (partly integration) is evident. This result suggests that there are no bilateral volatility spillover effects between New-Members and Non-Members, but only unilateral volatility dependence between them. The LR (likelihood ratio) test further supports this finding.

Next, we consider whether there is any significant change in the level of integration in the periods post-Euro circulation and post-enlargement in May 2004. We test the level of integration between these two periods to identify any differences on the level of integration despite the fact that the volatility spillovers have to do with two different series. We use the groups of Euro-Adopters and Non-Euro Adopters in the first period in order to assess the level of banking integration in the period following the circulation of Euro and the groups of New-Members and Non-Members for the period following the latest EU enlargement.

Table 5, shows that there is a lower level of integration in the second period than the first period with respect to the volatility transmission and a higher level of noise transmission in the second period than the first. Table 5, Panels A and B provide evidence that there is a difference in the level of volatility spillover between the groups of Euro-Adopters and Non-Euro-Adopters and similarly between New-Members and Non-Members. Columns 2 and 3 report the original results of volatility and noise transmissions between the above two mentioned series respectively, while column 3 contains the values of difference between the two volatility transmitted periods.

Table 5 about here

Our results show that there is a different pattern of the volatility and noise spillover effects between the two periods and amongst the groups of countries investigated. Over the first period, following the circulation of the Euro, there are asymmetric volatility spillover effects from the group of Euro-Adopters to the group of Non-Euro-Adopters. There is a negative and significant volatility spillover effect from the Non-Euro-Adopters group to the Euro-Adopters group. In contrast, the larger positive volatility spillover from the Euro-Adopters to the Non-Euro-Adopters is not statistically significant. Over the second period, following the EU expansion, we find that the volatility spillover from the New-Members to the Non-Members is positive and statistically significant. In contrast, the opposite effect, i.e. the volatility spillover from the Non-Members to the New-Members is negative but not significant.

The same holds for the influence of the circulation of Euro and the expansion of EU on the noise for the two periods and the respective groups of countries. The circulation of Euro and the expansion of EU affect the volatility patterns differently indicating dissimilar levels of integration between the two groups over these periods. Therefore, applying the R(k)-GARCH-BEKK model in the bivariate relation of two variables is important in uncovering a relation between the two variables in the two periods. In particular, we find that the volatility spillovers vary within the two periods and they are also asymmetric. That means that the influence of one group of countries over the other is different than the reverse influence. Therefore, both Euro events add a value of a different level of integration process for the countries that adopt the Euro and participate in the EU enlargement. The difference of the coefficients of volatility transmission suggests that the measurement of the level of integration in the second period is higher than the first period by 0.217. The above result is confirmed by the value of the t-statistic which is equal to 1.79, statistically significant at the 10% significance level. Therefore, we can conclude that the difference of the average values of the coefficients of $\mathrm{b}_{12(ST2)}, b_{21(ST2)}, \alpha_{12(ST2)}$ and $\alpha_{21(ST2)}$ of the second period minus the first period is statistically significant at the 10% significance level. We also estimate the values of the standard errors for the coefficients of $\mathrm{b}_{12(ST1)}, b_{21(ST1)}, \alpha_{12(ST1)}$ and $\alpha_{21(ST1)}$ that are reported in

Table 5, Panel C for the two periods[5]. The results indicate that the level of integration is higher in the period following the EU enlargement compared to the first period following the adoption of Euro.

Next, we estimate the average long-term covariance over the two periods post-circulation of Euro and post EU expansion. In line with the results reported in Panel B, the persistence of covariance is 1.020 in the first period and 0.628 in the second period. We use the formula in equation (14) and we extend the model of Engle and Bollerslev (1986) as it is shown below:

$$\begin{aligned} h_{12,t+1} &= \delta_{(LT)}\,\mathrm{Cv} + \alpha_{11(ST)}\alpha_{12(ST)}\varepsilon_{1,t}^2 + (\alpha_{21(ST)}\alpha_{12(ST)} + \alpha_{11(ST)}\alpha_{22(ST)})\varepsilon_{1,t}\varepsilon_{2,t} + \alpha_{21(ST)}\alpha_{22(ST)}\varepsilon_{2,t}^2 + \\ & b_{11(ST)}b_{12(ST)}h_{11,t} + (b_{12(ST)}b_{21(ST)} + b_{11(ST)}b_{22(ST)})h_{12,t} + b_{21(ST)}b_{22(ST)}h_{22,t} = h_{21,t+1} \end{aligned} \tag{37}$$

where Cv is the long-term covariance.

In particular, we extend the model proposed by Engle and Bollerslev (1986) to find the covariance that follows a predictable process. The restriction for this process to be followed is the following one:

$$\begin{aligned} &\delta_{(LT)} + \alpha_{11(ST)}\alpha_{12(ST)} + \alpha_{21(ST)}\alpha_{12(ST)} + \alpha_{11(ST)}\alpha_{22(ST)} + \alpha_{21(ST)}\alpha_{22(ST)} + b_{11(ST)}b_{12(ST)} + \\ &b_{12(ST)}b_{21(ST)} + b_{11(ST)}b_{22(ST)} + b_{21(ST)}b_{22(ST)} = 1 \end{aligned} \tag{38}$$

However, because the long-term average covariance is unknown, equation (38) takes the form of the equation (15) and it should hold:

$$c_{12(ST)}c_{11(ST)} + c_{12(ST)}c_{22(ST)} = \delta_{(LT)}Cv \tag{39}$$

In the period following the circulation of Euro, the covariance persistence is equal to:

$$\begin{aligned} \delta_{(ST)} &= \alpha_{11(ST)}\alpha_{12(ST)} + \alpha_{21(ST)}\alpha_{12(ST)} + \alpha_{11(ST)}\alpha_{22(ST)} + \alpha_{21(ST)}\alpha_{22(ST)} + \\ & b_{11(ST)}b_{12(ST)} + b_{12(ST)}b_{21(ST)} + b_{11(ST)}b_{22(ST)} + b_{21(ST)}b_{22(ST)} \end{aligned} = 1.020 \tag{40}$$

Therefore, for the two groups investigated (Euro-Adopters and Non-Euro-Adopters) we have:

$$\begin{aligned} &\delta_{(LT)} + \alpha_{11(ST)}\alpha_{12(ST)} + \alpha_{21(ST)}\alpha_{12(ST)} + \alpha_{11(ST)}\alpha_{22(ST)} + \alpha_{21(ST)}\alpha_{22(ST)} + \\ &b_{11(ST)}b_{12(ST)} + b_{12(ST)}b_{21(ST)} + b_{11(ST)}b_{22(ST)} + b_{21(ST)}b_{22(ST)} = 1 \\ &\Rightarrow \delta_{(LT)} + 1.020 = 1 \Rightarrow \delta_{(LT)} = 1 - 1.020 \Rightarrow \delta_{(LT)} = -0.020 \end{aligned} \tag{41}$$

It also holds: $c_{12(ST)}c_{11(ST)} + c_{12(ST)}c_{22(ST)} = \delta_{(LT)}Cv_1$

and the sum: $c_{12(ST)}c_{11(ST)} + c_{12(ST)}c_{22(ST)}$ for the post-circulation of Euro period is $0.205E^{-5}$.

Therefore:

[5] The procedure of the known t-test is not reported but it is available upon request.

$$c_{12(ST)}c_{11(ST)} + c_{12(ST)}c_{22(ST)} = \delta_{(LT)}Cv_1 \Rightarrow$$

$$\Rightarrow Cv_1 = \frac{c_{12(ST)}c_{11(ST)} + c_{12(ST)}c_{22(ST)}}{\delta_{(LT)}} \Rightarrow Cv_1 = -\frac{0.205E^{-5}}{0.020} \Rightarrow Cv_1 = -0.104E^{-3}$$

Similarly, for the period of post-adoption of Euro we find that $\mathrm{Cv}_2 = 0.112\mathrm{E}^{-3}$. Therefore, for the long-term the average covariances over the second period is higher than in the first period and they differ by $\Delta Cv = \mathrm{Cv}_2 - \mathrm{Cv}_1 = 0.217\mathrm{E}^{-3}$. This is in line with our findings for the volatility transmission coefficients reported in Table 4, Panel B. In particular, the difference of covariance of the second and first period in the long-term is equal to: $\delta_{2(LT)} - \delta_{1(LT)} = \delta_{1(ST)} - \delta_{2(ST)} = 0.39$.

This holds because,

$$\begin{aligned}
&\delta_{2(LT)} - \delta_{1(LT)} = (1 - \alpha_{11(ST2)}\alpha_{12(ST2)} - \alpha_{21(ST2)}\alpha_{12(ST2)} - \alpha_{11(ST2)}\alpha_{22(ST2)} - \alpha_{21(ST2)}\alpha_{22(ST2)} - \\
&b_{11(ST2)}b_{12(ST2)} - b_{12(ST2)}b_{21(ST2)} - b_{11(ST2)}b_{22(ST2)} - b_{21(ST2)}b_{22(ST2)}) - (1 - \alpha_{11(ST1)}\alpha_{12(ST1)} - \\
&\alpha_{21(ST1)}\alpha_{12(ST1)} - \alpha_{11(ST1)}\alpha_{22(ST1)} - \alpha_{21(ST1)}\alpha_{22(ST1)} - b_{11(ST1)}b_{12(ST1)} - b_{12(ST1)}b_{21(ST1)} - \\
&b_{11(ST1)}b_{22(ST1)} - b_{21(ST1)}b_{22(ST1)}) = \delta_{1(ST)} - \delta_{2(ST)}
\end{aligned} \tag{42}$$

Knowing the above relation between the coefficients of the short and long term, we examine if the difference of 0.39 between the two coefficients is statistically significant. The null hypothesis is that the above two coefficients are equal between the two periods. The null hypothesis is rejected in favour of the alternative that the average long-term covariance in the second period is higher than the covariance in the first period. We also reject the null hypothesis of equal covariance in the short-term, in favour of the alternative of the covariance in the first period is higher than the covariance in the second period.

## 6. CONCLUSIONS

In this paper, we explore the changes in the level of integration in the European banking industry following the Second Banking Directive (1989). We examine the impact of introduction of Euro on the volatility of bank equities in various portfolios over the period from 1990 to 2005. In particular, we compare the group of banks listed in the Euro-Adopters, Non-Euro-adopters, New-Members and Non-Members. For these samples of bank equities, we investigate the impact of introduction of CAD-I and the Euro.

The results reveal that the introduction of Euro has changed the level of integration in thebanking industry not only for the Euro-Adopters group but also for the Non-Euro-Adopters. In particular, the change in volatility and error is found to be larger for those countries that have not adopted the Euro. Further evidence on the effect of the latest EU enlargement by 10 new countries, in May 2004, indicate that volatility and error increase more for the countries that have adopted the Euro than the 10 new members. There is no difference on the volatility and error following the introduction of CAD-I in both the Euro-Adopters and Non-Euro-Adopters. Finally, volatility and error spillovers effects emanate unilaterally between Euro-Adopters and New-Members, with a bigger impact in the period after the last EU enlargement. In general, we find larger transmission affect from the New-Members to Euro-Adopters after the adoption of Euro than before the adoption of Euro.

Following the adoption of the Euro, bank stock returns in the Non-Euro-Adopter member states have a higher volatility and error that bank stocks in Euro-Adopters. Additionally, volatility and error changes increase more for New-Members than Euro-Adopters after the introduction of Euro. We also document that the effect of the adoption of CAD-I and CAD-II on volatility and error transmission changes, for a period before and after the adoption, is similar for Euro-Adopters and Non-Euro-Adopters. Finally, we find that the transmission of volatility between Euro-Adopters and Non-Memebers to be unilateral in early 1990s and after the latest EU enlargment.

Our results are in line with those of Bartram et al. (2005) with respect to the univariate GARCH analysis, as our findings suggest that volatility and error transmission of the bank stock returns have increased for Euro-Adopters and non-Euro-Adopters. Therefore, there is a degree of increase in European banking integration following the introduction of Euro. However, we further document that there are only unilateral spillover effects between the above groups of countries. In contrast, Fratzscher (2002) examines the market integration between Euro-Adopters and non-Euro-Adopters and reports that there is high volatility, especially after the adoption of Euro. Our results show that the degree of market integration is influenced not only by Euro-Adopters, but also by non-Euro-Adopters.

Following the introduction of Euro, the bank stock returns in the countries that have adopted the Euro, are more stable than those in the countries that have joined EU in May 2004 or have not adopted the Euro at all. Aditionally, we find that the introduction of the CAD-I and CAD-II has no measurable effect on the volatility of the bank stock returns in European countries, within or outside the Euro-zone. Overall, our findings suggest that the adoption of Euro as the common European currency has a positive effect on the integration of the European banking industry.

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**Table 1.** Sample characteristics

Panel A: Classification of European banks according to their home country membership and Euro adoption

| Euro-Adopters (12) | Non-Euro-Adopters (3) | New-Members (10) | Countries outside EU (7) |
|---|---|---|---|
| Austria | Denmark | Cyprus | Bulgaria |
| Belgium | Sweden | Czech Republic | Croatia |
| Finland | England | Estonia | Iceland |
| France | | Latvia | Norway |
| Germany | | Slovenia | Romania |
| Greece | | Malta | Russia |
| Ireland | | Poland | Turkey |
| Italy | | Lithuania | |
| Luxemburg | | Slovakia | |
| Netherlands | | Hungary | |
| Portugal | | | |
| Spain | | | |

Panel B: Distribution of banks in our sample data

| Group | Number of Countries | Number of Banks | Percentage |
|---|---|---|---|
| Euro-Adopters | 12 | 135 | 52% |
| Non-Euro-Adopters | 3 | 26 | 10% |
| New-Members | 10 | 54 | 21% |
| Countries outside EU | 7 | 46 | 18% |
| Total | 32 | 261 | 100% |

Panel C: Significant events

| | |
|---|---|
| January 1996 | CAD-I introduction |
| January 1998 | CAD-II introduction |
| January 1999 | Introduction of Euro* |
| May 2004 | EU enlargement – 10 New members |

* In January 2002, the circulation of the Euro as the common European currency, replaced the individual national currencies of the adopting counties.

**Table 2.** Descriptive statistics

| | Mean | Variance | Skewness | Kurtosis | JB | ARCH | ADF |
|---|---|---|---|---|---|---|---|
| EUROR | 0.00032 | 0.0039 | -0.5442 | 9.7081 | 8020.096* | 151.72* | -27.918*(3) |
| NONEUROR | 0.00009 | 0.0004 | 0.0810 | 7.2471 | 3137.291* | 4.21* | -32.668*(3) |
| NMEMBERSR | 0.00053 | 0.0123 | 2.1204 | 41.1523 | 255914.4* | 147.4486* | -29.856*(3) |
| OUTSIDEEUR | 0.00061 | 0.0078 | 0.0048 | 8.3274 | 4927.792* | 75.90* | -29.290*(3) |

Notes: (a) EUROR denotes the stock returns of banks in the Euro-Adopters group, NONEUROR denotes the stock returns of banks in the Non-Euro Adopters group, NMEMBERSR denotes the stock returns of banks in the New-Members group and OUTSIDEEUR denotes the stock returns of banks in the group of countries outside Euro. (b) JB denotes the Jarque-Bera normality test. (c) ADF denotes the augmented Dickey Fuller unit root test. In parentheses next to the ADF test statistic is the number of lags in the ADF regression. (d) * Denotes rejection of the null at the 5% level. For the ADF test, * denotes rejection of the null of nonstationarity. For the JB, * denotes rejection of the null of normality hypothesis.

**Table 3.** The Impact of CAD-I, CAD-II and the Adoption of Euro on Volatility for Bank Equities over the Periods of 1990-1998 and 1999-2005.

| **Panel A:** Period: 1990-1998 | Euro-Adopters | Non-Euro-Adopters | New-Members | Countries Outside EU |
|---|---|---|---|---|
| **Return Equation** | **R (1)** | **R (1)** | **R (1)** | **R (1)** |
| C | $0.174E^{-3}$*** (3.11) | $0.190E^{-4}$*** (2.73) | $-0.170E^{-4}$ (-0.91) | $0.021E^{-2}$** (2.26) |
| R(1) | 0.262*** (11.44) | 0.126*** (6.06) | 0.388*** (106.21) | -0.0650*** (-2.80) |
| **GARCH Equation** | **GARCH (1,2)** | **GARCH (1,1)** | **GARCH (1,2)** | **GARCH (2,1)** |
| C | $1.14E^{-5}$*** (11.53) | $2.87E^{-8}$*** (5.19) | $1.29E^{-7}$*** (8.0889) | $0.10E^{-5}$*** (13.468) |
| ARCH (1) | 0.221*** (12.13) | 0.082*** (10.79) | 0.672*** (31.87) | 0.222*** (10.58) |
| ARCH (2) | | | | -0.106*** (-5.13) |
| GARCH (1) | 0.160*** (4.06) | 0.902*** (99.60) | 0.229*** (6.87) | 0.878*** (131.71) |
| GARCH (2) | 0.512*** (12.67) | | 0.375*** (13.70) | |
| (ARCH+GARCH)<1 | 0.893 | 0.984 | 1.276 | 0.994 |
| Log-Likelihood | 10411.06 | 15270.11 | 8403.35 | 8507.60 |
| **Panel B:** Period: 1999-2005 | Euro-Adopters | Non-Euro-Adopters | New-Members | Countries Outside EU |
| **Return Equation** | **R 1)** | **R (1 TO 2)** | **R (1)** | **R (1)** |
| C | $0.045E^{-2}$*** (5.19) | $0.0103E^{-3}$ (1.38) | $0.066E^{-2}$*** (4.71) | $0.102E^{2}$*** (5.73) |
| R(1) | 0.110*** (4.37) | -0.038** (-2.06) | 0.052*** (1.81 | 0.067*** (2.80) |
| R(2) | | -0.0392**(-2.0634) | | |
| **GARCH** | **GARCH (1,1)** | **GARCH (1,1)** | **GARCH (3,2)** | **GARCH (1,1)** |
| C | $0.792E^{-6}$*** (5.16) | $0.538E^{-9}$*** (3.08) | $0.134E^{-5}$ (6.07)*** | $0.516E^{-5}$*** (9.25) |
| ARCH (1) | 0.094*** (9.39) | 0.049*** (9.24) | 0.228 (9.54)*** | 0.134*** (11.05) |
| ARCH (2) | | | -0.327 (-10.62)*** | |
| ARCH (3) | | | 0.190 (12.95)*** | |
| GARCH (1) | 0.864*** (58.25) | 0.948*** (194.87) | 1.451 (28.86)*** | 0.795*** (55.26) |
| GARCH (2) | | | -0.551 (-14.25)*** | |
| (ARCH + GARCH)<1 | 0.958 | 0.997 | 0.991 | 0.929 |
| Log-Likelihood | 7487.762 | 11807.39 | 6444.580 | 6251.252 |

| **Panel C:** Estimation of $S_e$ of the ARCH and GARCH coefficients for the series between the two periods | | |
|---|---|---|
| | **First period** | **Second period** |
| $S_e(c_{(ST)})$ of Euro-Adopters | $0.986E^{-7}$ | $0.135E^{-6}$ |
| $(\sum S_e(\beta_{p(ST)})$ of Euro-Adopters | 0.018 | 0.010 |
| $(\sum S_e(\beta_{q(ST)})$ of Euro-Adopters | 0.040+0.040=0.080 | 0.015 |
| $S_e(c_{(ST)})$ of Non-Euro Adopters | 0.000000000552 | 0.000000000174 |
| $(\sum S_e(\beta_{p(ST)})$ of Non-Euro Adopters | 0.008 | 0.005 |
| $(\sum S_e(\beta_{q(ST)})$ of Non-Euro Adopters | 0.009 | 0.005 |
| $S_e(c_{(ST)})$ of New-Members | $0.159E^{-8}$ | $0.221E^{-6}$ |
| $(\sum S_e(\beta_{p(ST)})$ of New-Members | 0.021 | 0.024+0.031+0.015=0.070 |
| $(\sum S_e(\beta_{q(ST)})$ of New Members | 0.033+0.027=0.060 | 0.050+0.039=0.089 |
| $S_e(c_{(ST)})$ of Countries outside EU | $0.812E^{-7}$ | $0.558E^{-6}$ |
| $(\sum S_e(\beta_{p(ST)})$ of Countries outside EU | 0.021+0.021=0.042 | 0.0122 |
| $(\sum S_e(\beta_{q(ST)})$ of Countries outside EU | 0.007 | 0.014 |

Notes: (1) Numbers in parentheses are z-statistics. (2) *, **, *** declare significance at 10%, 5% and 1% respectively. (3) The lag selection over the return and variance equation for the various GARCH models has been done using the Akaike and Schwartz criteria. The results are not reported due to limited space but are available upon request.

**Table 4.** Bivariate Transitions of News for the Period after the Circulation of Euro.

| Panel A: Circulation of Euro Period: (Jan. 2002 – Apr. 2004) – Euro-Adopters (1), Non-Euro-Adopters (2) | | | |
|---|---|---|---|
| Return Equation of Euro-Adopters | | Return Equation of Non-Euro-Adopters | |
| C | $0.162E^{-3}$ (1.28) | C | $0.437E^{-5}$ (0.35) |
| R1 (1) | 0.148*** (5.49) | R2 (1) | $0.779E^{-2}$ (0.29) |
| R1 (2) | 0.025 (0.93) | R2 (2) | -0.076*** (-2.84) |

| Bivariate GARCH Equation<br>Transmission of volatility and error between the Euro-Adopters: GARCH(1,1) and the Non-Euro Adopters: GARCH(1,1) | |
|---|---|
| $\mu_{1(ST)}$ | $0.372E^{-3}$*** (3.46) |
| $\mu_{2(ST)}$ | $0.131E^{-4}$ (1.13) |
| $c_{11(ST)}$ | $0.107E^{-2}$*** (9.21) |
| $c_{12(ST)}$ | $0.192E^{-4}$** (2.218) |
| $c_{22(ST)}$ | $0.264E^{-7}$ ($0.25E^{-3}$) |
| $b_{11(ST)}$ | 0.904*** (60.94) |
| $b_{12(ST)}$ | -0.003*** (-3.90) |
| $b_{21(ST)}$ | 0.123 (1.54) |
| $b_{22(ST)}$ | 0.990*** (252.35) |
| $\alpha_{11(ST)}$ | 0.356*** (12.61) |
| $\alpha_{12(ST)}$ | 0.012*** (6.83) |
| $\alpha_{21(ST)}$ | -0.317 (-1.22) |
| $\alpha_{22(ST)}$ | 0.143*** (7.98) |
| Log-Likelihood | 17161.73 |
| Null hypothesis: The volatility and error transmission between the Euro-Adopters and Non-Euro-Adopters is zero | |
| Chi-Squared (8) | 1506307.95 (0.000) |
| Null hypothesis: The residuals of the Euro-Adopters and Non-Euro-Adopters are equal | |
| LR | 6410.58 (0.000) |

| Panel B: Expansion of EU Period: May 2004 – 2005 - New Members (1), Countries outside EU (2) | | | |
|---|---|---|---|
| Return Equation of New members | | Return Equation of Countries outside EU | |
| C | $0.105E^{-2}$*** (3.766) | C | $0.161E^{-2}$*** (4.78) |
| R1(1) | 0.129*** (2.68) | R2(1) | 0.100** (2.08) |

| Bivariate GARCH Equation<br>Transmission of volatility and error between the New Members: GARCH(1,1) and the Non-Members: GARCH(1,2) | |
|---|---|
| $\mu_{1(ST)}$ | 0.887E$^{-3}$***<br>(3.242) |
| $\mu_{2(ST)}$ | 0.203E$^{-2}$***<br>(8.50) |
| $c_{11(ST)}$ | 0.433E$^{-2}$***<br>(9.76) |
| $c_{12(ST)}$ | 0.959E$^{-4}$<br>(0.22) |
| $c_{22(ST)}$ | 0.171E$^{-4}$<br>(0.56E$^{-3}$) |
| $b_{11(ST)}$ | 0.477***<br>(3.45) |
| $b_{12(ST)}$ | -0.076<br>(-0.53) |
| $b_{21(ST)}$ | 0.102***<br>(2.58) |
| $b_{22(ST)}$ | 0.866***<br>(19.52) |
| $\alpha_{11(ST)}$ | 0.350***<br>(8.12) |
| $\alpha_{12(ST)}$ | 0.041<br>(0.55) |
| $\alpha_{21(ST)}$ | -0.035<br>(-0.414) |
| $\alpha_{22(ST)}$ | 0.502***<br>(7.62) |
| Log-Likelihood | 4017.29 |
| Null hypothesis: The volatility and error transmission between the New-Members and Non-Members is zero | |
| Chi-Squared (8) | 3817.05<br>(0.000) |
| Null hypothesis: The residuals of the New-Members and Non-Members are equal | |
| LR | 141.47<br>(0.000) |

*Notes:* (1) Numbers in parentheses are t-statistics. (2)*, **, *** declare significance at 10%, 5% and 1% respectively. (3) $\mu_{1(ST)}$ is the long- term coefficient which replace the expected value of the return equation: $\alpha_0 + \sum_{i=1}^{n} R_{(t+1)-n}$ , $\mu_{2(ST)}$ is the long-term coefficient which replaces the expected value of the return equation: $\alpha_0 + \sum_{i=1}^{n} R_{(t+1)-n}$ , $c_{11(ST)}$ is the constant coefficient of the variance equation for the first series, $c_{12(ST)}$ is the joint constant coefficient of the two variables for the joint variance equation, $c_{22(ST)}$ is the constant coefficient for the variance equation of the second variable, $b_{11(ST)}$ declares volatility for series 1, $b_{12(ST)}$ indicates volatility transmission from the second variable to the first variable, $b_{21(ST)}$ indicates volatility transmission from the first variable to the second variable, $b_{22(ST)}$ indicates volatility for the second series, $\alpha_{11(ST)}$ indicates level of noise for the first series, $\alpha_{12(ST)}$ indicates transmission of noise from the second variable to the first variable, $\alpha_{21(ST)}$ indicates transmission of noise from the first variable to the second variable, $\alpha_{22(ST)}$ indicates level of noise for the second variable.

**Table 5.** Level of Integration in the Period 2002-2005.

Panel A: Volatility spillovers

| | 1st period: Circulation of Euro | 2nd period: Expansion of EU | Difference (2nd – 1st ) |
|---|---|---|---|
| | Euro-Adopters (1) Non-Euro-Adopters (2) | New Members (1) Non-Members (2) | Transmission difference |
| $b_{12(ST)}$ | -0.003 | -0.076 | -0.073 |
| $b_{21(ST)}$ | 0.123 | 0.102 | -0.021 |
| Total volatility spillover | 0.120 | 0.026 | -0.094 (↓ Integration) |
| $\alpha_{12(ST)}$ | 0.012 | 0.041 | 0.029 |
| $\alpha_{21(ST)}$ | -0.317 | -0.035 | 0.282 |
| Total noise spillover | -0.306 | 0.006 | 0.311 (↑Integration) |
| Total volatility and noise spillover | -0.186 | 0.031 | 0.217 (↑ Integration) |

Panel B: Calculation of volatility and covariance spillover

| | Circulation of Euro | Expansion of EU |
|---|---|---|
| Volatility spillover ( $h_{11}$ ) | 0.294 | 0.479 |
| Volatility spillover ( $h_{22}$ ) | 1.139 | 1.243 |
| Covariance spillover ( $h_{12}=h_{21}$ ) | 1.020 | 0.628 |

Panel C: Standard errors of coefficients of two periods

| | Circulation of Euro | Expansion of EU |
|---|---|---|
| $c_{11(ST)}$ | 0.117E$^{-3}$ | 0.444E$^{-3}$ |
| $c_{12(ST)}$ | 0.869E$^{-5}$ | 0.445E$^{-3}$ |
| $c_{22(ST)}$ | 0.105E$^{-3}$ | 0.031 |
| $b_{11(ST)}$ | 0.015 | 0.138 |
| $b_{12(ST)}$ | 0.855E$^{-3}$ | 0.145 |
| $b_{21(ST)}$ | 0.080 | 0.040 |
| $b_{22(ST)}$ | 0.004 | 0.044 |
| $\alpha_{11(ST)}$ | 0.028 | 0.043 |
| $\alpha_{12(ST)}$ | 0.002 | 0.074 |
| $\alpha_{21(ST)}$ | 0.261 | 0.084 |
| $\alpha_{22(ST)}$ | 0.018 | 0.066 |

Notes: (1) The probability values have been estimated taking the difference between (1-achieved confidence). In particular, the estimation has been done as it is shown here: [1-0.941=0.059]. For an explanation on the variables of $b_{12(ST)}$, $b_{21(ST)}$, $\alpha_{12(ST)}$, and $\alpha_{21(ST)}$ see the table 6. For an explanation on the variables of $b_{12(ST)}$, $b_{21(ST)}$, $\alpha_{12(ST)}$, and $\alpha_{21(ST)}$ see the table 6. (2) The symbols ↓ and ↑ characterize the increase or decrease of spillovers between the respective series of each period in order to see if the level of integration in the second period is higher than the first period in case where there were significant bilateral spillovers in each of the periods separately. We have found here that the level of integration in the second period would have been increased by 0.2172 from the first period with respect to the overall transmission of news between the two periods. (3) The volatility persistence of $h_{11}$ parameter for the circulation of Euro period is referred to the series of Euro-Adopters and for the latest period of adoption of Euro to New-Members, the volatility persistence of $h_{22}$ parameter for the circulation of Euro period is referred to the series of Non-Euro-Adopters and for the expansion of EU to Non-Members, the covariance persistence of $h_{12} = h_{21}$ for the circulation of Euro period is referred to the series of Euro-Adopters and Non-Euro-Adopters and for the expansion of EU period to the series of New-Members and Non-Members.