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THE IMPACT OF INTEREST RATES AND TRADING VOLUME ON VOLATILITY AND ERROR TRANSMISSION BETWEEN CROSS-LISTED EUROPEAN EQUITIES

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Abstract

This study examines the integration process for cross-listed equities in Europe. A primary focus of this study is to examine the volatility spillover effects for cross-listings across markets with different regulatory structures. This study investigates the relationship between spillover effects and stock market regulatory structures for cross-listed European firms. Using La Porta et al.'s (1998) stock exchange regulatory classification, which distinguishes between differences in capital market accounting disclosure rules, and shareholder and creditor protection regulations, we identify firms that have cross-listed on exchanges with either higher, lower or similar regulatory features compared with their home market listing. Using data on cross-listings from the UK, German, Swiss, and French markets we construct portfolios of the foreign listed companies based on the above mentioned regulatory features. After having identified the differences in the regulatory features associated with the cross-listing we then construct portfolios of the foreign (cross-listed) equities according to whether the listing is located in a higher, lower or similar regulatory environment to the home listing. The performances of these portfolios are then compared with the relevant market indices (FTSE100, CAC40, DAX100, and SBC100) to investigate volatility spillover effects both with the market index and between different cross-listed portfolios. Overall, we find that different regulatory environments have a significant impact on volatility spillovers. We also find that fundamental factors, such as the level of interest rates and trading volume, positively impact on the magnitude and persistence of these spillovers.

Keywords: Spillover effects, GARCH model, volatility, cross-listings

JEL classification:G15

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1. Introduction

In this study we examine the integration process for cross-listed equities in Europe. Our primary focus is to relate the volatility spillover effects for cross-listings across markets with different regulatory structures. More specifically, we investigate the relationship between spillover effects and stock market regulatory structures for cross-listed European firms. Using La Porta et al.'s (1998) stock exchange regulatory classification, which distinguishes between differences in capital market accounting disclosure requirements, and shareholder and creditor protection rules, we identify firms that have cross-listed on exchanges with either higher, lower or similar regulatory features compared with the home market. Using data on cross-listings from the UK, German, Swiss, and French markets we construct portfolios of the foreign listed companies based on the aforementioned regulatory conditions[1].

After having identified the differences in the regulatory environment associated with the cross-listing we then construct portfolios of the foreign (cross-listed) equities according to whether the listing is in a higher, lower or similar regulatory environment. The performance of these portfolios is then compared with the relevant market indices (FTSE100, CAC40, DAX100 and SBC100) to investigate volatility spillover effects both with the market index and between different cross-listed portfolios.

In his seminal study Karolyi (1995) examines volatility spillover effects between the United States (S&P 500) and Canada (TSE 300)[2] and demonstrates that such spillovers on the portfolios of 'inter-listed' versus 'non-inter-listed' stocks are distinctly different. That is, the

[1] For instance companies from Belgium, Netherlands, Spain, Austria, Germany, and Denmark that have a cross-listing on the Paris exchange are (according to La Porta et al.) listing on an exchange with higher accounting standards. A UK, Finland, Norway and Swedish firm listing in Paris is listing on an exchange with lower accounting standards than the home market.

magnitude and persistence of S&P 500 shocks are greater for subsequent returns of 'inter-listed' stocks than 'non-inter-listed' stocks. Likewise, Eun and Jang (1997) find statistical evidence that there are dynamic interactions among the prices of those stocks that are 'cross-listed' on the three major stock markets of the world, i.e. New York, London and Tokyo. Based on these findings, it is suggested that investment barriers relating to restrictions on the free flow of capital, tax considerations, foreign-ownership restrictions and differences in accounting standards and disclosure practices may be important for understanding the dynamics of co-movements in stock prices around the world. Such factors might also dampen the cross-market impact of large stock-price movements. The intention of the present study is based on these inferences by developing a model to analyse whether similar barriers influence the market transmission mechanism for European cross-listed stocks.

The starting point for the current study is the extension of the above-mentioned research to the European security market. In particular, the multivariate GARCH-BEKK model introduced by Karolyi (1995) is extended to control for regulatory differences between exchanges that may act as investment barriers to the transmission mechanism. Multivariate GARCH models are commonly used to investigate such transmission patterns [e.g. Theodossiou and Lee (1993) and Kanas (1998)] and the GARCH-BEKK model has been suggested as an approach that offers greater flexibility for modelling these dynamic effects[3]. The latter approach allows for the measurement of the magnitude and persistence on a portfolio own lagged returns [Koutmos (1996)].

Overall, we find that spillover effects are important within European markets for cross-listed companies. The magnitude and persistence of these information spillovers varies

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[2] S&P 500 is the Standard and Poor 500 share index on the New York and TSE300 is the Toronto Stock Exchange 300 index.

[3] See Engle and Kroner (1995) for a discussion of GARCH-BEKK model advantages over previous GARCH models. In addition, Eitman and Stoneheill (1989) support that listing requirements for foreign firms on the London exchange are fairly liberal, as disclosure requirements, accounting costs and the respective fees are fairly modest compared to the US market.

according to the dynamics of such relationships. In addition, we find that different regulatory environments have a significant impact on volatility spillovers. We also find that fundamental factors, such as the level of interest rates and trading volume, impact on the magnitude and persistence of these spillovers positively.

First, this study extends current understanding about the determinants and intentions underlying transmission patterns by introducing regulatory investment barriers into the modelling framework. In this way it may be seen as a contribution to the current debate on the effects of volatility spillovers [e.g. Koutmos and Booth (1995)] in circumstances where the dynamics of market integration may be better understood. Our analysis of transmission patterns amongst cross-listed European equities shows what seems to be an effect of barrier restrictions on market integration. That is, regulatory differences between markets appear to have an impact on volatility spillover effects for European cross-listed shares. This is an important contribution to the debate given the view, prevalent amongst some capital market regulators, that harmonisation of regulatory standards will reduce barriers and therefore spillover effects across markets [Stulz (1981 and 1999)].

Second, this study is also of importance as it provides an empirical link between research in finance and accounting. It investigates the effects on accounting standards and shareholder and creditor protection legislation on the volatility spillover effects of cross-listed equities within Europe.

Our study is structured as follows. Section 2 provides a literature review covering the main hypotheses that are tested. Section 3 outlines the research design and discusses the data and sample selection. Section 4 provides the empirical results and finally, the conclusions are set out in Section 5.

2. Literature Review

A number of studies bring to light empirical evidence on inter-temporal relationships between volatility and expected returns. The seminal work by Engle (1982) and those of

Pindyck (1984) and Bollerslev, Engle and Wooldridge (1988) all provide evidence that volatility is ‘time-varying’ and that news tends to be clustered together with regard to the size of their impact on stock prices. This is known as 'volatility clustering' and may be related to market dynamics. According to Bollerslev, Chou and Kroner (1992), ‘volatility clustering’ means that a market tends to be volatile for a week or two and then relatively calm for the following several weeks. Therefore, if traders have heterogeneous expectations, with some having insider information, news may disseminate after one period. However, differences in investors’ expectations may take some time to be eradicated.

Volatility clustering also characterises the transmission of news from one market to another. Among others, Bennett and Kelleher (1988), Von Furstenberg and Jeon (1989), Hamao, Masulis and Ng (1990), King and Wadhwani (1990), Schwert (1990), Susmel and Engle (1990), Neumark, Tinsley and Tosini (1991) and Becker, Finnerty and Tucker (1992) demonstrate this type of transmission of news. In their various analyses, they report that the transmission of volatility between markets is also time-varying that lagged spillovers of price changes and price volatility exist between major stock markets implying that, when volatility is high, price changes in major stock markets tend to become highly correlated.

This type of correlation may be caused because volatility spillovers that emanate from more efficient markets and transmitted to less efficient markets are simply contagious. One possibility is that such patterns of spillovers lead regulators to impose rules on markets in a more pervasive way in order to remove inefficiencies. This, in turn, breaks down the regulatory restrictions that act as barriers to capital market integration. There is some evidence that relates volatility spillovers to barriers on structural differences between markets.

For instance, Kanas (1998) shows that spillovers across markets with diverse structures are different to those with similar structures. While Kanas (1998) focuses on London, Paris and Frankfurt, other studies [e.g. Hamao et al. (1990), Theodossiou and Lee (1993)] focus on stock markets of US, Canada, Japan, UK and Germany. In particular, Hamao et al. (1990), Koutmos and Booth (1995) and Susmel and Engle (1994) focus on spillovers across New York and London, while Theodossiou and Lee (1993) examine spillovers across US, Japan, Canada and Germany. Hamao et al. (1990) find the existence of spillovers from the US and UK markets to Japan, while Koutmos and Booth (1995) find that the transmission of volatility is asymmetric and is more pronounced when news is bad and coming from either market. Other evidence from Susmel and Engle (1994) displays that volatility transmission is short and small between New York and London, in contrast to Theodossiou and Lee (1993) who note that the US capital market is the major 'exporter' of volatility to other financial markets.

The research design of each of the above studies involves the use of GARCH models to examine transmission patterns. The power of univariate GARCH models, however, is relatively low and in their critique of such models Martens and Poon (1999) indicate that they are imprecise in estimating true spillover patterns and therefore, systematic error that is related to factors like transmission smoothing patterns bias GARCH estimates. For instance, Hamao et al. (1990) cannot confirm if their results were a 'true spillover effect' or a 'non-dynamic correlation' problem. More recent papers such those of Theodossiou, Kaya, Koutmos and Christofi (1997) and Ng (2000) use a multivariate GARCH modelling framework to address some of these limitations.

GARCH models with conditional correlation are developed extensively in the finance literature to model spillover effects. As research reveals, volatility spillovers from the US capital markets could lead the rest of the world [Eun and Shim (1989)] and also correlation between markets could increase over time [Koch and Koch (1991), Von Furstenberg and Jeon (1989)]. In particular, Eun and Shim (1989) study the change in daily stock returns across nine stock markets using a VAR approach adjusting for non-synchronous stock price trading hours in different markets. As already mentioned, these authors found that the US market is by far the most influential vis-à-vis other markets. On the other hand, Von Furstenberg and

Jeon (1989) investigate the relationships between change in daily stock price returns in Japan, Germany, the UK, and the USA markets over the period 1986 to 1988. They find an increase in the correlation between the above markets especially after the October crash in 1987. Studies that have used the GARCH modelling framework in the past, however, have typically not used specifications that control for the impact of regulatory barriers (such as different stock market rules) on equity market interrelationships, which is the main focus of this study.

If someone examines the correlation of equities returns alone, he cannot reach conclusions with regard to the impact of regulatory barriers on market integration. As Karolyi (1995) has pointed out, barrier restrictions have an impact on interdependencies and this fact should be taken into account using GARCH models in order to draw correct inferences on such spillover relationships. Such interdependencies may be related to the ongoing debate on capital market standards and the impact of 'cross-listing' on the quality of market standards. The debate on market interdependence and its relation to different regulatory standards is also of particular importance in Europe where there have been regulatory moves to foster market integration[4].

In this respect, an analysis of volatility spillovers between cross-listed equities between exchanges with different regulatory structures may help to inform us more about the market integration process. Huddart et al. (1998), for instance, suggests that market exchanges lower their disclosure standards in order to attract more listed foreign firms and this reduces the market integration process as this competition results to 'a race to the top' for admission of firms to other stock exchanges. In general, it is assumed in the literature [Saudagaran and Biddle (1992)] that stringent disclosure requirements reduce access to foreign exchanges and consequently, the investment in capital markets. Baker (1992) finds that the most important investment barriers are the costs faced by companies and the level of disclosure requirements.

[4] See Tondkar et al. (1990) regarding the implementation of three European Union Directives on Admission requirements, Listing and Interim reporting requests aimed at harmony. The EU's Financial Services Action Plan announced in 1999 is a current ongoing initiative aimed at fostering integration in many financial services areas throughout Europe including capital markets.

Potential relaxation of these standards may result in stock exchanges gaining poorer quality listings as the benefits of a foreign listing may not outweigh the cost of compliance with the disclosure and other standards. Higher standards, however, may result in stock exchanges attracting higher quality corporations because of the stricter environment [e.g. Cheung and Lee (1995)].

While there have been regulatory initiatives aimed at harmonising European stock market rules, substantial differences still remain between markets. Adhikari and Tondkar (1995) note that EU exchanges set their requirements with a 'lower bound', however, without setting any 'higher bound' when they accept new financial corporations. For instance, in France, Germany, the Netherlands and Sweden companies surpass the requirements demanded by the stock exchanges providing additional voluntary disclosures that are important for shareholders and investors [e.g. Meek and Gray (1989)]. Differences in accounting disclosure requirements and protection of shareholders and creditors may impact on the financial regulation on capital markets. For example, La Porta et al. (1998) document a variety of regulatory differences relating to investor protection rules and accounting disclosure regulations across EU markets.

In the 1980s, European capital markets changed radically. Traditional intermediaries such as the agents de change in France and banks in Germany saw their roles significantly reduced by the introduction of automation on the floor of the exchanges. Competition among neighbouring markets such as Paris, London, and Frankfurt led to an increase in volume in these markets and a fall in brokers' commission fees. Cross-listing of securities has become the rule for big conglomerates in their quest for new sources of financing [Benos and Crouhy (1996)]. Large firms have sought to expand their investor bases, typically in export countries, in order to have greater access to new financial markets. At the same time, legislation has been passed in order to stimulate competition and allow domestic and foreign firms to trade both as agents (brokers) and principals (for their own accounts) on European stock exchanges.

European markets have abandoned floor trading and except for London's market-making system, electronic stock auction systems now predominate [Roll (1989)]. Security markets and, more specifically, equity markets have been traditionally organised either as continuous dealer markets, such as the SEAQ in London, or as call auction or continuous auction markets. France and Germany, once organised primarily as periodic call markets, have become continuous electronic auction markets. Call markets are also used for thinly traded issues (e.g., the Paris Bourse) or by proprietary trading systems such as the Instinet crossing network of Reuters.

Given these changes, an important question arising relates to the influence, if any, of various regulations and institutional rules on price volatility. Empirical evidence from Karolyi (1995) and Fabozzi and Modigliani (1996) suggest that because stock markets are characterised by different structures, the potential investment barriers that arise may affect volatility spillovers (information transfers) between markets. For example, tax considerations may influence on stock price volatility changes that cannot be fully explained by 'fundamental' factors alone [Stiglitz (1989) and Summers (undated)].

Given that regulations are believed to have an impact on stock price volatility, we examine how such investment barriers (arising from accounting disclosure standards, creditor and shareholder protection rules) may impact on both stock price and trading noise changes in Europe. We also examine the impact of trading volume on the volatility of stock prices in association with different investment barriers of markets[5].

This work analyses volatility transmission for European cross-listed equities in order to show the influence of regulations on spillovers between different markets. The available empirical evidence to date simply confirms the interrelationship between stock prices and volatilities without taking into account regulatory barriers as discussed above. To mention a

[5] Stiglitz (1989) notes that transaction taxation can influence the liquidity of a market by reducing the influence of noise traders and volatility. We do not specifically investigate the case of a transaction tax in this paper but though it is interesting to investigate whether market liquidity and trading volume influence volatility across exchanges.

few seminal researches on the relationship of volatility and stock price returns, French, Schwert and Stambaugh (1987) have suggested that the relationship between expected returns and anticipated stock price volatility may be positive. In contrast, Glosten, Jagannathan and Runkle (1993) point out that the relationship between stock price volatility and returns is not always positive, but may also be negative or non-existent between stock price returns and volatilities. Engle and Mezrich (1996) support the view that the main role played by financial markets relates to correlation and not covariance between equities. Economic information and non-economic information may affect this correlation as well. This suggests that there are other factors that may influence volatility spillovers, such as market liquidity and the level of interest rates.

Chan, Fong and Stulz (1995) who investigate the effects of market liquidity (trading volume) on volatility spillovers find that the magnitude and persistence of spillovers are reduced when the market liquidity is higher. A more recent work by Ng (2000) examines the impact of news on stock price volatility in Pacific-Basin markets, in particular, the impact of shocks on the above-mentioned stock markets. Ng also investigates the impact of trading volume on market integration, suggesting that trading volume increases volatility persistence. Gallo and Pacini (2000) also find that the impact of trading volume of ten US stocks on volatility persistence is significant. Overall, the literature that examines the impact of trading volume on spillover effects confirms that the inclusion of trading volume in the GARCH model decreases the persistence of stock price volatility, at least in the US market. Other studies, such as that of Lamoureux and Lastrapes (1990), provide empirical evidence that ARCH effects tend to disappear when trading volume is included in these types of models. This suggestion that more liquid stocks are associated with lower market volatility, is important in this literature [e.g. Amihud and Medelson (1987), Biais (1993), Demsetz (1968), Ho and Stoll (1981 and 1983), Stoll (1978) and Bollerslev and Jubinski (1999)].

In addition to market liquidity, various studies have investigated the impact of interest rates on stock price volatility and market integration. For instance, volatility correlation between portfolios of equities traded on different exchanges may be sensitive to trading volume as well as to interest rate changes. Studies by Bhoocha-oom and Stansell (1990), Elyasiani and Mansur (1998) and Karfakis and Moschos (1990) all measure the impact of interest rates on European stock markets. More specifically, Bhoocha-oom and Stansell (1990) find that there is a substantial degree of interest rate harmonisation and financial market integration between Hong Kong, Singapore and the US. Elyasiani and Mansur (1998) find shifts in volatility according to change in the monetary policy regime in the US between 1979 and 1982 and significant feedback effects on volatility.

To investigate how interest rates impact on various equities' covariance, we adopt King et al.'s (1994) suggestion[6] and we use the GARCH-BEKK modelling approach to investigate the impact of interest rates on the magnitude and persistence of volatility spillovers for our sample of cross-listed European equities.

One can see that there is an extensive empirical literature that examines information transfer or spillover effects in equity markets. Most of this literature has examined the interrelatedness of major exchanges in the US, Europe and Asia [Eun and Shim (1989), and Koch and Koch (1991)]. When significant spillover effects are found these are explained by different structural and regulatory features associated with the respective markets, but these specific features are (as far as we are aware) never tested for. We, therefore, do not know what impact different regulatory features have on such spillover effects. In addition, market liquidity and macroeconomic conditions (proxied by interest rate levels) may also influence information transfer between markets. This study aims to address these issues by examining the influence that regulatory structures, market liquidity and interest rates have on volatility transmission of cross-listed European equities. The following section 3 outlines the methodology adopted to investigate spillover effects for European cross-listed companies. The analysis mostly aims to investigate volatility spillovers in a similar manner to the established literature and then to test to see how specific regulatory factors such as accounting standards, shareholder and creditor protection rules influence such spillovers. Finally, this study examines how market liquidity and interest rate levels impact on these spillover effects.

3. Data and Methodology

3.1. Sample selection

This study focuses on 'cross-listed' equities in Europe[7]. Sample selection requires that we obtain information on European cross-listed equities in order to construct portfolios so that we can test for spillover effects between markets. This means that data has to be obtained on firms that have cross-listings and we collect information on their home and foreign equity performance over the period 1987 to 1998.

In order to identify European companies with 'inter-listings' we first wrote to the European stock exchanges asking for information on companies that were listed on their exchanges and quoted on other European markets. Based on the responses, we selected stock price information for firms with multiple quotations that were available on 'Datastream' during the period 1987 to 1998. In order to avoid the survivorship bias in data collection, firms involved in de-listings, bankruptcies, mergers and acquisitions were also included in the sample.

To be included in the sample, firms that experienced bankruptcies, de-listings and mergers or acquisitions had to meet the following criteria:

(1) The merger/acquisition announcement had to be identified by the FT-EXTEL database over the period of January 1987 to December 1998. The gap between the announcement and consummation day during the acquisition process is determined by finding the 'effective date'

[6] King et al. (1994) suggest that the construction of covariance between markets on the basis of economic data is difficult.

[7] Portugal, Greece, and Luxembourg are excluded because of unavailability of data.

in *Mergers and Acquisitions magazine, REUTERS and DATASTREAM databases*. The exact effective date of consummation of the merger is determined for 81 out of 100 acquisitions and the effect scheme of capital change arrangements for the 81, added automatically by DATASTREAM. The effective date of consummation arrangement for the remaining 19 acquisitions is found in DATASTREAM, however, without a back-filling process. Thus, a 'back-filling' process is added in the acquired company's equity upon its de-listing date and backward to add the effective scheme of capital offer arrangements (similar to Datastream). In any given case above, the stock price of acquired and acquiring equities of companies that traded in the same stock exchange are averaged together in order to examine them as one equity during the period 1987 through 1998. This procedure improves the way in which we examine high-frequency return equities over a long-term period, because mergers/acquisitions are treated as special cases in the data sample. This approach helps us to specify these returns so as to avoid overestimation or underestimation of stock price volatility distributions in the constructed equity portfolios used in the spillover analysis.

(2) We also deal with equity de-listings from 1987 to 1998 by using the electronic news retrieval services LEXIS, FT-EXTEL, and DATASTREAM. Based on stock price data availability on DATASTREAM, we identify equity prices prior to a delisting. DATASTREAM provides evidence that many de-listings involve suspensions before proceeding to bankruptcy. While many of these companies' equities are in financial distress, most of them continue to trade before delisting. A company with different types of equities that list on a certain stock exchange might experience de-listing in a certain type of security (e.g. ordinary shares) with 'normal' performance in other types of listed securities (e.g. A and B shares). In this case, there are survivorship bias effects that may be caused by the performance of non-survived equities (e.g. ordinary shares).

In order to avoid this bias, non-survived equities are included in our sample. In addition to identifying survivorship bias brought about by M & A and de-listings we also take account of a variety of other factors that can influence volatility and spillover effects. Such factors include identifying the following: unsuccessful mergers, de-mergers (e.g. BAT Industries demerged into BAT PLC and Allied Zurich), siamese twin equities (e.g. Royal Dutch / Shell), change of name equities (e.g. from Sanofi to Elf Sanofi), subsidiaries that trade separately from the holding equity (e.g. AEG), integration of equities to other equities (e.g. Siemens Nixdorf to Siemens) and different types of equities that belong to the same company (e.g. 'A' and 'B' shares). In all cases, equities are identified in a similar fashion as with the mergers and acquisitions or de-listing cases as mentioned above. To recap, the sample that is used is based on 'cross-listing' data and checked to account for all the above possible survivorship biases that might arise in the sample in order for us to construct the appropriate portfolios.

To determine how much the categories of equities above contribute to variations in stock price volatility transmission between equities, only the average return of these groups are added into the constructed equity portfolios. In addition, the data is transformed into Euros by using the European Central Bank (ECB) exchange rates at the end of 1998 or beginning of 1999. In addition trading holidays as identified by Datastream are excluded so we have a continuous data series[8]. After following the aforementioned data selection procedure we arrive at a sample of 210 firms that have 409 foreign cross-listings across different European markets as shown in Table 1.

3.2. Description

Table 1 displays our sample of 'cross-listed' equities in European stock markets. The current study covers 'cross-listed' equities from 14 European stock exchanges. These are*: Vienna, Brussels, Copenhagen, Helsinki, Paris, Frankfurt+ (comprising Berlin, Dusseldorf, Stuttgart, Munich, XET - XETRA stock index- and Frankfurt), Amsterdam, Milan, Oslo, Madrid, Stockholm, London+ (comprising London and XSQ - international stock exchange),*

[8] Trading dates around the October 1987 crash, namely the 16th, 19th-21st October are excluded from the sample.

Zuric, and Dublin. The total number of 'cross-listed' equities (home and foreign) across the 14 European stock markets is 689; 280 are home equities and 409 are foreign equities. The current study concentrates on all the home equities of companies with cross-listings in 14 stock exchanges and their foreign equities that are listed in *Frankfurt+, Paris, London+ and Zurich*[9].

[9] We look only at these four foreign stock markets, as the number of foreign listings is larger in comparison to the other stock exchange foreign listings.

Table 1: Within Sample-Inter-listing of Stock Prices

Markets	Firms	Equities	Paris	Frankfurt+	London+	Zurich	Total
Austria	6	7	1	8	2	0	11
Belgium	7	8	6	4	5	2	17
Denmark	7	9	0	5	2	2	9
Finland	4	7	1	3	4	0	8
France	32	34	0	31	15	7	53
Germany	26	56	14	0	20	28	62
Netherlands	26	30	12	30	13	17	72
Italy	12	14	7	12	7	0	26
Norway	6	11	1	6	7	0	14
Spain	20	23	4	19	7	1	31
Sweden	13	20	3	13	8	0	24
UK	40	45	18	33	0	6	57
Switzerland	7	11	3	10	4	0	17
Ireland	4	5	0	4	4	0	8
Total	210	280	70	178	98	63	409

Notes: Frankfurt+ comprises Berlin, Dusseldolf, Stuttgart, Munich, Xet, and Frankfurt. London+ comprises London, and XSQ. The sample includes ordinary shares, ‘A’ shares, ‘B’ shares, registered shares, but not Redeemable shares (regarded as a preference share and therefore as non-equity share).

The number of foreign listings varies within the stock exchanges; there are 178 European foreign listings in *Frankfurt+* and 98 foreign listings in *London+*. There is also a large number of foreign listings in *Paris (70)* and *Zurich (63)*. However, the number of foreign listings in *Frankfurt+* is larger than that of home market 'cross-listings' (56). It is also indicated that there is a total number of 45 'cross-listings' in the UK 'home' market.

All the above mentioned 280 'home' market 'cross-listings' come from 159 firms that belong to the General Industry Sector[10], five firms that operate in the consumer goods, recreation and services sectors, ten firms that are utilities (e.g. telecommunications) and 36 firms are financial and/or investment companies.

Table 2 displays various descriptive statistics for home and foreign stock equity returns. It is illustrated that home equity returns and some foreign equity returns (in particular, the UK and Swiss markets*)* have negative skewness. Also, there are fat tails present in the distribution of equity returns and excessive kurtosis, with exception of the home equity returns in Italy. The descriptive statistics are influenced by the days around the market crash in October 1987 despite us omitting the most influential days (i.e. October 16, 19, 20, and 21).

[10] The General Industry sector contains Chemicals, Printing and Publishing, Oil, Gas and Related Services, Miscellaneous, Food Producer, Engineering, Beverages, Metal Producers, Metal Products Manufacturers, Machinery and Equipment, Drugs, Cosmetics, Health Care, Automative, Diversified Paper, Construction, Book, Materials, Tobacco, Metal Producers, Apparel, Electrical, Retailers and Textiles.

Table 2: Descriptive Statistics for Stock Returns

	Mean	St.Dv.	T-statistic	Skewness	Kurtosis
	Home	**Portfolios**	**of**	**Equities**	
Amsterdam	0.00026	0.0084	1.71	-0.34	14.36
Brussels	0.00036	0.0092	2.16	-0.30	13.94
Copenhagen	0.00024	0.011	1.22	-0.28	6.33
German	0.00035	0.012	1.62	-0.31	6.40
Helsinki	0.00050	0.015	1.70	0.0038	2.85
Ireland	0.00054	0.011	2.67	-0.27	6.55
UK	0.00038	0.010	2.05	-0.12	4.63
Madrid	0.00038	0.013	1.54	-0.03	3.83
Milan	0.00013	0.015	0.47	0.10	1.09
Oslo	0.00012	0.016	0.41	-0.34	3.48
Paris	0.00019	0.011	0.90	-0.44	6.00
Stockholm	0.00027	0.013	1.17	-0.30	6.10
Swiss	0.00039	0.012	1.82	-0.40	7.88
Vienna	0.00018	0.013	0.77	-0.34	8.93
	Foreign	**Portfolios**	**of**	**Equities**	
German	0.00037	0.0088	2.27	0.073	9.88
UK	0.00026	0.02	0.86	-0.24	11.03
Paris	0.00035	0.02	0.84	1.47	58.90
Swiss	0.00036	0.02	0.85	-0.35	27.47

Notes: German contains Frankfurt, Berliner, Dusseldorf, Stuttgart, Munich, and XET equities. UK contains London and XSQ equities.

In Table 3, descriptive statistics are shown for the returns of stock market indices for the trading volume of cross-listed companies and for the interest rates in Germany, the UK, France, and Switzerland. These statistics are displayed because the later empirical work on spillover effects of foreign cross-listings will focus on the impact of market liquidity and interest rates. Information on trading volume and interest rates is obtained from Datastream. There is a weak kurtosis present in stock market indices and in interest rates, with negative skewness in most of the series. In addition, trading volume has significant kurtosis and positive skewness with fat tails in the series.

Table 3: Descriptive Statistics for Stock Indices, Foreign Equity Trading Volumes and Interest Rates

	Mean	St.Dev.	T-Stat.	Skewness	Kurtosis
			Stock Market Indices		
German	0.00056	0.011	2.62	-1.15	14.64
UK	0.00040	0.0096	2.32	-1.36	20.62
France	0.00032	0.012	1.42	-0.48	6.52
Swiss	0.00045	0.010	2.35	-1.55	18.12
			Foreign Equity Trading Volume		
German	NA	NA	NA	NA	NA
UK	224.44	291.44	42.42	2.40	6.95
France	4.62	6.86	33.16	9.79	172.25
Swiss	50.74	609.72	4.22	16.59	289.90
			Long - Term Interest Rates		
	Mean	St.Dev.	T-Statistic	Skewness	Kurtosis
German	6.74	1.25	296.18	0.16	-0.54
UK	8.63	1.53	310.98	-0.33	-0.13
France	7.71	1.68	251.39	-0.40	-0.91
Swiss	4.76	1.13	232.09	0.27	-0.87

Notes:
(i) German contains Frankfurt, Berliner, Dusseldorf, Stuttgart, Munich, and XET equities. UK contains London and XSQ equities. NA means not available.
(ii) The long-term interest rates are collected from Datastream; in particular this study covers interest rates from Germany, UK, France, and Switzerland, from the beginning of 1987 to the end of 1998. In contrast to this, the starting date of the stock indices varies amongst countries. In particular, in France the starting date is 9/7/87 while in Germany, and Switzerland, the starting dates are 30/12/87 and 1/4/87, respectively. However, the last trading date for the stock index is at the end of 1998.

Table 4 accounts for ARCH effects with one lag for different portfolios of equities. It shows simple ARCH tests for one period lagged autocorrelation portfolios. The top half of Table 4 shows ARCH effects for the returns for the constructed home portfolios (home equity portfolios for domestic firms listed in these markets that have a foreign cross-listing), while the bottom part of the Table shows the same for foreign portfolios (cross-listed foreign equities in the respective markets). The estimated results indicate that ARCH effects are significant in all the 14 home and 4 foreign portfolios of equities. This suggests that a GARCH modelling framework is appropriate for investigating return behaviour for cross-listed companies.

Table 4: ARCH Test Effects Results

	Chi-squared (1)
Home Portfolios of equities	
Amsterdam	83.26
Brussels	55.30
Copenhagen	106.07
Ireland	97.04
Germany	294.16
Helsinki	79.33
Madrid	66.36
Milan	71.84
Oslo	173.02
Paris	100.93
Stockholm	160.24
Swiss	442.37
UK	162.58
Vienna	106.52
Foreign Portfolios of Equities	
Germany	73.48
Paris	5.21
Swiss	552.35
UK	317.87

Note: (i) Germany contains Frankfurt, Berliner, Dusseldorf, Stuttgart, Munich, and XET equities. UK contains London and XSQ equities.
(ii) Critical level of Chi-squared (1) is: 3.84.

3.3. Methodology-Cross-listing, Volatility spillovers and the Regulatory Environment

As already noted the main aim of this study is to investigate volatility spillovers relating to cross-listed companies in Europe. This requires us first to identify the relevant data sample, as outlined in the previous section and then to model the interrelatedness of returns between markets. In order to do the latter, we follow Karolyi (1995), Karolyi and Stulz (1996) and Eun and Shim (1989) and we construct portfolios for the home and foreign equity of cross-listed companies in European exchanges. Rather than examining volatility spillovers across all markets, we narrow the focus by using La Porta et al.'s (1998) broad legal classification to examine the influence of regulatory differences on information transmission across the main European capital markets.

La Porta et al. (1998) note that European countries impose different legal rules on their stock markets with respect to investor protection in the context of accounting disclosure rules, and creditor/shareholder protection rules. They suggest that the legal status of countries also affects the decisions of where companies may seek a foreign listing. For example, over a hundred European companies have obtained a public cross-listing in the United Kingdom, whereas few European firms seek Italian listings [Pagano, Panetta and Zingales (1998)]. Therefore, legal rules appear to affect the decision of companies to cross-list. La Porta et al. (1998) identify four broad types of legal structure governing European exchanges: English, French, Germanic and Scandinavian. The London+ and Dublin stock exchanges are governed by English law which is a common law made by judges and incorporated into legislature; French, German, and Scandinavian law, in contrast, is based on a civil law tradition dating back to Roman times [David and Brieley (1985)].

In order to undertake this analysis we take the following steps:

This stage aims to investigate similar relationship for the foreign equity of cross-listed companies. Here we examine spillover effects between foreign cross-listings and the market index where they have the foreign listing. We also investigate how different types of regulations impact on spillover effects. Karolyi (1995) has suggested that differences in accounting disclosure requirements between Canada and the US may affect information transmission between these two markets. We aim to investigate whether such regulatory differences between exchanges impact on volatility spillovers between foreign equity cross-listings of European companies and their respective foreign market indices. Karolyi (1995) does not test to see if different disclosure requirements impact on spillover effects and we, therefore, aim to address this issue in STEP 1 by testing to see if different regulations impact on information transfer for cross-listed equities in the markets where the foreign listing takes place.

In order to distinguish between regulatory differences between European stock exchanges we take the following step.

STEP 1: First, the regulatory classification provided in La Porta et al. (1998) is used to distinguish between different levels of regulation relating to accounting standards, creditor and shareholder protection rules across European stock exchanges. These are then used to identify firms that have obtained foreign cross-listings in markets with higher, lower or similar regulatory conditions compared with the home listing. These are shown in Tables 5 to 7. Table 5 shows differences in accounting standards between home and foreign markets. For instance, a French company that has a foreign listing in London and Frankfurt has to comply with higher accounting disclosure requirements in the former, but lower requirements in the latter, compared with home rules. Similarly, Table 6 shows differences for creditor protection rules covering bankruptcy and Table 7 shareholder protection rules.

Table 5: Accounting Disclosure Standards' differences between 'Home' and 'Foreign' Markets

		Foreign	**Markets**	
	London+	**Paris**	**Frankfurt+**	**Zurich**
Home Market				
UK		LOW	LOW	LOW
Belgium	HIGH	HIGH	HIGH	HIGH
France	HIGH		LOW	LOW
Italy	HIGH	HIGH	SAME	HIGH
Netherlands	HIGH	HIGH	LOW	HIGH
Spain	HIGH	HIGH	LOW	HIGH
Austria	HIGH	HIGH	HIGH	HIGH
Germany	HIGH	HIGH		HIGH
Switzerland	HIGH	HIGH	LOW	
Denmark	HIGH	HIGH	SAME	HIGH
Finland	HIGH	LOW	LOW	LOW
Norway	HIGH	LOW	LOW	LOW
Sweden	LOW	LOW	LOW	LOW

Source: Authors' own construction defined from La Porta et al. (1998)
Note: The index has been created by examining and rating using a minimum of three companies in each country using 1990 annual reports studying the inclusion or omission of 90 items. These items fall into seven categories (general information, income statements, balance sheets, funds flow statement, accounting standards, stock data, and special items). The companies represent a cross section of various industry groups; industrial companies represent 70 percent, and financial companies represent the remaining 30 percent (La Porta et al., pp. 1125).

Table 6: Creditor Bankruptcy Protection Rules' Differences between 'Home' and 'Foreign' Markets

	Foreign Markets			
	London+	**Paris**	**Frankfurt+**	**Zurich**
Home Market				
UK		HIGH	HIGH	HIGH
Ireland	HIGH	HIGH	LOW	SAME
Belgium	HIGH	HIGH	LOW	HIGH
France	HIGH		LOW	LOW
Italy	HIGH	HIGH	LOW	HIGH
Netherlands	HIGH	HIGH	LOW	HIGH
Spain	HIGH	HIGH	LOW	HIGH
Austria	HIGH	HIGH	SAME	HIGH
Germany	HIGH	HIGH		HIGH
Switzerland	HIGH	HIGH	LOW	
Denmark	HIGH	HIGH	SAME	HIGH
Finland	HIGH	HIGH	LOW	SAME
Norway	HIGH	HIGH	LOW	HIGH
Sweden	HIGH	HIGH	LOW	HIGH

Source: Authors' own construction defined from La Porta et al. (1998)

Note: An index aggregating different creditor rights. The index is formed by adding when (1) the country imposes restrictions, such as creditors' consent or minimum dividends to file for reorganization; (2) secured creditors are able to gain possession of their security once the reorganization petition has been approved (no automatic stay); (3) secured creditors are ranked first in the distribution of the proceeds that result from the disposition of the assets of a bankrupt firm; and (4) the debtor does not retain the administration of its property pending the resolution of the reorganization. The index ranges from zero to four (La Porta et al., 1998).

Table 7: Shareholder Protection Rules' Differences between 'Home' and 'Foreign' Markets

	Foreign Markets			
	London+	**Paris**	**Frankfurt+**	**Zurich**
Home Market				
UK		HIGH	HIGH	HIGH
Ireland	LOW	LOW	HIGH	HIGH
Belgium	LOW	LOW	LOW	LOW
France	LOW		HIGH	HIGH
Italy	LOW	LOW	LOW	LOW
Netherlands	LOW	LOW	HIGH	HIGH
Spain	LOW	LOW	LOW	LOW
Austria	LOW	LOW	LOW	LOW
Germany	LOW	LOW		LOW
Switzerland	LOW	LOW	HIGH	
Denmark	LOW	LOW	HIGH	LOW
Finland	LOW	LOW	HIGH	HIGH
Norway	LOW	LOW	HIGH	HIGH
Sweden	LOW	HIGH	HIGH	HIGH

Source: Authors' own construction defined from La Porta et al. (1998)

Note: La Porta et al. (1998) use ownership concentration in 10 largest private firms as an index of investor protection: The index is constructed using the average percentage of common shares owned by the three largest shareholders in the 10 largest non-financial, privately owned domestic firms in a given country. A firm is considered privately owned if the state is not a known shareholder. It is often efficient to have some ownership concentration in companies since large shareholders might monitor managers and thus increase the value of a firm. Concentration of ownership is an adaptation to poor legal protection. Countries that for some reason have heavily concentrated ownership and small stock markets might have little use for good accounting standards, and so fail to develop them. Good accounting standards and shareholder protection measures are associated with a lower concentration of ownership, indicating that concentration is indeed a response to poor investor protection (La Porta et al., 1998).

For each foreign market shown in Table 5 to 7 we construct portfolios according to whether the regulatory requirements are higher, lower or the same as for the home listing. For example, from Table 5 for foreign listings on the London stock market we construct one portfolio for those equities exposed to higher disclosure requirements and another for those exposed to lower requirements (e.g. Sweden). For Frankfurt, three portfolios are constructed, one comprises cross-listing firms from Belgium and Austria that are exposed to higher accounting disclosure rules, another for UK, French, Dutch, Spanish, Swiss and Scandinavian companies that are faced by lower disclosure rules and, finally, a third portfolio for cross-listed Italian and Danish firms that face similar requirements. We do the same for shareholder and creditor rules as shown in Tables 6 and 7. All in all, this provides us with groups of foreign equity portfolios for cross-listed companies exposed to varying regulatory environments. After constructing these portfolios we examine volatility spillovers between these separate portfolios and the respective market indices (FTSE100 in London, DAX100 in Frankfurt, CAC40 in Paris, and SBC100 in Zurich) to examine whether cross-listing on exchanges with lower or higher regulatory requirements has any influence on the magnitude and persistence of spillover effects.

STEP 2: Finally, we use the GARCH-BEKK approach to investigate whether the level of market liquidity (turnover) and the level of interest rates influence the magnitude and persistence of spillover volatilities as investigated in STEP 1. Longin and Solnik (1995) and Lamoureux and Lastrapes (1990) have suggested that market liquidity and interest rate levels have a significant influence on information transfer between markets and this will be investigated in the final part of our analysis.

3.4. Modeling Volatility and Error Transmission between Equities

Using the approach suggested by Karolyi (1995) and Engle and Kroner (1995) volatility and error transmission of cross-listed equities are estimated. Time-series daily returns are for the 12-year period from 1987 to 1998. Autoregressive conditional heteroskedastic (ARCH) type models have traditionally been used to investigate information transfer (volatility spillovers) between equities and stock exchanges. Engle (1982) notes that it is reasonable for stock return variances to be conditional on current information and following this assumption, Bollerslev (1986 and 1987), Engle, Lilien and Robins (1987) use models to account for second moments of errors in their investigations of spillover effects. Examining the descriptive validity of these models, French, Schwert and Stambaugh (1987) find that the extended generalised autoregressive conditional heteroskedastic-in-mean (GARCH-M) model provides a good representation for the behaviour of US daily stock returns[11]. Engle and Kozicki (1993) note it is quite possible for two stock markets to be dependent through their second moments and furthermore, additional evidence by Engle and Susmel (1993) suggests that stock markets are linked through their second moments. Overall, these studies suggest that volatility spillovers should be investigated using ARCH type models that take account of second moments.

Among GARCH models, multivariate GARCH approaches are the most widely used in time-varying (second moments) covariance studies. Such approaches include the Vector (VEC) of Bollerslev, Engle and Wooldridge (1988), the constant correlation (CCORR) of Bollerslev (1990), the factor ARCH (FARCH) of Engle, Ng and Rothschild (1990) and the GARCH-BEKK of Engle and Kroner (1995). The GARCH-BEKK model represents a successful attempt to overcome the various technical difficulties associated with previous approaches, such as the fact that the definite H_t matrix may not always be positive (a restriction imposed in the previous empirical approaches). Previous approaches impose the restriction for the estimated variance to be greater than zero when spillovers are examined. 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.

[11] Bollerslev, Chou, and Kroner (1992) provide a summary of ARCH-type models.

Underlying these theoretical developments, the multivariate GARCH-BEKK [Berndt, Hall, Hall and Hausman (1974) and Engle and Kroner (1995)] model is written as:

$$r_t = \alpha + \sum_{p=1}^{n} \Phi_p r_{t-n} + e_t, e_t \mid \Omega_{t-1} \sim N(0, H_t) \tag{1}$$

where,

r_t is the return series,

e_t is the error term of return equation,

α is the constant term in the above return equation,

Φ_p is the matrix of coefficients with the p lagged values of r_t,

Ω_{t-1} is the matrix of conditional past information that includes the P lagged values of r_t.

To avoid the problems of dealing with normal distributions[12], the first moment of errors e_t is represented by a martingale process, as shown in equation (2). It is assumed that e_t in equation (1) follows a process of E (ε_t).

where,

$$E(\varepsilon_t) = E(r_t - \mu_t) \tag{2}$$

μ_t is the long-term drift coefficient

and

$$H_{t+1} = CC' + \mathrm{B}' H_t B + A' \varepsilon_t * \varepsilon_t' \mathrm{A} \tag{3}$$

Suppressing the time subscripts and the GARCH terms, in a bivariate case, the GARCH-BEKK model takes the form:

$$h_{11} = c_{11} + a_{11}^2 \varepsilon_1^2 + 2\alpha_{11}\alpha_{21}\varepsilon_1\varepsilon_2 + \alpha_{21}^2 \varepsilon_2^2 \tag{4}$$

$$h_{12} = c_{12} + \alpha_{11}\alpha_{12}\varepsilon_1^2 + (\alpha_{21}\alpha_{12} + \alpha_{11}\alpha_{22})\varepsilon_1\varepsilon_2 + \alpha_{21}\alpha_{22}\varepsilon_2^2 \tag{5}$$

$$h_{22} = c_{13} + \alpha_{12}^2 \varepsilon_1^2 + 2\alpha_{12}\alpha_{22}\varepsilon_1\varepsilon_2 + \alpha_{22}^2 \varepsilon_2^2 \tag{6}$$

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[12] This is important for smoothing the series for calculating the conditional volatility of returns according to the data. In this way, we transform the non-linear GARCH-BEKK model into a stochastic model.

where,

α_{11} is the coefficient of volatility for the first portfolio of equities,

α_{12} is the coefficient of volatility transmission from the second portfolio of equities to the first portfolio of equities,

α_{21} is the coefficient of volatility transmission from the first portfolio of equities to the second portfolio of equities,

α_{22} is the coefficient of volatility of the second portfolio of equities,

h_{11} is the estimated volatility of the first portfolio of equities,

h_{22} is the estimated volatility of the second portfolio of equities,

h_{12} is the estimated volatility transmission from the second portfolio of equities to the first portfolio of equities,

ε_1 is the error term in the first portfolio of equities,

ε_2 is the error term in the second portfolio of equities,

c_{11} is the constant coefficient of volatility for the first portfolio of equities,

c_{12} is the constant coefficient of volatility spillovers from the second portfolio of equities to the first portfolio of equities,

c_{13} is the constant coefficient of volatility for the second portfolio of equities,

This model can be economised by imposing the following restriction on the above equation: $B'H_tB=0$[13]. In fact, for a bivariate model, the above representation of the GARCH-BEKK model reduces to only eight parameters.

[13] The main limitation to estimating multivariate 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. Thus, for a GARCH model with four variables, the number of parameters in the log-likelihood function is 210. In this case, Pagan (1996) states that for most practical applications of the multivariate GARCH models one should consider undertaking estimates with various parameter restrictions. 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. The second restriction is suggested by Bollerslev

In the variance equation (3) of the GARCH-BEKK model the squared innovation series are smoothed with an n-period moving average technique. This is written as:

$$\tilde{\varepsilon}^2{}_t = \tfrac{1}{n}(\varepsilon_t{}^2 + \varepsilon_{t-1}{}^2 + \ldots + \varepsilon_{t-n+1}{}^2) \qquad (7)$$

An expansion of the GARCH-BEKK parameterisation equation (3) for the bivariate GARCH (p, q) model takes the form:

$$\begin{pmatrix} h_{11,t+1} & \\ h_{12,t+1} & h_{22,t+1} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{12} & c_{22} \end{pmatrix} * \begin{pmatrix} c_{11} & c_{12} \\ c_{12} & c_{22} \end{pmatrix} + \begin{pmatrix} b_{11} & b_{21} \\ b_{12} & b_{22} \end{pmatrix} * \begin{pmatrix} h_{11,t} & \\ h_{12,t} & h_{22,t} \end{pmatrix} * \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} + \begin{pmatrix} \alpha_{11} & \alpha_{21} \\ \alpha_{12} & \alpha_{22} \end{pmatrix} * \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} * \begin{pmatrix} \varepsilon_{1,t} & \varepsilon_{2,t} \end{pmatrix} * \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \qquad (8)$$

where,

$h_{11,t+1}$ is the volatility for the first portfolio of equities in period t+1,

$h_{22,t+1}$ is the volatility for the second portfolio of equities in period t+1,

$h_{12,t+1}$ is the volatility spillover from the second portfolio of equities to the first portfolio of equities in period t+1,

c_{11} is the constant coefficient for the first portfolio of equities in period t,

c_{12} is the constant coefficient for the volatility spillovers between the two portfolios of equities in period t,

c_{22} is the constant coefficient for the second portfolio of equities in period t,

b_{11} is the volatility coefficient for the first portfolio of equities in period t,

b_{21} is the volatility spillover coefficient from the first portfolio of equities to the second portfolio of equities in period t,

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(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: hijt= pij (hiit*hjjt)1/2. 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. One of the limitations of this approach, however, is that the restriction in correlation between pricing series may be appropriate for equity returns but not for exchange rates, as noted by Sheady (1997).

b_{12} is the volatility spillover coefficient from the second portfolio of equities to the first portfolio of equities in period t,

b_{22} is the volatility coefficient for the second portfolio of equities in period t,

α_{11} is the squared coefficient of error term for the first portfolio of equities in period t,

α_{21} is the coefficient of error transmission from the first portfolio of equities to the second portfolio of equities in period t,

α_{12} is the coefficient of error transmission from the second portfolio of equities to the first portfolio of equities in period t,

α_{22} is the squared coefficient of error term for the second portfolio of equities in period t,

$\varepsilon_{1,t}$ is the error term for the first portfolio of equities in period t, and

$\varepsilon_{2,t}$ is the error term for the second portfolio of equities 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:

$$\begin{pmatrix} h_{11,t+1} & \\ h_{12,t+1} & h_{22,t+1} \end{pmatrix} = \begin{pmatrix} c_{11}^2 + c_{12}^2 & \\ c_{11}c_{12} + c_{12}c_{22} & c_{22}^2 + c_{12}^2 \end{pmatrix} + \begin{pmatrix} b_{11}^2 h_{11,t} + 2b_{11}b_{21}h_{12,t} + b_{21}^2 h_{22,t} & \\ b_{11}b_{12}h_{11,t} + (b_{11}b_{22} + b_{12}b_{21})h_{12,t} + b_{21}b_{22}h_{22,t} & b_{22}^2 h_{22,t} + 2b_{12}b_{22}h_{12,t} + b_{12}^2 h_{11,t} \end{pmatrix} + \begin{pmatrix} \alpha_{11}^2\varepsilon_{1,t}^2 + 2\alpha_{11}\alpha_{21}\varepsilon_{1,t}\varepsilon_{2,t} + \alpha_{21}^2\varepsilon_{2,t}^2 & \\ \alpha_{11}\alpha_{12}\varepsilon_{1,t}^2 + (\alpha_{11}\alpha_{22} + \alpha_{12}\alpha_{21})\varepsilon_{1,t}\varepsilon_{2,t} + \alpha_{21}\alpha_{22}\varepsilon_{2,t}^2 & \alpha_{22}^2\varepsilon_{2,t}^2 + 2\alpha_{12}\alpha_{22}\varepsilon_{1,t}\varepsilon_{2,t} + \alpha_{12}^2\varepsilon_{1,t}^2 \end{pmatrix} \tag{9}$$

Expanding equation (1) to consider the effects of interest rates and trading volume on spillover effects, gives us:

$$r_t = \alpha + \sum_{p=1}^{n} \Phi_p r_{t-n} + z_{1t} + z_{2t} + e_t, e_t \mid \Omega_{t-1} \sim N(0, H_t) \tag{10}$$

where,

r_t is the return series,

z_{1t} represents the actual data series for interest rate,

z_{2t} represents the actual data series for trading volume,

Φ_p is the matrix of coefficients with the p lagged values of r_t, and

Ω_{t-1} is the matrix of conditional past information that includes the P lagged values of r_t.

Error terms are then extracted from the above equation (10) in order to use them in the equation (3) to measure the impact of interest rates and trading volume on the magnitude and persistence of volatility spillovers between different equity portfolios.

The above outlines the main features of the GARCH-BEKK modelling approach that will be used to investigate volatility spillovers for our sample of cross-listed companies. The same modelling approach is used to investigate information relationships between the returns of foreign cross-listed shares and domestic stock indices (according to different regulatory environments for varying disclosure rules and investor protection regulations).

4. Empirical Results

We extend the above analysis by considering the impact of interest rates and trading volume on volatility transmission effects. While a substantial literature has emerged examining the impact of interest rates and trading volume on equity returns [e.g. Lamoureux and Lastrapes (1990) and Elyasiani and Mansur (1998)] as far as we are aware, no studies have examined how such factors impact on volatility between markets.

As illustrated in Equation 10 in section 3.4, we use the GARCH-BEKK model and include in the return equation two fundamental factors, interest rates (z_1) and the portfolios trading volume (z_2) in order to see if these 'macro' factors influence volatility spillover estimates. Again, we use the same approach as obtained in the previous section by considering the spillover effects relating to foreign cross-listed equities according to various regulatory environments (different accounting disclosure rules, creditor protection rules governing bankruptcy and shareholder protection rules).

Table 8 (panel A to C) compares estimates of spillover effects from foreign cross-listed equities on the Frankfurt exchange with the market index DAX100 as estimated using the GARCH-BEKK model including and excluding interest rates. For ease of exposition we look at the case of Frankfurt with respect to different accounting regimes, creditor bankruptcy and shareholder protection rules to see if interest rates have any impact on volatility transmission[14].

Table 8: Impact of Interest Rate on Volatility Spillovers between German Cross-listed European Equities

	With interest rates	**Without interest rates**
Panel A: German foreign equity portfolios with the DAX100: Disclosure of accounting standards -period: 27/9/88-31/12/98	**Low High Same DAX100**	**Low High Same DAX100**
Volatility Transmission from Low to High	0.09 (0.04)	0.11 (0.04)
Volatility Transmission from High to Low	0.08 (0.03)	
Volatility Transmission from Same to High	0.14 (0.07)	
Volatility Transmission from DAX100 to Low	-0.12 (0.04)	
Volatility Transmission from High to DAX100	-0.14 (0.03)	
Volatility Transmission from Low to DAX100	0.13 (0.02)	
Volatility Transmission from DAX100 to High	NA	0.26 (0.06)
Error Transmission from Low to High	-0.041 (0.01)	-0.02 (0.01)
Error Transmission from High to Low	-0.05 (0.02)	0.06 (0.02)
Error Transmission from Same to High	-0.06 (0.03)	
Error Transmission from High to Same	0.05 (0.03)	
Error Transmission from DAX100 to Low	0.10 (0.02)	0.12 (0.03)
Error Transmission from High to DAX100	0.08 (0.02)	
Error Transmission from DAX100 to High	NA	0.25 (0.02)
Volatility persistence		
Low	0.74	0.71
High	0.56	0.81
Same	0.88	0.90
DAX100	0.86	0.35
Log-Likelihood	44253.57	44195.29

[14] We look only at this case because the German interest rate is independent of the changes of other European interest rates [Karfakis and Moschos (1990)].

Panel B: German foreign equity portfolios with the DAX100: Creditor bankruptcy protection rules-period: 27/9/88-31/12/98	**High Low Same DAX100**	
Volatility Transmission from High to Same	-0.20 (0.09)	
Volatility Transmission from High to DAX100	0.33 (0.16)	
Error Transmission from DAX100 to Low	0.12 (0.04)	0.11 (0.04)
Error Transmission from DAX100 to Same	0.11 (0.04)	0.13 (0.03)
Error Transmission from Low to DAX100	NA	0.05 (0.02)
Volatility persistence		
High Low Same DAX100	-0.47 0.86 0.37 0.97	0.87 0.13 0.56 0.51
Log-likelihood	42642.12	42560.39
Panel C: German foreign equity portfolios with the DAX100: Shareholder protection rules-period: 27/9/88-31/12/98	**High Low DAX100**	
Volatility Transmission from High to DAX100	0.10 (0.01)	0.075 (0.00)
Volatility Transmission from Low to High	NA	0.04 (0.01)
Volatility Transmission from High to Low	NA	-0.02 (0.00)
Volatility Transmission from DAX100 to High	NA	-0.11 (0.018)
Error Transmission from High to Low	0.02 (0.01)	0.057 (0.00)
Error Transmission from DAX100 to High	0.08 (0.03)	0.19 (0.02)
Error Transmission from DAX100 to Low	0.03 (0.02)	0.05 (0.01)
Error Transmission from Low to DAX100	NA	0.03 (0.00)
Volatility persistence		
High Low DAX100	0.68 0.92 0.79	0.65 0.91 0.98
Log-likelihood	34135.019	

Note: (i) 'Hgh' refers to where the foreign cross-listing is located in a market with more onerous regulatory requirements in the context of accounting rules, creditor bankruptcy and shareholder protection rules. 'Low' refers to less onerous regulatory environments and the 'Same' refers to exchanges that have similar rules.
(ii) Only statistically significant results are reported.
(iii) NA means not available.

Comparing the two columns that report the spillover effects it can be seen that the inclusion of interest rates in our model results in a wider range of dynamic spillover effects. There is much greater intereladness in volatilities between the various portfolios ('High', 'Low' and 'Same' and with the index) in the interest rate model. In general, it seems that when one takes account of interest rates in our modelling framework this adds to the dynamics of the spillover effects although the magnitude of these effects is relatively low. The period of study was characterised by a declining and relatively low interest rate environment through the second part of 1990s and this may explain the modest magnitude of these spillovers. According to Longin and Solnik (1995) correlation between markets/ portfolios could be higher in periods characterised by high levels of interest rates.

In addition to investigating the influence of interest rates on spillover effects, we also examine whether trading volume and interest rates together impact on volatility transmission. Lamoureux nad Lastrapes (1990 has examined the influence of trading volume using GARCH type models and, in general, this found that the inclusion of a market liquidity term (such as trading volume) decreases the size of ARCH or GARCH effects. As far as we are aware, however, no study has examined the impact of trading volume on spillover effects. In order to investigate the impact of trading volume on volatility transmission, we repeat the methodology as outlined earlier in this section, but at this time we include both interest rates and the trading volume of the foreign cross-listed equities in our GARCH-BEKK model[15].

Table 9 reports the spillover coefficients for cross-listed equity portfolios (according to different regulatory environments) that are found to be statistically significant for the London, Paris, and Zurich stock exchanges. We just want to see if trading volume and interest rates together, have any impact on volatility transmission for London, Paris, and Zurich markets with different regulatory regimes. In this respect, we do not examine the impact of the above-mentioned factors on the volatility transmission in Frankfurt+ market. In general, we find that the inclusion of the foreign equity trading volume variable has little impact on spillovers in the London market. For instance, the error transmission coefficient from the FTSE100 to the

[15] We do not use trading volume data for the expected stock indices as the impact of trading volume of stock price indices on spillovers between markets tends always to be significant. In contrast, we expect cross-listed equities to have thin trading volume on the foreign market, and thus we do not know if changes in trading volume for the foreign sample of cross-listed equities has a significant impact on volatility spillovers or not.

‘High’ (accounting standards) portfolio has fallen from –0.06 (in the model that excludes interest rates and trading volume) to –0.05. Other interactions remain the same.

In Paris the spillover dynamics has increased in terms of magnitude (the volatility transmission coefficient from ‘High’ to CAC40 has increased from 0.03 to 0.07) plus a wider range of other spillover interactions emerge. Finally, the results for the foreign cross-listed equity portfolios in Zurich suggest that spillover effects are reduced when their trading volume is taken into account.

While the results may appear ad hoc, taken together they do suggest that both economic news (as proxied by interest rates) and market news (as proxied by trading volumes) can have an influence on volatility transmission between portfolios and market indices.

Table 9: Impact of Interest Rate and Trading Volume on Volatility Spillovers between Cross-listed European Equities

Panel A: London foreign equity portfolios with the FTSE100: Disclosure of accounting standards-Period: 5/1/87-31/12/98	**High FTSE100**
Volatility Transmission from FTSE100 to High	0.03 (0.00)
Error Transmission from FTSE100 to High	-0.05 (0.01)
Volatility persistence	
High FTSE100	0.97 0.70
Log-Likelihood	24920.20
Panel B: Paris foreign equity portfolios with the CAC40: Creditor bankruptcy protection rules-period: 10/7/87-31/12/98	**High CAC40**
Volatility Transmission from CAC40 to High	-0.02 (0.00)
Volatility Transmission from High to CAC40	0.07 (0.02)
Error Transmission from CAC40 to High	0.87 (0.01)
Volatility persistence	
High CAC40	0.92 0.85
Log-Likelihood	22059.07
Panel C: Zurich foreign equity portfolios with the SBC100: Shareholder protection rules-period: 28/3/90-31/12/98	**Low High SBC100**
Volatility Transmission from SBC100 to High	0.14 (0.06)
Volatility Transmission from High to SBC100	0.04 (0.02)
Error Transmission from Low to SBC100	0.07 (0.02)
Volatility persistence	
Low High SBC100	0.91 0.85 0.90

Log-Likelihood	27682.97

Note: (i) 'Hgh' refers to where the foreign cross-listing is located in a market with more onerous regulatory requirements in the context of accounting rules, creditor bankruptcy and shareholder protection rules. 'Low' refers to less onerous regulatory environments and the 'Same' refers to exchanges that have similar rules.
(ii) Only statistically significant results are reported.

5. Conclusion

This study examines the short-term dynamics of volatility and error for cross-listed equities traded on European stock markets for the period 1987 to 1998. The methodology has been designed to account for the fact that different regulations between exchanges influence volatility spillovers between markets. In particular, this paper includes La Porta et al.'s (1998) classification of regulatory conditions so as to facilitate the analyses of the magnitude and persistence of volatility spillovers for cross-listed equities within markets.

We investigate the relationship between spillover effects and stock market regulatory structures for cross-listed European firms. In particular, we examine the influence of differences in capital market accounting disclosure requirements and shareholder and creditor protection rules on volatility spillovers for the foreign listings of companies quoted on the Frankfurt, London, Paris, and Zurich exchanges. This part of the analysis examines the impact of interest rates and trading volumes on the magnitude and persistence of these spillovers.

The main results can be summarised as follows:

1. A multivariate GARCH-BEKK model provides a useful modelling framework to examine the process governing spillovers between markets with different regulatory structures. The magnitude and persistence of these spillovers that originate in one market and that are transmitted to another market (or between portfolios) depend importantly on how the cross-market (portfolio) dynamics in the conditional volatilities of the respective markets (portfolios) are modelled.

2. The impact of differences in accounting standards, and shareholder and creditor protection rules on spillovers between foreign cross-listed equities and market indices are distinctly

different. This suggests that investment barriers relating to the above mentioned regulations are important for understanding the dynamics of spillover patterns in stock prices within Europe.

3. The level of interest rates and foreign equity trading volumes are also shown to influence the structure of cross-market dependencies in terms of conditional volatilities or errors between markets with different regulatory features.

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