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The Impact of Stock Exchange Rules on Volatility and Error Transmission — The Case of Frankfurt and Zurich Cross-Listed Equities

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This paper investigates the relationship between spillover effects and stock market regulations for a sample of cross-listed firms in Frankfurt+ and Zurich markets. Using La Porta et al.'s (1998) stock exchange regulatory classification we identify firms that have cross-listed on foreign exchanges with either tougher, weaker or similar accounting disclosure, bankruptcy and shareholder protection rules. We then use the GARCH approach suggested by Karolyi (1995) and Engle and Kroner (1995) to estimate volatility and error transmission for our sample of cross-listed equities, taking into account regulatory differences between exchanges. Our results show the differences in stock exchange rules that can influence spillovers between foreign cross-listed equities and the respective market indices. Shareholder protection rules also seem to have less of an effect on cross-listed share volatility transmission than do differences in accounting disclosure and bankruptcy protection rules.

Key Words: Volatility spillovers; GARCH-BEKK; Regulatory differences.
JEL Classification Number: G15.

1. INTRODUCTION

This paper examines the integration process for cross-listed equities in Zurich and Frankfurt+. A primary focus of this study is to relate the volatility spillover effects for cross-listings across markets with different

1529-7373/2006

regulatory structures. In particular, the paper investigates the relationship between spillover effects and stock market regulatory structures for cross-listed firms in specific European markets. Using La Porta et al.'s (1998) stock exchange regulatory classification (that 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 tougher, weaker or similar regulatory features compared with the home market. Using data on cross-listings from the German, and Swiss markets we construct portfolios of the foreign listed companies based on the aforementioned regulatory conditions.

The main finding of this paper is that spillover effects are important within Zurich and Frankfurt+ markets for cross-listed companies. In addition, different regulatory environments have a significant impact on volatility spillovers. Our 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 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.

The paper 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 OVERVIEW AND INTENTION OF THIS STUDY

Volatility clustering 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), 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, and that, when volatility is high, price changes in major stock markets tend to become highly correlated.

Fratzcher (2001) examines the stock market integration process in Europe from the period of January 1986 to June 2000 with a GARCH model. He found that the process of financial liberalization in Europe increased the degree of stock market integration for EMU participants. Bekaert et al. (2003) found that more than 30% of the conditional variance is caused to shocks from the US. In addition, they found that there are intra-European contagion effects without evidence of strong correlation between Europe and the US. This type of correlation may be caused because volatility spillovers that emanate from more efficient markets to less efficient markets are simply contagious.

There is some evidence that relates volatility spillovers to barriers on structural differences between markets. 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 the major stock markets (US, Canada, Japan, UK, and Germany). For example, Hamao et al. (1990), Koutmos and Booth (1995), and Susmel and Engle (1994) focus on spillovers across New York and London, and Theodossiou and Lee (1993) examine spillovers across US, Japan, Canada and Germany. In addition to the above, Hamao et al. (1990) find the existence of spillovers from the USA and UK markets to Japan. 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) find that volatility transmission is short and small between New York and London, in contrast to Teodossiou and Lee (1993) who note that the US capital market is the major 'exporter' of volatility to other financial markets.

The research reveals that volatility spillovers from the US capital markets could lead the rest of the world (Eun and Shim, 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. In addition, the correlation between markets could increase over time (Von Furstenberg and Jeon, 1989). Specifically, Von Furstenberg and Jeon (1989) examine 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 found an increase in correlation for the markets that involved especially after the market crash of October 1987.

Research studies in the past, which examined the volatility transmission effects between markets using GARCH models, did not account for the impact of regulatory variables on such interdependencies, the main focus of this study. Examining the correlation of equities returns alone, one cannot reach conclusions with regard the impact of regulatory barriers on market integration. As Karolyi (1995) has pointed out, barrier restrictions have an impact on interdependencies and these needs to be taken into account using GARCH models in order to be able to draw correct inference 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.

With respect to the above, an analysis of transmission of news between cross-listed equities and stock indexes with different regulatory structures may help to inform us more on stock market integration process. Huddart et al. (1998), for instance, suggest 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 investment in capital markets).

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 European exchanges set their requirements with a 'lower bound' without any 'higher bound' when they accept new financial corporations. 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.

An important question with regard to cross-listings relates to the influence, if any, of various regulations and institutional rules on price volatility. Empirical evidence (Karolyi (1995)) suggests that since 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, as cited by Stiglitz (1989) and Summers (undated) may influence stock price volatility changes that cannot be fully explained by 'fundamental' factors alone.

Given that regulations are believed to have an impact on stock price volatility, this paper examines 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 specific European markets. As far as we are aware, the available empirical evidence simply confirms the interrelationship between stock prices and volatilities without taking into account regulatory barriers. 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 never tested for. We therefore do not know the impact of different regulatory features have on such spillover effects. This paper aims to address these issues by examining the influence that regulatory structures have on volatility transmission for cross-listed European equities.

3. DATA

3.1. Sample selection

This paper focuses on 'cross-listed' equities in specific European markets. Portugal, Greece, and Luxembourg are excluded because of unavailability of data. 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. We collect information on 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 of various European Stock markets, 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.

In addition, the data is transformed into Euro's by using the European Central Bank (ECB) exchange rates at the end of 1998 or beginning of 1999. Trading holidays as identified by Datastream are excluded so we have a continuous data series. Trading dates around the October 1987 crash, namely the 16th, 19th-21st October are excluded from the sample. We finally arrive at a sample of 210 firms that have 521 cross-listings (home and foreign) across specific European markets as shown in Table 1.

3.2. Data Description

The current study covers 'cross-listed' home 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), Zurich, and Dublin. The total number of 'cross-listed' equities (home + foreign) across the 14 European stock markets is 521; 280 are home equities and 241 are foreign equities. The current study concentrates on the foreign equities that are listed in Frankfurt+, and Zurich. We look only at these two 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	Frankfurt+	Zurich	Total
Austria	6	7	8	0	8
Belgium	7	8	4	2	6
Denmark	7	9	5	2	7
Finland	4	7	3	0	3
France	32	34	31	7	38
Germany	26	56	0	28	28
Netherlands	26	30	30	17	47
Italy	12	14	12	0	12
Norway	6	11	6	0	6
Spain	20	23	19	1	20
Sweden	13	20	13	0	13
UK	40	45	33	6	39
Switzerland	7	11	10	0	10
Ireland	4	5	4	0	4
Total	210	280	178	63	241

Notes: (i) Frankfurt+ comprises Berlin, Dusseldolf, Stuttgart, Munich, Xet, and Frankfurt. 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).
(ii) Out of the 280 home listings, 22 have been delisted. In addition, 31 home equity listings involve mergers.

The number of foreign listings varies within the stock exchanges; there are 178 European foreign listings in Frankfurt+. There is also a large number of foreign listings in Zurich (63). All the above mentioned 210 'home' market 'cross-listings' comprise 159 firms that belong to the General Industry Sector, 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. Financial companies include banks, investment banks, and investment trusts. In terms of the sample size in most cases the home and foreign issues of cross-listed companies account for around 8 percent of total issues in the respective markets. We also undertake a one-way ANOVA (analysis of variance) to test for differences in the market capitalisation of the respective stock market indices and the market capitalisation of the sample. These were not significant different at the 5% level suggesting that the data is a representative sample.

In Table 2, various descriptive statistics are displayed for foreign stock equity returns that shows skewness to be negative in home equity returns and in some foreign equity returns (in particular in Frankfurt+ and Zurich).

Also, there are fat tails present in the distribution of equity returns and excessive kurtosis. The descriptive statistics also appear to be influenced by the days around the market crash in October 1987 even though we omitted the most influential days (i.e. October 16, 19, 20, and 21).

TABLE 2.

Descriptive Statistics for Foreign portfolios of Cross-Listed Equities

	Mean	St.Dv.	T-statistic	Skewness	Kurtosis
Foreign Portfolios of Equities					
German	0.00037	0.0088	2.27	0.073	9.88
Swiss	0.00036	0.02	0.85	−0.35	27.47

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

In Table 3, descriptive statistics are shown for the returns of stock market indices. There is excessive kurtosis present in stock market indices, with negative skewness in most of the series.

TABLE 3.

Descriptive Statistics for Stock Indices

	Mean	St.Dev.	T-Stat.	Skewness	Kurtosis
Stock Market Indices					
German	0.00056	0.011	2.62	−1.15	14.64
Swiss	0.00045	0.010	2.35	−1.55	18.12

Notes: (i) German contains Frankfurt, Berliner, Dusseldorf, Stuttgart, Munich, and XET equities.
(ii) The starting date of the stock indices varies amongst countries. In particular, in Germany, and Switzerland, the starting dates are 30/12/87 and 1/4/87, respectively.

4. METHODOLOGY

4.1. 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, 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. Bollerslev, Chou, and Kroner (1992) provide a summary of ARCH-type models. 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) suggest that stock markets are linked through their second moments. Overall, this suggests 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 studies). 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.

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

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

where, r_t is the return series of cross-listed portfolios of equities, e_t is the error term of return equation, and 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, 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 $E(\varepsilon_t)$.

$$\text{where,} \quad E(\varepsilon_t) = E(r_t - \mu_t) \tag{2}$$

μ_t is the long-term drift coefficient and

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

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

$$h_{11} = c_{11} + \alpha_{11}^2 \varepsilon_1^2 + 2\alpha_{11}\alpha_{21}\varepsilon_1\varepsilon_2 + \alpha_{21}^2\varepsilon_2^2 \quad (4)$$

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

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

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: $B'H_tB = 0$. 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, Pagano (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 (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: $h_{ij,t} = p_{ij}(h_{ii,t} * h_{jj,t})1/2$. 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). In fact, for a bivariate model, the above representation of the GARCH-BEKK model reduces to only eight parameters. An expansion of the GARCH-BEKK parameterisation equation (3) for the bivariate $GARCH(p,q)$ model takes the form:

$$\begin{aligned} \begin{pmatrix} h_{11,t+1} & \\ h_{12,t+1} & h_{22,t+1} \end{pmatrix} &= \begin{pmatrix} c_{11} & c_{12} \\ c_{12} & c_{22} \end{pmatrix} * \begin{pmatrix} c_{11} & c_{12} \\ c_{12} & c_{22} \end{pmatrix} \\ &+ \begin{pmatrix} b_{11} & b_{21} \\ b_{12} & b_{22} \end{pmatrix} * \begin{pmatrix} h_{11,t} & \\ h_{12,t} & h_{22,t} \end{pmatrix} * \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} \\ &+ \begin{pmatrix} \alpha_{11} & \alpha_{21} \\ \alpha_{12} & \alpha_{22} \end{pmatrix} * \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} * \begin{pmatrix} \varepsilon_{1,t} & \varepsilon_{2,t} \end{pmatrix} * \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \end{aligned} \tag{7}$$

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, and 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, 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. Finally, $\varepsilon_{1,t}$ 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:

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

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.

5. SPILLOVERS, FOREIGN EQUITY CROSS-LISTINGS AND THE REGULATORY ENVIRONMENT — THE RESULTS

This section reports the findings of our analysis considering spillover effects between foreign equity cross-listings and the respective markets indices. In particular we focus our analysis on the Frankfurt+ and Zurich exchanges.

Table 4 presents the GARCH-BEKK results of the spillover effects for the portfolios of foreign cross-listed companies on the Frankfurt exchange in relation to the market index (DAX100).

Table 4 Panel A shows the spillover effects relating to the cross-listings with exposure to different accounting standard requirements. For each exposition we refer to foreign cross-listings on exchanges with more onerous accounting requirements as 'HIGH' and in the opposite case we refer to those as 'LOW'. Exchanges with similar rules we refer to as 'SAME'. The magnitude of spillovers is greater from DAX100 to 'High' (0.26) compared with spillovers from DAX100 to both the 'Low' (0.11) and 'Same' (0.13) portfolios.

In other words, companies that have foreign listings on the Frankfurt exchange (and have home listings where accounting rules are less onerous) appear to experience greater spillover effects. This suggests that the domestic index influences cross-listed foreign equities from less onerous accounting disclosure regulatory environments in a stronger manner than compared with those coming from more stringent or similar regulatory environments. The coefficients for the DAX100 to 'High' error transmission estimates are equal in magnitude to volatility transmission. This means that both change in prices and noise significantly contribute to information transfers from the DAX100 index to the 'High' portfolios. We do not find evidence that there is any return volatility transmission from the DAX100 to 'Low' or 'Same' portfolios. However, the error (noise) transmission from DAX100 to 'Low' is found to be significant at 0.12. This means that trading noise in

TABLE 4.

Spillovers between cross-listed foreign equities on the Frankfurt exchange and DAX100 accounting for differences in regulatory regimes

Panel A: German foreign equity portfolios with the DAX100-Disclosure of accounting standards-period: 27/9/88-31/12/98	Parameter Estimates (Standard Errors in parentheses)
Volatility Transmission from Low to High	0.11 (0.04)
Volatility Transmission from DAX100 to High	0.26 (0.06)
Error Transmission from Low to High	−0.02 (0.01)
Error Transmission from High to Low	0.06 (0.02)
Error Transmission from DAX100 to High	0.25 (0.02)
Error Transmission from DAX100 to Low	0.12 (0.03)
Volatility persistence	
High	0.81
Low	0.71
Same	0.90
DAX100	0.35
Log-Likelihood	44195.29
Panel B: German foreign equity portfolios with the DAX100-Creditor bankruptcy protection rules-period: 27/9/87-31/12/98	Parameter Estimates (Standard Errors in parentheses)
Error Transmission from DAX100 to Low	0.11 (0.04)
Error Transmission from DAX100 to Same	0.13 (0.03)
Error Transmission from Low to Stock Index	0.05 (0.02)
Volatility persistence	
Low	0.87
High	0.13
Same	0.56
DAX100	0.51
Log-Likelihood	42560.39
Panel C: German foreign equity portfolios with the DAX100-Shareholder protection rules-period: 27/9/87-31/12/98	Parameter Estimates (Standard Errors in parentheses)
Volatility Transmission from Low to High	0.04 (0.01)
Volatility Transmission from High to Low	−0.02 (0.00)
Volatility Transmission from DAX100 to High	−0.11 (0.018)
Volatility Transmission from High to DAX100	0.075 (0.00)
Error Transmission from High to Low	0.057 (0.00)
Error Transmission from DAX100 to High	0.19 (0.02)
Error Transmission from DAX100 to Low	0.05 (0.01)
Error Transmission from Low to DAX100	0.03 (0.00)
Volatility persistence	
High	0.65
Low	0.91
DAX100	0.98
Log-Likelihood	34472.31

Note: (i) 'High' 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.

DAX100 equities contributes significantly to information transfers to the 'Low' portfolio.

Panels B and C report spillover coefficients relating to different shareholder and creditor protection rules. Again we use the same 'High', 'Low' and 'Same' classification. Panel B suggests that differences in creditor bankruptcy rules between exchanges have no influence on volatility transmission for cross-listed equities on the Frankfurt exchange. However, there is some evidence to suggest that trading noise can have significant transmission effects between the market index and cross-listed equities where the home listing has tougher shareholder rules covering corporate bankruptcies.

Finally, Panel C of the Table suggests that there are both volatility and error transmission spillovers for the cross-listed equities when we take differences in shareholder protection rules between the home and Frankfurt exchange into account. One can see that volatility spillovers are bidirectional between the DAX100 for both the 'High' and 'Low' portfolios, although the magnitude of spillover is greater from DAX100 to both types of portfolios. Looking at the results, together, spillover dynamics in Frankfurt appear more prevalent when we consider differences in shareholder protection rules across exchanges compared with variations in accounting disclosure rules and creditor regulations governing bankruptcy protection.

Table 5 presents the results of the spillover effects for foreign cross-listed firms on the Zurich exchange and Panel A shows the results for cross-listed firms with different bankruptcy protection rules between exchanges. The magnitude of spillovers is dominant from 'Low' to both the 'High' portfolio and the SBC100 stock index. This suggests that the foreign equities from tougher creditor bankruptcy protection rules environments appear to transmit information to either the SBC100 stock index and to the foreign equities from less onerous markets.

The coefficients for 'High' to the SBC100 stock index volatility estimates and also for the SBC100 stock index to 'Low' error estimates are found to be significant at 0.05 and 0.08, respectively. Changes in the stock prices from the 'High' portfolio to the SBC100 stock index contribute 'equally' significant with changes in trading noise from the SBC100 index to the 'Low' portfolio. Panel B suggests that differences in shareholder protection rules between exchanges again influence volatility transmission from cross-listed foreign equities from less onerous shareholder protection rules regulatory environments to cross-listed foreign equities from tougher regulatory environments (and also to the SBC100 stock index). Also, there is some evidence to suggest that error spillovers are directed from cross-listed foreign equities from laxer to tougher shareholder protection rules regulatory environments. This means that both changes in prices and noise in the 'High' portfolio of cross-listed equities significantly contribute to information transfers to 'Low' portfolios and to the SBC100 stock index.

TABLE 5.

Spillovers between cross-listed foreign equities on the Zurich exchange and the SBC100 index accounting for differences in regulatory regimes

Panel A: Zurich foreign equity portfolios with the SBC100: Creditor bankruptcy protection rules-period: 2/7/90-31/12/98	High Low SBC100
Volatility Transmission from Low to High	0.02 (0.00)
Volatility Transmission from High to SBC100	0.08 (0.03)
Volatility Transmission from Low to SBC100	0.15 (0.03)
Error Transmission from Low to High	−0.02 (0.01)
Error Transmission from SBC100 to Low	0.05 (0.02)
Error Transmission from Low to SBC100	0.08 (0.02)
Volatility persistence	
High	0.90
Low	0.69
SBC100	0.99
Log-Likelihood	26101.86
Panel B: Zurich foreign equity portfolios with the SBC100: Shareholder protection rules-period: 28/3/90-31/12/98	High Low SBC100
Volatility Transmission from High to Low	0.01 (0.00)
Volatility Transmission from High to SBC100	0.10 (0.05)
Volatility Transmission from SBC100 to Low	0.02 (0.00)
Error Transmission from High to Low	−0.02 (0.00)
Error Transmission from SBC100 to Low	−0.02 (0.00)
Volatility persistence	
High	0.36
Low	0.90
SBC100	0.74
Log-Likelihood	27536.57

Note: (i) 'High' 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.

Overall, spillover dynamics in Zurich appear more prevalent from 'Low' ('High') to either 'High' ('Low') portfolio of cross-listed equities or the SBC100 stock index taking into account variations in creditor bankruptcy and shareholder protection rules between exchanges.

6. CONCLUSION

This paper examines the short-term dynamics of volatility and error transmission for cross-listed equities traded on specific European stock markets for the period 1987 to 1998. The methodology has been designed to specifically account for differences in regulations between exchanges and the assumption that these may influence spillovers between markets. In particular, we use 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.

In particular, we examine the influence of differences in stock exchange disclosure requirements and shareholder and creditor protection rules on volatility spillovers for the foreign listings of companies quoted on the Frankfurt+, and Zurich exchanges. The paper shows that the impact of differences in accounting standards, and shareholder and creditor protection rules on spillovers is distinctly different across exchanges. Differences in shareholder protection rules across markets also appear to have more of an effect on cross-listed share volatility transmission than do differences in accounting disclosure and bankruptcy protection rules. Overall, our paper suggests that investment barriers relating to the above mentioned regulations are important for understanding the dynamics of spillover patterns in stock prices of Frankfurt+ and Zurich.

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