Volatility Transmission for Cross Listed Firms and the Role of International Exposure[*]

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(February 2006)

Abstract

We find empirical evidence suggesting that the volatility dynamics of Japanese firms cross-listed in the US is characterized as a Meteor Shower with Country-Specific News. Furthermore, we find differences in volatility dynamics depending on the international exposure of firms. These differences are consistent with a higher contribution of foreign traders (foreign markets) to the price discovery process of Japanese firms with higher international exposure, and with a news-correlated process for these firms. We also find weaker empirical evidence suggesting a higher contribution of Japanese traders to the price discovery process of Japanese firms with lower international exposure.

Keywords: Cross-listing, Volatility, GARCH, Stock Market, Information transmission.
JEL: G10, G14, G15

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1. Introduction

Nowadays, a growing number of stocks are quoted on different markets. For example, Pulatkonak and Sofianos (1999) document an increasing number of foreign firms listed on the New York Stock Exchange (NYSE). For this reason, there is increasing interest in the price behaviour of these stocks in the different markets where they are traded. Many studies have been made of the price discovery process of these firms (e.g. Lau and Diltz, 1994; Eun and Jang, 1997; Ding *et al.*, 1999; Lieberman *et al.*, 1999; Hupperets and Menkveld, 2002; Pascual *et al.*, 2003; Eun and Sabherwal, 2003; Grammig *et al.*, 2005). The usual finding is that the foreign country contributes to some extent. The methodology of these papers is based on simple regressions on overlapped stock returns in different markets (e.g. Lau and Diltz, 1994), on Vector Error Correction Models (e.g. Eun and Jang, 1997; Lieberman *et al.*, 1999; Eun and Sabherwal, 2003), and on common trend representations of a Vector Error Correction Model (e.g. Ding *et al.*, 1999; Hupperets and Menkveld, 2002; Pascual *et al.*, 2003; Grammig *et al.*, 2005) on returns time series of the different markets where the stocks are listed. These methodologies are used to measure the contribution of each market to the price discovery process.

In a related research field, the seminal paper by Engle *et al.* (1990) studied intraday volatility dynamics on the foreign exchange market around the world. That is, they studied the dynamic relation of the volatility of returns rather than the dynamic relation of returns. This approach enables the price discovery process to be studied from a different point of view; that of the process of the incorporation of news into the exchange rate. These authors found volatility transmission from one time zone to the next (Meteor Shower). As they point out, there are several explanations for this finding; (i) failures of market efficiency (e.g. due to technical analysis behaviour); (ii) market dynamics in response to news (e.g. Kyle, 1985; Admati and Pfleiderer, 1988); (iii) the data generating process, such as stochastic policy coordination or competition. In a posterior paper, Ito *et al.* (1992) analyzed the data generating process and found that stochastic policy coordination is not a major explanation.

With respect to cross-listed stocks, several papers have analyzed volatility dynamics (e.g. Wang *et al.*, 2002; Xu and Fung, 2002; Alaganar and Bhar, 2002). However, these papers either do not investigate the volatility dynamics found (e.g. Wang *et al.*, 2002) or they implement the analysis on close-to-close returns (e.g. Xu and Fung, 2002; Alaganar and Bhar, 2002), where the returns on the different stock markets partially overlap and therefore the Engle *et al.* (1990) analysis cannot be implemented. Regarding an explanation for the volatility dynamics found, Xu and Fong (2002) obtained weak evidence of the international exposure of a firm affecting the volatility transmission. They measured this exposure with the percentage of each firm's volatility in the foreign market explained by the foreign market main index.

In this paper we implement an experiment similar to that of Engle *et al.* (1990) on cross-listed stocks.[1] In a first step, we analyze whether these stocks present Meteor Shower characteristics, and find evidence supporting this. In a second step, we analyze whether firms' international exposure affects Meteor Shower dynamics. We measure international exposure by quantifying the business activity in the time zone of the foreign market (i.e. in the geographical area).[2] On cross-listed stocks, the market

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[1] We have to introduce several modifications in order to adapt the experiment to the characteristics of cross-listed stocks. For example, there is no continuous trading 24 hours per day, and we consider just trading returns, that is, open to close returns in the considered markets.

[2] See Forbes (2004) for an example of empirical evidence on trading relations between countries affecting stock price relations across markets.

dynamics and the data generating process may cause different patterns of volatility depending on the geographical distribution of the firms' business. Regarding market dynamics, Chan *et al.* (1996) found that US investors mainly trade foreign stocks on the basis of public information previously released on the domestic market. This explanation is inspired by the trading models of Varian (1989) and of Harris and Raviv (1993). Our hypothesis is that this behaviour could be reinforced within foreign firms characterized by a significant level of business activity in the US time zone geographical area. For example, this may be the case if correct interpretation of the effect of public information released on the domestic country requires knowledge related to the business activity of these firms in the US time zone geographical area. Furthermore, as shown by Kang and Stulz (1997) and by Dahlquist and Robertsson (2001), foreigners tend to invest more in firms that they are better informed about. Regarding the data-generating process, there may be a news release correlated process for firms with significant business activity in the US time zone geographical area. This correlated process may resemble the stochastic policy coordination process studied in Ito *et al.* (1992),[3] by which a news release in the local market induces another news release in the foreign market. For example, if a Japanese firm decides to fire 10% of its workers in the US and this information is released from the firm's headquarters in Japan, this information will influence the stock price in Japan. Then there will be a reaction by workers in the US, and even among competitors and regulators there, during the US business day. This new information then influences stock prices in the US. Therefore, volatility in Japan causes posterior volatility in the US (see Ross, 1989, for the relation between volatility and the incorporation of information into stock prices,

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[3] Their explanation is that a policy innovation in Japan precedes a policy response in the US and vice versa. The response is stochastic and therefore a policy innovation causes volatility transmission from one market to the other.

and Kalev *et al.*, 2004, for empirical evidence on this relation, and on the autocorrelation of the rate of news arrival).

We study the volatility dynamics of Japanese firms cross-listed on the US market. These firms are traded in the US as American Depository Receipts (ADR).[4] We find volatility transmission from Japan to the other markets analyzed, and also between these other markets (Meteor Showers). Furthermore, we find that these volatility dynamics are affected by the firms' international exposure in the US time zone geographical area. Our empirical evidence suggests that volatility transmission from Japan is higher for firms with significant business activity in the US time zone geographical area. This evidence supports two hypotheses: (i) that the contribution of foreign traders (foreign markets) to the price discovery process is more intense among Japanese firms with business activity in the foreign markets' time zone geographical area; (ii) there is a correlated information generation process concerning these firms. We also find weaker empirical evidence suggesting a higher degree of transmission from the US and Europe to Japan for Japanese firms with lower levels of business activity in the US time zone geographical area. This is consistent with Japanese traders trading on the basis of public information previously released in the US or Europe being more intense for Japanese firms with a higher percentage of business activity in the Japanese time zone geographical area. Finally, we find a greater persistence of volatility shocks on posterior volatility among the non-international Japanese firms. This suggests that for these firms there is more persistence in the degree of disagreement between investors on the interpretation of news releases.

Thus, the contribution of this paper is to shed some light on the process of information incorporation into prices for cross-listed stocks. Furthermore, this evidence

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[4] See Gande (1997) or Karolyi (1998) for a description of American Depository Receipts.

complements that of Chan *et al.* (2003), suggesting that the geographical distribution of business as well as the location of trade is relevant to price fluctuations.

In the next section we present the empirical methodology. Section 3 gives the data summary. Section 4 reports the empirical analysis, and the final section summarizes the main conclusions.

2. The empirical methodology

The empirical design of our experiment is similar to that of Engle *et al.* (1990). However, trading in stocks is not continuous, 24 hours a day, as is the case in the foreign exchange market. It takes place only during the trading hours of the stock markets where the stocks are traded. Various studies, for example by French and Roll (1986), have shown that information is introduced into stock prices mainly during trading hours, and therefore we will consider just trading periods returns, that is, we consider the open to close returns of the main markets where the Japanese stocks we analyze are quoted, namely the Japanese and the US stock markets. However, after the Japanese trading interval and before the US trading interval there is trading activity in Europe. New information affecting stock prices may be released during the European interval, and therefore, in order to control for a possible misspecified model, we estimate a second version of the empirical model including the European market.[5] The European and US trading periods partially overlap. This may cause contemporaneous correlation due to the same information being incorporated simultaneously in both markets. Werner and Kleidon (1996) found that information regarding US firms quoted

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[5] Several papers analyzing transmission of movements between the Japanese and the US markets do not include the European market, such as Lin *et al*., (1994), Lau and Diltz (1994), or Chan *et al*., (2000). However, these papers do not relate open to close returns.

on the London market was introduced into both markets' prices during the overlap. Furthermore, their evidence suggested that US traders lead the price formation process. Therefore, in order to obtain orthogonal European and US returns, we regress the European return on the US return (explanatory variable) and take the residual as the orthogonalized European return. The three-markets model analysis is performed with the European returns and with orthogonalized European returns. Very similar results were obtained with the two analyses, and so in order to save space we present only the analysis with orthogonalized returns. The results of this analysis are given in the Appendix.[6]

A VAR-GARCH model is used to model the dynamic process of returns time series on the US and the Japanese markets.

$$\begin{pmatrix} R_{1,t} \\ R_{2,t} \end{pmatrix} = \begin{pmatrix} a_{10} \\ a_{20} \end{pmatrix} + \begin{pmatrix} \sum_{k=0}^{p_1} (\beta_{21k} R_{2,t-k} + \beta_{11k} R_{1,t-k-1}) \\ \sum_{k=0}^{p_2} (\beta_{12k} R_{1,t-k-1} + \beta_{22k} R_{2,t-k-1}) \end{pmatrix} + \begin{pmatrix} e_{1,t} \\ e_{2,t} \end{pmatrix} \qquad [1]$$

Here, $R_{1,t}$ represents the open to close log return (the logarithm of the closing price minus the logarithm of the opening price) in the US market for day t and $R_{2,t}$ represents the corresponding value for the Japanese market.

We define the error vector 2x1 as

$$\varepsilon_t = \begin{pmatrix} e_{1,t} \\ e_{2,t} \end{pmatrix}.$$

We define $h_{ij,t}$ as the covariance between $e_{j,t}$ and $e_{i,t}$ for $j \neq i$ and the variance of $e_{i,t}$ for $i = j$. Then, $\varepsilon_t | \psi_{t-1} \sim N(0, \Omega_t)$, where ψ_{t-1} is the conditional set of information

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[6] The analysis with the non-orthogonalized European returns is available upon request.

available in *t*-1, and the conditional variance and covariance matrix is $\Omega_t = \begin{pmatrix} h_{1,t} & h_{12,t} \\ h_{12,t} & h_{2,t} \end{pmatrix}$.

In order to model the variance and covariance matrix, we use the constant correlation multivariate GARCH(*p*,*q*) specification by Bollerslev (1990), modified in order to accommodate the spillover effect in variance across markets.[7] This specification is:

$$\begin{aligned} h_{1,t} &= a_1 + b_1 h_{1,t-1} + \sum_{l=0}^{z_1} (c_{21l} e^2_{2,t-l} + c_{11l} e^2_{1,t-l-1}) \\ h_{2,t} &= a_2 + b_2 h_{2,t-1} + \sum_{l=0}^{z_2} (c_{12l} e^2_{1,t-l-1} + c_{22l} e^2_{2,t-l-1}) \qquad [2] \\ h_{12,t} &= \rho_{12} \sqrt{h_{1,t} h_{2,t}} \end{aligned}$$

The parameters of the model formed by [1] and [2] are estimated by the quasi-maximum likelihood method with conditional normal density.[8] The logarithm of the likelihood function ($\log L$) is defined by:

$$\log L = f - \sum_{t=1}^{T} \log\left|\Omega_t\right| - \frac{1}{2} \varepsilon_t' \Omega_t^{-1} \varepsilon_t$$

where *f* is a constant term.

The main difference between our model specification and that of Engle *et al.* (1990) is that we estimate a multivariate model in variance while they estimate different

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[7] This specification simplifies the estimation because it allows an important reduction in the number of parameters in comparison to other specifications such as the BEKK (Engle and Kroner, 1995). In the empirical application it is tested whether this is appropriate for our data and we got positive results.

[8] The second version of the model including the European market has the same design. It has a third equation for the European market in the model of returns defined by [1] and in the model of variance defined by equations [2], and two equations more for the covariance between the European return and the Japanese, and the US returns in [2].

univariate GARCH models. We use the multivariate specification to obtain more efficient estimations.

Regarding the statistical inference on this model, a robust estimate of the variance and covariance matrix of the parameter estimates is obtained using the matrix of second derivatives and the average of the period by period outer products of the gradient. The BFGS algorithm and consistent covariance techniques allow us to obtain the necessary estimates. Under fairly weak conditions, the resulting estimates are consistent even when the conditional distribution of the residuals is non-normal (see Bollerslev and Wooldridge, 1992, and Lumsdaine, 1991). As in Engle *et al.* (1990), we test the Meteor Shower hypothesis with a likelihood ratio test for the null of Heat Waves. That is, under the null, the transmission parameters satisfy $\beta_{12k} = \beta_{21k} = c_{12l} = c_{21l} = 0$. Furthermore, whenever the Meteor Shower hypothesis is accepted, we also investigate whether the Meteor Shower with World Wide News specification in Engle *et al.* (1990) is more suitable. Under this specification, volatility dynamics imply a Meteor Shower where the geographical origin of volatility shocks is not relevant. This specification is estimated with a univariate GARCH model on a time series obtained by stacking the Japanese and the US returns sequentially. This univariate specification is nested with [1] and [2] where the following restrictions are implied; $a_{10} = a_{20}$, $\beta_{21k} = \beta_{12k}$, $\beta_{11k} = \beta_{22k}$, $a_1 = a_2$, $b_1 = b_2$, $c_{21l} = c_{12l}$, $c_{22l} = c_{11l}$, and $\rho_{12} = 0$. Therefore, we allow three characterizations of the volatility dynamic process; Heat Waves, Meteor Showers with Country Specific News, and Meteor Showers with World Wide News (see Engle *et al.*, 1990, for further details).

Finally, we obtain the impulse response function for conditional volatility from the model [1]-[2] when $z_1 = z_2 = 0$ in [2]. This allows us to explain how new information (volatility shocks) will affect future expected volatility. The impulse response function for conditional volatility is defined as the impact of a small perturbation of the *i*-th innovation on the future predicted volatility.

By setting $y_t = \left(h_{1,t}h_{2,t}\right)'$ and $v_t = \left(e_{1,t}^2 - h_{1,t}, e_{2,t}^2 - h_{2,t}\right)'$, where $v_{i,t} = e_{i,t}^2 - h_{i,t}\ (i = 1,2)$, the preceding system [2] can be written as $y_t = c + By_{t-1} + A_1 v_t + A_2 v_{t-1}$, with:

a) $c = H^{-1}A$, where $H = \begin{bmatrix} 1 & -c_{21} \\ 0 & 1 \end{bmatrix}$ and $A = \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$, is the coefficient vector of constants in the GARCH(1,2) equation,

b) $B = H^{-1}B_1$, where $B_1 = \begin{bmatrix} (c_{11} + b_1) & 0 \\ c_{12} & (c_{22} + b_2) \end{bmatrix}$ is the coefficient matrix of y_{t-1}.

c) $A_1 = H^{-1}A_{11}$, where $A_{11} = \begin{bmatrix} 0 & c_{21} \\ 0 & 0 \end{bmatrix}$, is the coefficient matrix of v_t terms, and

d) $A_2 = H^{-1}A_{21}$, where $A_{21} = \begin{bmatrix} c_{11} & 0 \\ c_{12} & c_{22} \end{bmatrix}$, is the coefficient matrix of v_{t-1}.

Because this is analogous to the GARCH(1,2) model, the impulse response function to a one-unit shock of v_t can be derived easily by following the work of Engle *et al.* (1990). The s-step impulse response function of y_t to v_t is denoted as $R_{s,2}$, a 2x2 matrix. This is specified as $R_{0,2} = A_1$, $R_{1,2} = BA_1 + A_2$, and $R_{s,2} = BR_{s-1,2}$ for $s \geq 2$ as in Lin (1997).

Using the theorem defined in Lin (1997), we can obtain the asymptotic distribution of the impulse response function $R_{s,2}$. This has the following general form:

$T^{1/2}\left(vec\hat{R}_{s,2} - vecR^0_{s,2}\right) \sim N\left(0, G_{s,2}\Sigma_\theta G'_{s,2}\right)$, where Σ_θ is the variance and covariance matrix of the parameter vector $\theta = \begin{pmatrix} c_{11} & b_1 & c_{21} & c_{22} & b_2 & c_{12} \end{pmatrix}'$ of order 6x6, $G_{s,n}$ is the first-order analytical derivative of $R_{s,2}$ with respect to the parameter vector θ, which is a 4x6 matrix, and $G_{s,2}\Sigma_\theta G'_{s,2}$ is the asymptotic covariance matrix of order 4x4. The first-order derivatives are obtained recursively as: $G_{0,2} = A_{1\theta}$, where $A_{1\theta} = \nabla_{vec\theta} vecA_1 = \begin{bmatrix} I_4 & 0_{4x2} \end{bmatrix}$, with I_4 being an identity matrix of order 4x4 and 0_{4x2} a rectangular matrix of zeros of order 4x2. $G_{1,2} = (A_1 \otimes I_2)B_\theta + (I_2 \otimes B)A_{1\theta} + A_{2\theta}$, where $\otimes$ is the Kronecker product, I_2 is an identity matrix of order 2x2, $B_\theta = \nabla_{vec\theta} vecB = \begin{bmatrix} 0_{4,2} & I_4 \end{bmatrix}$, $A_{2\theta} = \nabla_{vec\theta} vecA_2 = \begin{bmatrix} 0_{4,2} & I_4 \end{bmatrix}$ and, finally, $G_{s,2} = (I_2 \otimes B)G_{s-1,2} + (R_{s-1,2} \otimes I_2)B_\theta$ for $s \geq 2$. A consistent estimator of the covariance matrix for the impulse response function can be derived in a two-step procedure. First, by obtaining the covariance matrix of the quasi maximum likelihood estimator (QMLE) robust to the non-normal density; and second, by computing the first derivatives of the impulse response function with respect to the parameters of interest evaluated at the QMLE. To estimate the corresponding standard errors, we replace the unknown quantities by the usual estimates of $\hat{R}_{s,2}$, $\hat{G}_{s,2}$ and $\hat{\Sigma}_\theta$. Thus, the square roots of the diagonal elements of $\frac{1}{T}\hat{G}_{s,2}\hat{\Sigma}_\theta\hat{G}'_{s,2}$, where T is the sample size, are estimates of the asymptotic standard errors of the elements of $\hat{R}_{s,2}$.

3. The data

The Japanese firms cross-listed on the New York Stock Exchange (NYSE) or on the Nasdaq Stock Exchange (Nasdaq) at the end of 2000 form our initial sample.[9] Our sample time period was from 12/12/96 to 31/12/2000. Four criteria were applied to eliminate some of the firms in order to work with significantly traded firms for which all the required data is available. Table 1 describes this initial sample and the criteria used to exclude firms. The first criterion is to rule out firms that are not listed on the Tokyo Stock Exchange (three firms). The second criterion concerns firms that started to have a US quotation during the sample time period (three firms). The third criterion is to exclude firms with over 10% of missing values in the opening or closing daily prices on the US, the Japanese or the European stock markets (eleven firms). Our empirical methodology is designed to work with open to close return, and so our main concern was to avoid little-traded firms with a high number of days without an opening or a closing transaction price. The European market requirement allows us to estimate the three markets model on the same sample of firms as the two markets model. We took the London Stock Exchange (LSE) as the European stock market, and whenever there was no listing on the LSE we took the Frankfurt Stock Exchange (FSE). Whenever a stock was listed in both markets we found fewer missing values in the LSE than in the FSE.[10] In our final sample, the European data was in fact from the LSE for all firms. The fourth criterion is to exclude the firms for which we could not obtain information on the geographical distribution of their business activity (one firm). After all these exclusions, twelve firms remained in our sample (see Table 1, Criteria I).

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[9] We obtained this list from the NYSE and the Nasdaq web sites The NYSE list was updated in October 2000, and Nasdaq list in September 2000.

[10] If we drop from the sample all the firms with a non-trading period longer than five consecutive trading days in any stock market (US, Japan or Europe), we obtain the same final samples of stocks. Furthermore, the periods of consecutive days without trading are longer in the FSE than in the LSE.

[Table 1]

The second step of our empirical analysis is aimed at determining whether there are different volatility dynamics in companies with business activity in both the US and the Japanese markets' time zone geographical areas (international firms) than in companies with business activity in just one market time zone geographical area (Japan) (non-international firms).

The Japan time zone area is taken to include Asia and the Pacific Ocean, while the US time zone area includes America, Africa and Europe. We include Africa and Europe in the New York time zone because New York opens at 14:30 and closes at 21:00 hours in London time. All the news released in Europe during this period of time will be reflected in New York quotes, and similarly with Africa. Also in London time, Tokyo opens at 00:00 and closes at 07:00 hours, so that in Europe and Africa there is a negligible proportion of daily business activity during the Tokyo trading period. The majority of daily business activity in Asia takes place during the Tokyo trading period. Australia, New Zealand and New Guinea are in the Tokyo time zone area, and represent most of the economic activity in the Pacific Ocean area.

To obtain the business geographical distribution of each firm, we used its financial statements for 1996 to 2000 as published on each company's Web site. The information used to classify the companies as international or non-international was the revenue distribution between the US and the Japan time zone geographical areas.[11] For each year we calculated the percentage of revenues in the time zone geographical area of the foreign market (US), took the mean of this percentage for each firm, and used this mean

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[11] We use the revenues distribution instead of the profits distribution since profits are subject to accounting rules, such as the amortization rules or the method of determining the cost of material used for inventory, that may distort the geographical distribution of each firm's business interest.

percentage as the indicator of real activity in the foreign market.[12] We call this measure FOREIGN. Table 2 describes the sample.

[Table 2]

For each stock, we calculated daily returns from the opening and closing transaction prices in the US, Japanese and European stock markets. Whenever there was no trading for a given stock in a given market, its missing closing price was replaced by the previous day's closing price, and whenever there was no opening price, the missing value was replaced by the previous day's closing price.[13] These returns were adjusted to take into account dividends and modifications to the structure of capital, such as splits.

In order to investigate whether there are differences in volatility dynamics for Japanese firms with significant business activity in the US geographical time zone, we need to compare similar stocks, and for this we take into account the systematic risk, the size of each stock and the volume traded in each market.

The systematic risk is measured with the beta of each stock in each market where it is quoted. We obtained closing prices of the S&P 500 index to calculate this measure in the US market, of the Nikkei 500 index for the Japanese market, and of the FTSE 100 index for the London market. Then we calculated the daily close-to-close log returns of each index and stock in each market.[14] The beta of each stock in each market is calculated from the regression of each stock return as the dependent variable and the index return as the explanatory variable.

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[12] For NEC and TDK we could obtain the revenues distribution between the US and the Japan time zone geographical areas just from 1997 to 2000. For Fuji Photo Film, Nissan Motor, and Toyota Motor for 1998 to 2000.

[13] An alternative treatment of missing observations could be to replace them by the previous price in the same market or in the previous market. For example, if the opening price in Europe is missing it could be replaced by the closing price in Tokyo. However in this way stock prices of one market are attributed to another market. This may distort the role of each market in the volatility process. In addition this treatment needs synchronized foreign exchange data with a time stamp equal to the opening and closing times in each stock exchange. This foreign exchange data was not available for this study.

[14] Whenever there is no trading for a given day the missing return is replaced by a zero return.

The size of each stock is measured as the market capitalization in US dollars. The market capitalization of each stock was obtained for each day in the sample and the mean value calculated.

With respect to the trading volume, we were only able to obtain data for the US and the Japanese markets, and calculated the percentage of traded volume in each one during our sample time period. All the stock market data (stock prices, index closings, market capitalization and volume) were obtained from Datastream.

Finally, as suggested by an anonymous referee, we checked whether our main conclusions remained unchanged for a bigger sample of firms and over a longer time series period. To do this, we added into the sample all the firms that were excluded solely due to a high percentage of missing values in the European market (Criteria II in Table 1; two firms added). Secondly, we relaxed the criterion on the percentage of missing values to 20% (Criteria III in Table 1; one firm added). We also expanded the sample time series period to 31/12/2003, and then implemented the same analysis. However, in the longer time series period, the Bank of Tokyo Mitsubishi was dropped due to a merger that took place in 2001, and Fuji Photo Film was excluded due to the non-availability in our database of its new market data from the Nasdaq stock market.

4. Empirical analysis

4.1. Meteor Showers or Heat Waves

In order to test the Meteor Showers hypothesis in cross-listed stocks, we implemented the above-described methodology on an equally weighted portfolio with the 12 Japanese stocks that constituted our sample (Total Portfolio). Table 3 shows the estimated VAR-GARCH models with their corresponding likelihood ratio tests of the

Meteor Shower hypothesis and of the Meteor Shower with World Wide News hypothesis.[15] The estimated VAR-GARCH models contain two dummy variables in each equation of the model [1] that are included in order to take into account some anomalous observations. For example, the first dummy variable of the first equation takes a value 1 for US returns that exceed the mean of US returns by more than four times its standard deviation. The second dummy variable does the same for US returns lower than the mean of US returns by more that four times its standard deviation. For reasons of space, we do not report summary statistics or the diagnostic tests of the estimated models, but these are available on request. In Table 3, the first column presents the results of the Total Portfolio, showing that there is transmission in the mean and in the variance from the Japanese to the US market. Furthermore, the likelihood ratio tests show that the Meteor Shower model with Country Specific News is the most appropriate model, as is the case for foreign exchange in Engle *et al.* (1990). This means that the effect of a volatility shock in the US market is not equal to the effect of one in the Japanese market; thus, the origin of shocks is relevant. The nulls of Heat Waves (no transmission) and of Meteor Showers with World Wide News are rejected.

[Table 3]

Figure 1 shows the impulse response functions for the conditional volatility of this portfolio and their confidence intervals, at the 95% significance level, as described in Section 2. We want to detect only the significant volatility dynamics. Therefore, the impulse response functions presented in this paper are calculated assuming that the non-significant coefficients of the VAR-GARCH models, at the 10% level, are zero. In Figure 1, for example, the graph entitled USA-USA represents the impulse response

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[15] For the Meteor Showers hypothesis we test whether transmission parameters in volatility are statistically significant (Meteor Showers I in table 3), and whether both types of transmission parameters, in volatility and in mean, are statistically significant (Meteor Showers II in table 3).

function of US volatility shocks on posterior volatility in the US market. The graph entitled JAP-USA represents the impulse response function for Japanese volatility shocks on posterior US volatility. Figure 1 only reflects significant volatility transmission from Japan to the US. This is consistent with the findings in the literature that the home market is the principal generator of information (e.g. Chan *et al.*, 1996; Menkveld *et al.*, 2003; Eun and Jang, 1997; Ely and Salehizadeh, 2001; Hauser *et al.*, 1998).

[Figure 1]

The analysis was then repeated including the European market. The first column of Table A1 in the Appendix contains the estimated model for the Total Portfolio and the corresponding likelihood ratio tests. These tests confirm that the Meteor Shower model with Country Specific News is the most appropriate model. Figure A1 in the Appendix presents the impulse response functions for the Total Portfolio. The results are consistent with Japan being the main news generator. There is transmission from Japan to the other markets but there is no transmission to Japan. Thus we see that adding in the European market does not change the results found with the two markets model.

4.2. The effect of international exposure

In order to detect the effect of international exposure on volatility transmission dynamics, we analyzed two equally weighted portfolios, one of which was termed the International Portfolio (IP) and contained international firms, while the other was called the Non-International Portfolio (NIP) and contained the non-international firms. We calculated the median value of FOREIGN across the firms and classified as international all firms with a FOREIGN value higher than the median. The characteristics of the IP and the NIP are presented in Table 4 (Criteria I, Case 1) and represent Case 1 in our analysis.

[Table 4]

In this table we see that the mean market capitalization of the IP almost doubles that of the NIP. The systematic risk measures, as well as the trading volume in the US and the Japanese markets, are similar in both portfolios. Therefore, in order to standardise the size of the two portfolios, the biggest stock in the IP (Toyota) is excluded from the sample. The characteristics of the new IP and NIP portfolios are described in Table 4 (Criteria I, Case 2), and represent Case 2 of our analysis. In this case, the NIP is the same as in Case 1 and the measures of systematic risk and trading volume remain similar in the two portfolios.[16]

In both cases, we implement the empirical analysis presented in Section 2. The estimated VAR-GARCH models and the Meteor Shower tests are presented in Table 3, columns 2-4. The likelihood ratio tests again suggest that Meteor Showers with Country Specific News is the most appropriate characterization of the volatility dynamics process. In Case 1 (with Toyota), comparison of the second column (NIP) with the third column (IP) in Table 3 shows that there is statistically significant transmission in the mean and the variance from Japan to the US in both portfolios. Furthermore, the transmission coefficients are higher for the IP. Transmission from the US to Japan is significant only for the NIP. When Toyota is excluded from the sample (column 2, NIP, and column 4, IP) this finding remains unchanged. These results are consistent with a higher contribution of US investors to the price discovery process of international Japanese firms. It is also consistent with a news-correlated process related to the firms' business activity, where news releases in Japan cause posterior news releases in the US.

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[16] Although the percentage of traded shares in the US is higher for the IP in both cases, it is small and reflects the predominant role of the Japanese market for the IP and for the NIP.

Regarding the transmission from the US to Japan, the evidence is consistent with Japanese investors trading on previously released news in the US (as found by Chan *et al.*, 1996 for US investors). This is more intense for the non-international Japanese firms, those with a higher percentage of business interest in the Japanese time zone. It is also consistent with news released in the US causing posterior news releases in Japan. However, since the firms' headquarters are in Japan this explanation does not seem realistic. For international firms, there could be news generated in the US, related to the firms' business there, causing a reaction from the headquarters in Japan and then volatility transmission from the US to Japan. However, transmission to Japan is only observed for non-international firms.

In order to obtain a deeper understanding of the dynamic processes of information incorporation into prices, we calculated the impulse response functions in volatility and their confidence intervals, at the 95% significance level. These functions are presented in Figure 2 for Case 1, and in Figure 3 for Case 2. In these figures, each graph shows the impulse response function and its confidence intervals for the IP and for the NIP. The continuous line represents the impulse response function for the IP, and the continuous line with small circles the corresponding function for the NIP. The confidence intervals of the impulse response functions are represented by non-continuous lines; dots for the IP, and long dashes for the NIP. The confidence intervals delimit the range of the true impulse response function with a probability of 95% under the assumed probability distribution. Therefore, in order to interpret the results in Figures 2 and 3, we consider that the impulse response function takes a higher value in one portfolio than in the other when the full confidence interval for the first portfolio is higher than that for the second. When the confidence intervals of both portfolios share some values, we adopt a conservative interpretation of equality.

[Figures 2 and 3]

Figures 2 and 3 show the same results, which are also consistent with the results found in Table 3. Regarding the US market volatility, Japanese and US volatility shocks have a higher initial impact for the IP than for the NIP, although there is greater subsequent persistence in the NIP. The effect of US shocks seems to reinforce the idea that the US market contribution to the price discovery is higher for Japanese international firms. On Japanese volatility, US shocks have a higher impact on the NIP. Regarding the effect of Japanese shocks on posterior Japanese volatility, the confidence intervals are initially overlapping for both portfolios, but after some periods the NIP interval is higher than that of the IP and reveals a greater degree of persistence. The longer persistence of volatility shocks on the NIP detected in the four impulse response functions is a surprising result. For these firms, there seems to be a longer period of disagreement among traders on the interpretation of the effect of news releases on stock prices.

Regarding the analysis with the three markets model, the estimated models for Cases 1 and 2 are described in Table A1 in the Appendix. The impulse response functions in volatility are also given in the Appendix, in Figures A2 and A3. Table A1 gives the same results as does Table 3 except for the non-significant transmission from the US to Japan in the NIP. There is transmission from Japan to the US, and the transmission coefficients are higher for the IP than for the NIP in the mean and in the variance. The results regarding the effects on posterior US volatility shown in Figures 2 and 3 are maintained in Figures A2 and A3. Japanese and US volatility shocks have a higher initial impact on posterior US volatility for the IP, and there is greater persistence for the NIP. The main difference between the two and three markets models is found in the effects on posterior Japanese volatility, namely the non-significant transmission from the US to the Japan for the NIP. Regarding the European market, the clearly higher transmission to the US market for the IP is consistent with the higher transmission from Japan to the US for this portfolio. This, too, may be consistent with our two hypotheses, namely a higher US contribution to the price discovery process for international Japanese firms, and a news correlated process related to the firms' business activity.[17] Regarding the effects on European volatility, we detect similar effects in the two portfolios. This suggests the differences between international and non-international firms are irrelevant in this context.[18]

In the next sub-section, we investigate whether these results are robust when more firms are included in the sample and when the analysis is implemented on a longer time series sample.

4.3. Robustness analysis

4.3.1. A larger sample of stocks

In order to add firms into the sample, we relaxed the criterion on the percentage of missing transaction prices. However, as shown in Table 1, when a firm is excluded because of a high percentage of missing observations in the European market, the lowest percentage is 51%. Furthermore, when the percentage of missing observations in Europe is reasonable, there is another criterion that impedes the inclusion of the firm in the sample (e.g., the case of Japan Airlines, for which we have no data on the business

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[17] However, since the firm's headquarters are in Japan the news-correlated process seems less realistic.

[18] Japanese shocks have a slightly higher effect on the European posterior volatility for the NIP. Although the difference is small, is inconsistent with our two hypotheses. The slightly higher initial effect of European shocks on posterior European volatility for the IP is consistent with a higher contribution of European traders to the price discovery process of international Japanese firms, like US traders. However, the slightly higher effect of US volatility shocks on posterior European volatility for the NIP is inconsistent with this behaviour.

geographical distribution). Therefore, we could not increase the number of firms in the three markets model. In consequence, only the two markets model was used to test the robustness of our results to the inclusion of more firms in the sample. To do so, we first included in the sample all the firms that were initially dropped due to a high percentage of missing opening or closing prices in the European market (Bank of Tokyo-Mitsubishi and Matsushita Electric Industrial). In a second step, we relaxed the criterion on the percentage of missing opening or closing prices up to 20% (adding Makita). By this procedure, we implemented the two markets model on two more samples of firms. Table 4, Criteria II and III respectively, describes the characteristics of the IP and NIP constructed in these samples of stocks. Given that the values for Toyota distorted the mean market capitalization of the IP in both cases, we repeated the analysis without Toyota (Case 2). The results of these analyses are presented in Table 3. However, in order to save space, and given that the results of Case 1 (with Toyota) and Case 2 (without Toyota) are almost the same, only the results for Case 1 are presented. Table 3 shows that the empirical evidence found with the two markets model does not change when more firms are included in the sample. The impulse response functions are almost identical to those presented in Figures 1, 2 and 3 and for reasons of space are not presented, although they are available from the authors on request.

4.3.2. A longer time series sample

Subsequently, the time series sample was extended to 31/12/2003, and the two and three markets models were again implemented, for this longer time series sample. However, as described in the data section, some of the previously analyzed firms could not be included in the latter analysis. The sample of stocks constructed with Criteria I is composed of the same 12 firms (Table 4, panel B) except Fuji Photo Film, which is deleted from the NIP, the IP remaining unchanged. Under Criteria II and III, the samples of stocks are as in Table 4, panel B except for two firms; the IP firms are as in this table except Bank of Tokyo Mitsubishi, and the NIP are unchanged except for Fuji Photo Film.[19] The characteristics of the new IP and NIP are not reported, as they are similar to those presented in Table 4, Panel A. Toyota is the firm that varies most in market capitalization and we repeated the analysis with and without Toyota (Cases 1 and 2, respectively).

Table 5 shows the estimations of the two markets model for the total portfolio, the NIP, and the IP under Criteria I, II, and III. Again, dropping Toyota does not produce a significant impact on the results, and so only the results for Case 1 are shown. For the total portfolio, results on volatility transmission are as in the shorter time series period. Regarding the IP and the NIP, the results for the shorter time series period remain unchanged except for the effect of Japanese volatility shocks on posterior Japanese and US volatility. The effect on US volatility is non-significant for the IP, except under Criteria III. The effect on Japanese volatility becomes significant for both portfolios.

[Table 5]

The impulse response functions (Figures 4 and 5) confirm these results. For reasons of space, this paper only shows the impulse response functions for the total portfolio, the IP and NIP in Case 1 under Criteria I. These functions produce similar results under Criteria II and III, in Case 2 and in Case 1, respectively. The impulse response functions in the expanded time series sample are similar to those in the shorter time series sample except for the non-significant transmission from Japan to the US in the IP, and the

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[19] In order to evaluate the comparability of results in the longer and in the shorter time series samples, we repeated the two and three markets models analysis with the sample of stocks constructed under Criteria I less Fuji Photo Film in the shorter time series sample. We find that the results found in the previous section are maintained without this stock. These results are available upon request.

significant effect of Japanese volatility shocks on posterior Japanese volatility. The difference most relevant to our hypotheses on the effects of international exposure is the non-significant transmission from Japan to the US in the IP. Only under Criteria III do the IP present a higher transmission from Japan to the US than do the NIP. This may imply a structural change in the behaviour of US investors or in the news-correlated process. It may also imply that US traders' behaviour in trading Japanese firms on receiving previously released public information in Japan, and the news-correlated process, are unrelated to the Japanese firms' international exposure.

[Figures 4 and 5]

The three markets model estimations (Table A1 columns 5-7) again show the non-significant direct transmission from Japan to the US for the IP. However, there is significant transmission through Europe. Figure A5 presents the impulse response functions for the three markets model in the sample constructed with Criteria I, Case 1 (Case 2, without Toyota, is almost the same). The impulse response functions relating US and Japanese volatility, and the effect of US (Japanese) volatility on posterior US (Japanese) volatility show similar results to those shown in Figure 5 for the two markets model. The difference is that although the impulse response function from Japan to the US is higher for the NIP, the confidence intervals partially overlap and it is not as evident that there is higher transmission for the NIP. Furthermore, the IP and the NIP present clearly different results regarding the European market. These differences are consistent with our two hypotheses on the relevance of firms' international exposure. The most important finding from this is the higher effect of Japanese volatility shocks on posterior European volatility for the IP. This is consistent with European traders' trading on public information previously released in Japan being more intense for Japanese firms with higher business activity in the US time zone (which includes

Europe and Africa). This is also consistent with the news-correlated process hypothesis, that news generated in Japan causes posterior news releases in the US time zone for international Japanese firms (even if they are then incorporated into prices in the European market). Except for the transmission from Japan to Europe, the European market presents results that are analogous to those of the US market. The impact from Europe and the US to Japan is higher for the non-international firms. Between Europe and the US (Europe to US, Europe to Europe, US to Europe, and US to US) there is always a higher initial impact for the international firms. This suggests a higher contribution to the price discovery process of international Japanese firms by European and US traders.

Regarding volatility transmission, we found notable differences between the volatility dynamics of international and non-international Japanese firms. Our evidence suggests that there is higher volatility transmission from the Japanese time zone to the US time zone for international firms (the US or the European markets). In the shorter time series sample, this higher transmission is detected from Japan to the US, in the expanded time series sample to Europe. We also obtained some weaker evidence (it is not detected in the three markets model for the shorter time series sample) of higher transmission from the US time zone (US and Europe) to Japan for the non-international firms.

5. Conclusions

In this paper we have analyzed the volatility dynamics of cross-listed Japanese stocks around the world during the 24-hour-day period. In a first step we reproduced the analysis in Engle *et al.* (1990) and found empirical evidence suggesting that volatility dynamics on these stocks may be characterized as a Meteor Shower with Country Specific News, as the above authors found for the foreign exchange market. Therefore, news released in Japan seems to have a different effect on posterior volatility than does news released in the US. In the second step, we sought possible differences in the volatility dynamics of cross-listed Japanese firms with significant business activity in the US time zone geographical area. On the foreign exchange market, Engle *et al.* (1990) suggested that volatility transmission may be due to market dynamics, to the data generating process, or to failures of market efficiency. These explanations are also appropriate for cross-listed stocks, but in this case our hypothesis is that market dynamics and the data generating process may cause different volatility dynamics for Japanese firms with significant business activity in the US market time zone geographical area. Specifically: (i) the behaviour of US investors detected in Chan *et al.* (1996), trading foreign stocks on public information previously released in the domestic market, could be reinforced on Japanese firms with significant business activity in the US time zone geographical area; (ii) the data-generating process may be different for these firms. Business related news released in Japan might cause posterior news releases in the US time zone, thus causing volatility transmission.

Our empirical evidence documents higher volatility transmission from Japan to the foreign markets for Japanese firms with significant business activity in the foreign markets' time zone geographical area. This evidence is consistent with our hypotheses on market dynamics and the data-generating process.

Furthermore, we also found weaker empirical evidence of higher transmission from the foreign markets to Japan for Japanese firms with fewer business interests in these markets' time zone geographical area. This is consistent with Japanese traders' trading on public information previously released in the foreign markets to be more intense for these firms. In this case, the news-correlated process seems less realistic given that these firms' headquarters are in Japan.

Finally, it is worth mentioning that our evidence suggests that for non-international Japanese firms there is a greater persistence in the effect of volatility shocks. This is consistent with a longer persistence in the degree of disagreement on the interpretation of news releases between traders.

The empirical evidence presented in this paper complements that given in Chan *et al.* (2003), suggesting that the geographical distribution of business, as well as the location of trade, is relevant to the price fluctuations that may occur.

Appendix

Table A1. Three markets models

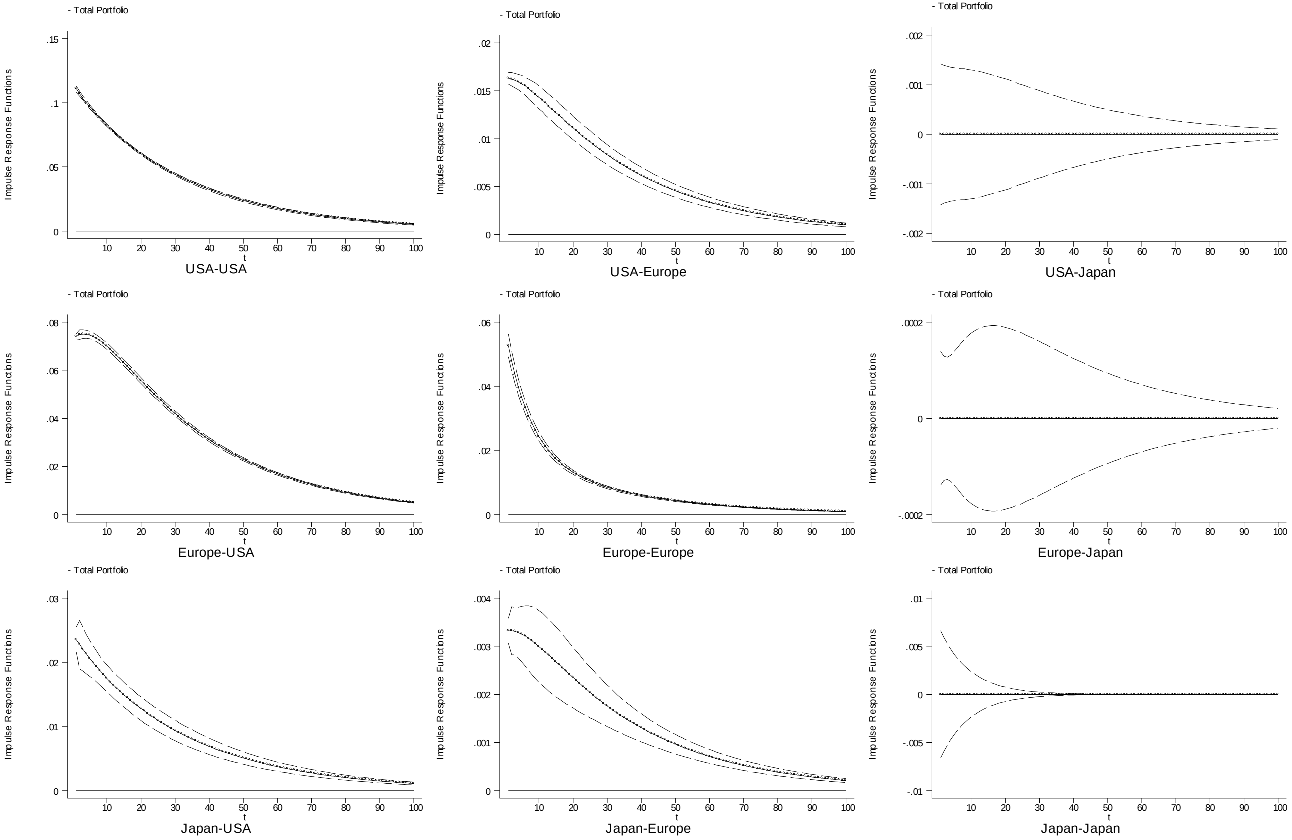
This table presents the results of the three markets models for the total portfolio, the NIP and the IP in the shorter time series sample and in the extended time series sample. For the extended time series sample we only present the results of Case 1 (including Toyota) since there are no significant differences between this and Case 2 (without Toyota), as is shown in the shorter time series sample analysis. Since there are two hours of overlapped trading between the US and the European markets, the European return is orthogonalized. This is done by replacing the European return by the error term in a regression model where the European return is the dependent variable and the US return is the explanatory variable.

		12/12/1996-31/12/2000				**12/12/1996-31/12/2003**		
		Total Portfolio	**NIP**	**IP Case 1**	**IP Case 2**	**Total Portfolio**	**NIP**	**IP Case 1**
USA Mean	Constant	0.00099 [a]	0.00128 [a]	0.00057 [c]	0.00063 [b]	0.00079 [a]	0.00121 [a]	0.00050 [b]
	$R_{2,t}$	0.14550 [b]	0.05640	0.24310 [a]	0.24260 [a]	0.14020 [a]	0.02710	0.25890 [a]
	$R_{3,t}$	0.17770 [a]	0.12280 [a]	0.15660 [a]	0.21800 [a]	0.13220 [a]	0.05250	0.07210 [b]
	$R_{1,t-1}$	0.03640	0.02950	0.01120	0.00938	0.03950	0.03270	0.03560
	$R_{2,t-1}$	0.02260	0.06460	-0.01860	-0.01650	0.05480	0.01570	0.03470
	$R_{3,t-1}$	-0.00817	-0.02890 [c]	-0.02440	-0.02080	-0.01550	-0.01240	-0.03670 [b]
	$R_{1,t-2}$	0.01880	0.01920	0.00501	0.00530	0.01070	-0.02350	-0.00117
	D_{11}	0.12610 [a]	0.02710 [a]	0.28140 [a]	0.33650 [a]	0.09710 [a]	0.03420 [a]	0.21040 [a]
	D_{12}	-0.01370 [a]	-0.03030 [a]	0.00000	0.22200	0.00396 [b]	-0.03370 [a]	-0.09880 [a]
Europe Mean	Constant	0.00011	0.00007	0.00011	0.00011	-0.00012	0.00004	-0.00031 [a]
	$R_{3,t}$	0.04890 [b]	-0.04430	0.01870	0.01620	-0.04870 [a]	-0.03560 [b]	-0.07990 [a]
	$R_{1,t-1}$	0.01000	0.06890 [a]	0.00311	0.00194	0.03850 [a]	0.05350 [a]	0.02550
	$R_{2,t-1}$	0.04100	0.01650	0.05110 [c]	0.05950 [b]	0.02960	0.01300	0.08270 [a]
	$R_{3,t-1}$	-0.00687	-0.00423	-0.00578	-0.00554	-0.01460 [a]	-0.00309	-0.02270 [a]
	$R_{1,t-2}$	-0.03080	-0.03690 [b]	-0.01310	-0.01140	-0.01400	-0.01030	-0.01400
	$R_{2,t-2}$	0.02770	-0.00243	0.02190	0.01190	0.00914	-0.01260	-0.06540 [a]
	D_{21}	0.02340 [a]	0.02460 [a]	0.02800 [a]	0.02790 [a]	0.03310 [a]	0.02840 [a]	0.04630 [a]
	D_{22}	-0.02510 [a]	-0.02580 [a]	-0.02580 [a]	-0.02750 [a]	-0.02300 [a]	-0.02630 [a]	-0.03080 [a]
Japan Mean	Constant	-0.00046	-0.00024	-0.00047	-0.00048	-0.00067 [a]	-0.00042	0.00016 [a]
	$R_{1,t-1}$	-0.00695	0.04480	0.00134	0.00347	-0.04510	-0.04330	-0.01510
	$R_{2,t-1}$	-0.04870	-0.01290	-0.04230	0.01990	0.09500 [b]	0.01740	0.08980 [b]
	$R_{3,t-1}$	-0.07400 [a]	-0.06880 [b]	-0.05870 [b]	-0.06050 [b]	-0.04800 [b]	-0.00473	-0.04430 [b]
	$R_{1,t-2}$	-0.01720	-0.04380	-0.00220	-0.00196	0.00840	0.01190	-0.01280
	$R_{2,t-2}$	-0.11800 [b]	-0.13770 [c]	-0.11290 [b]	-0.08450	-0.08660 [b]	-0.09770 [c]	-0.06180 [b]
	$R_{3,t-2}$	0.02320	0.00245	0.02640	0.04440	0.01700	-0.00182	0.01920
	D_{31}	0.03250 [a]	0.03710 [b]	0.04370 [a]	0.03980 [b]	0.04900 [a]	0.05560 [a]	0.04710 [a]
	D_{32}	-0.04030 [a]	-0.04150 [a]	-0.04410 [a]	-0.04460 [a]	-0.03820 [b]	-0.05290 [a]	-0.04130 [a]
USA Variance	Constant	0.00000 [a]	0.00000	0.00000 [b]	0.00001 [b]	0.00000 [a]	0.00000 [c]	0.00006 [a]
	$h_{1,t-1}$	0.84680 [a]	0.91500 [a]	0.70720 [a]	0.71213 [a]	0.83460 [a]	0.89620 [a]	-0.03890
	$e_{1,t-1}^2$	0.10930 [a]	0.06120 [a]	0.10700 [a]	0.10142 [a]	0.08670 [a]	0.06010 [a]	0.14300 [a]
	$e_{2,t}^2$	0.07410 [b]	0.04040 [b]	0.10690 [b]	0.09287 [c]	0.09090 [a]	0.04860 [b]	0.52080 [a]
	$e_{3,t}^2$	0.02330 [a]	0.00464	0.04530 [a]	0.04439 [a]	0.03880 [a]	0.01480 [a]	-0.00958
Europe Variance	Constant	0.00000 [a]	0.00000	0.00000	0.00000	0.00001 [a]	0.00000 [a]	0.00001 [a]
	$h_{2,t-1}$	0.83270 [a]	0.79330 [a]	0.79360 [a]	0.77144 [a]	0.04050	0.86980 [a]	0.20170 [a]
	$e_{1,t-1}^2$	0.01630 [a]	0.02910 [a]	0.02030 [a]	0.02207 [a]	0.03250 [a]	0.01330 [a]	0.04070 [a]
	$e_{2,t-1}^2$	0.05150 [a]	0.07030 [a]	0.09110 [a]	0.08654 [a]	0.28300 [a]	0.05810 [a]	0.57270 [a]
	$e_{3,t}^2$	0.00332 [a]	0.01110 [a]	0.00860 [a]	0.00699 [a]	0.01350 [a]	0.00183 [b]	0.01160 [a]
Japan Variance	Constant	0.00001	0.00000	0.00001	0.00001 [c]	0.00001 [b]	0.00000 [b]	0.00001 [b]
	$h_{3,t-1}$	0.89170 [a]	0.96160 [a]	0.90610 [a]	0.90857 [a]	0.89860 [a]	0.93000 [a]	0.92550 [a]
	$e_{1,t-1}^2$	-0.00295	0.02200	0.02080	0.02041	0.00947	0.01810 [b]	0.00502
	$e_{2,t-1}^2$	0.06710	0.06140	0.02760	0.02267	0.00340	0.15460 [a]	-0.00339
	$e_{3,t-1}^2$	0.02810	-0.00264	0.01200	0.02240	0.03110 [a]	0.02910 [a]	0.03230 [a]
Correlation	ρ_{12}	0.03650	-0.13700 [a]	0.02460	0.03416	-0.00588	-0.00865	-0.02210
	ρ_{13}	-0.07350	-0.01560	-0.01660	-0.07461	0.03490	0.14400	0.11830
	ρ_{23}	-0.20560 [c]	0.02790	-0.12950	-0.11461	0.10730 [c]	0.05370	0.14120
Log L		14395.59	14489.01	13967.11	13768.91	24356.30	24173.15	23578.05
Meteor Showers (I)[1]		281.20 [a]	696.84 [a]	1063.77 [a]	998.98 [a]	167.98 [a]	184.49 [a]	432.83 [a]
Meteor Showers (II)[2]		114.76 [a]	1090.78 [a]	1298.81 [a]	1258.74 [a]	542.51 [a]	204.85 [a]	634.69 [a]
World Wide News[3]		2681.74 [a]	1658.84 [a]	819.15 [a]	5032.26 [a]	849.44 [a]	2863.51 [a]	3939.69 [a]

- See Table 3.

Figure A1: Total Portfolio

For an equally weighted portfolio composed of the 12 stocks in the sample, the graph entitled USA-USA represents the impulse response function in the variance of US volatility shocks on posterior US volatility. The graph entitled USA-Japan represents the impulse response function in the variance of US volatility shocks on posterior Japanese volatility. In each graph the continuous line with small circles represents the impulse response function in variance, and the non-continuous lines represent the upper and lower bounds of the confidence intervals for this function. Under the assumed probability distribution, the true value of the impulse response function in variance is in the confidence interval with a probability of 95%.



USA-USA

USA-Europe

USA-Japan

Europe-USA

Europe-Europe

Europe-Japan

Japan-USA

Japan-Europe

Japan-Japan

Figure A2: Case 1 (with Toyota)

The graph entitled USA-USA represents the impulse response functions in the variance of US volatility shocks on the posterior US volatility. The graph entitled USA-Japan represents the impulse response functions in the variance of US volatility shocks on the posterior Japanese volatility. In each graph the continuous line represent the impulse response function in the variance for the IP, and the continuous line with small circles, that for the NIP. The non-continuous lines represent the upper and lower bounds of the confidence intervals for these impulse response functions, with small dots for the IP and long dashes for the NIP. Under the assumed probability distribution, the true value of the impulse response function in the variance is in the confidence interval with a probability of 95%.

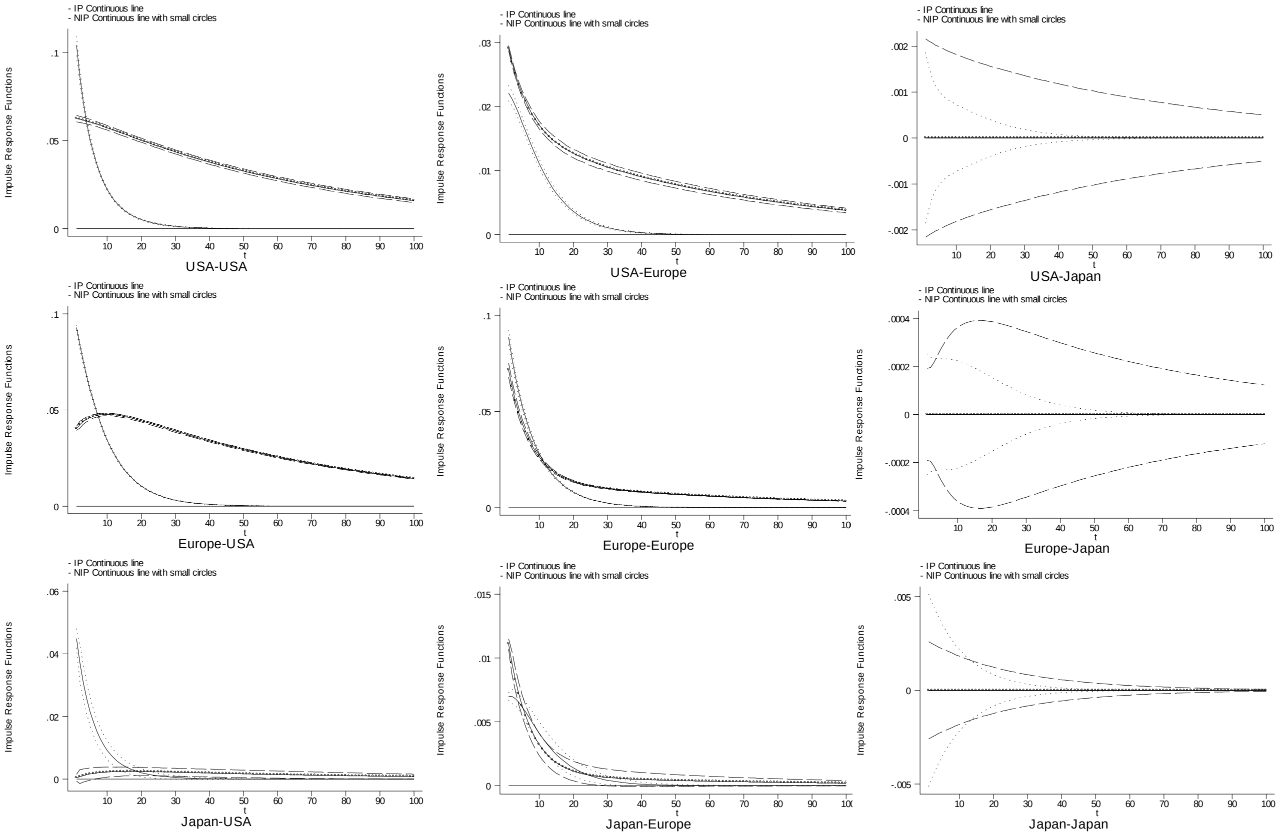


Figure A3: Case 2 (without Toyota)

The graph entitled USA-USA represents the impulse response functions in the variance of US volatility shocks on posterior US volatility. The graph entitled USA-Japan represents the impulse response functions in the variance of US volatility shocks on posterior Japanese volatility. In each graph the continuous line represent the impulse response function in the variance for the IP, and the continuous line with small circles, that for the NIP. The non-continuous lines represent the upper and lower bounds of the confidence intervals for these impulse response functions, with small dots for the IP and long dashes for the NIP. Under the assumed probability distribution, the true value of the impulse response function in the variance is in the confidence interval with a probability of 95%.

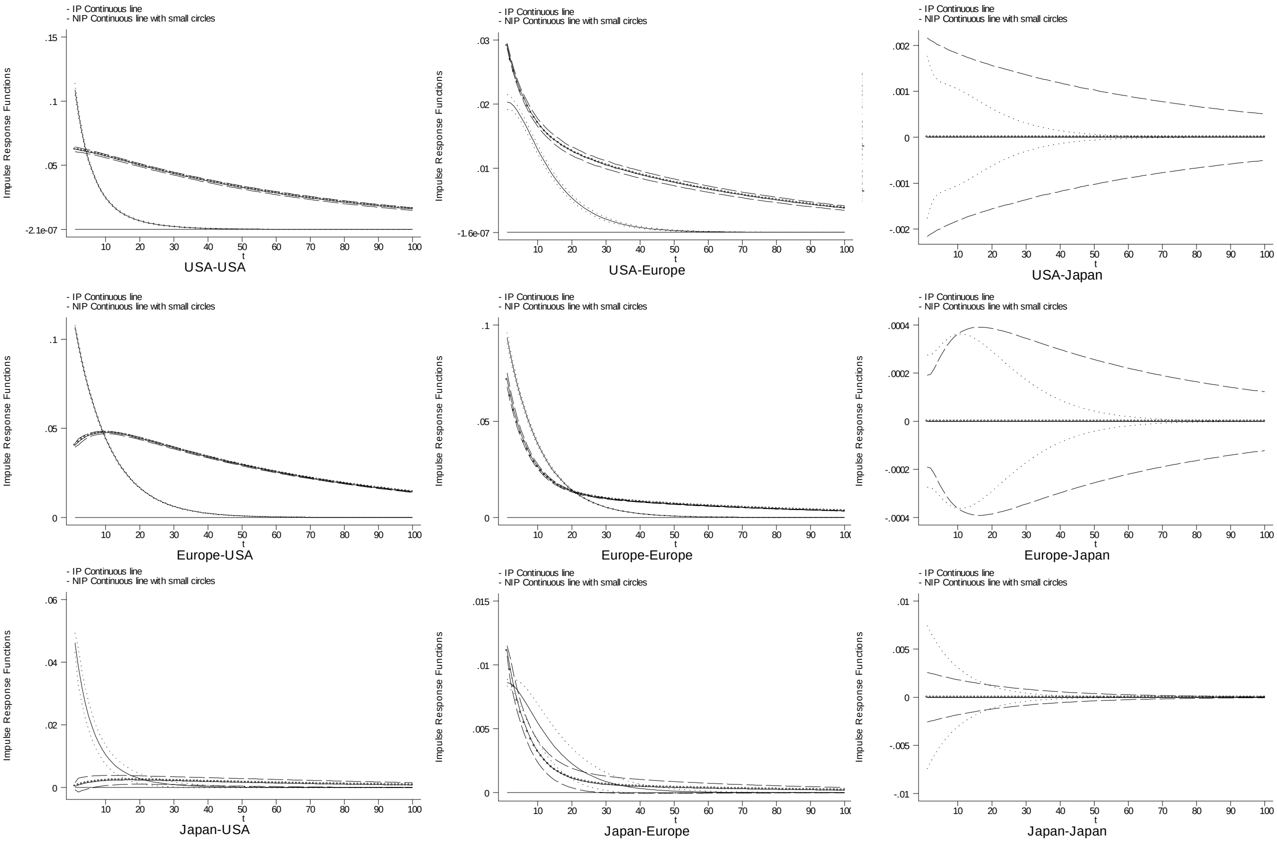


Figure A4: Total Portfolio: Extended time series sample

For an equally weighted portfolio composed of the 11 stocks in the sample, the graph entitled USA-USA represents the impulse response function in the variance of US volatility shocks on posterior US volatility. The graph entitled USA-Japan represents the impulse response function in the variance of US volatility shocks on posterior Japanese volatility. In each graph the continuous line with small circles represents the impulse response function in the variance, and the non-continuous lines represent the upper and lower bounds of the confidence intervals for this function. Under the assumed probability distribution, the true value of the impulse response function in the variance is in the confidence interval with a probability of 95%.

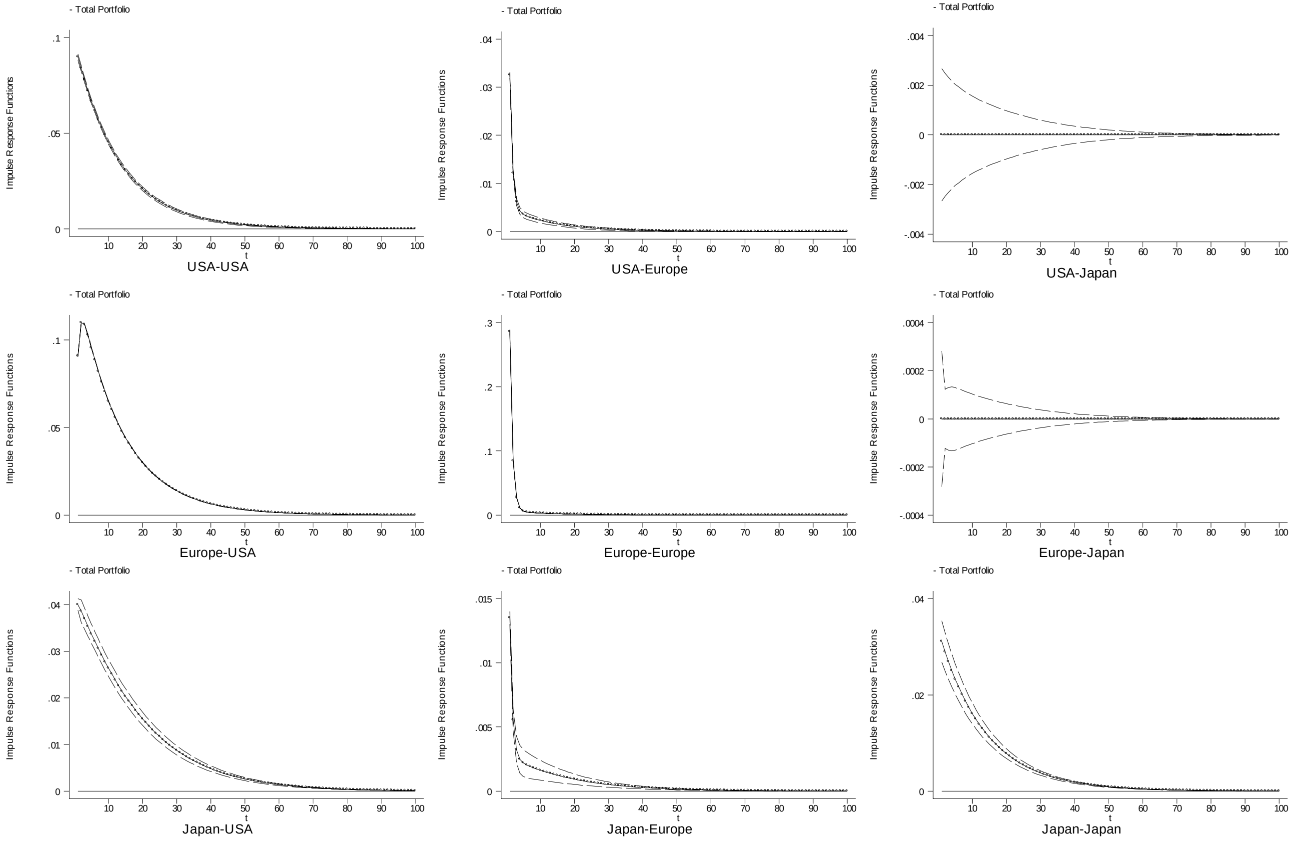
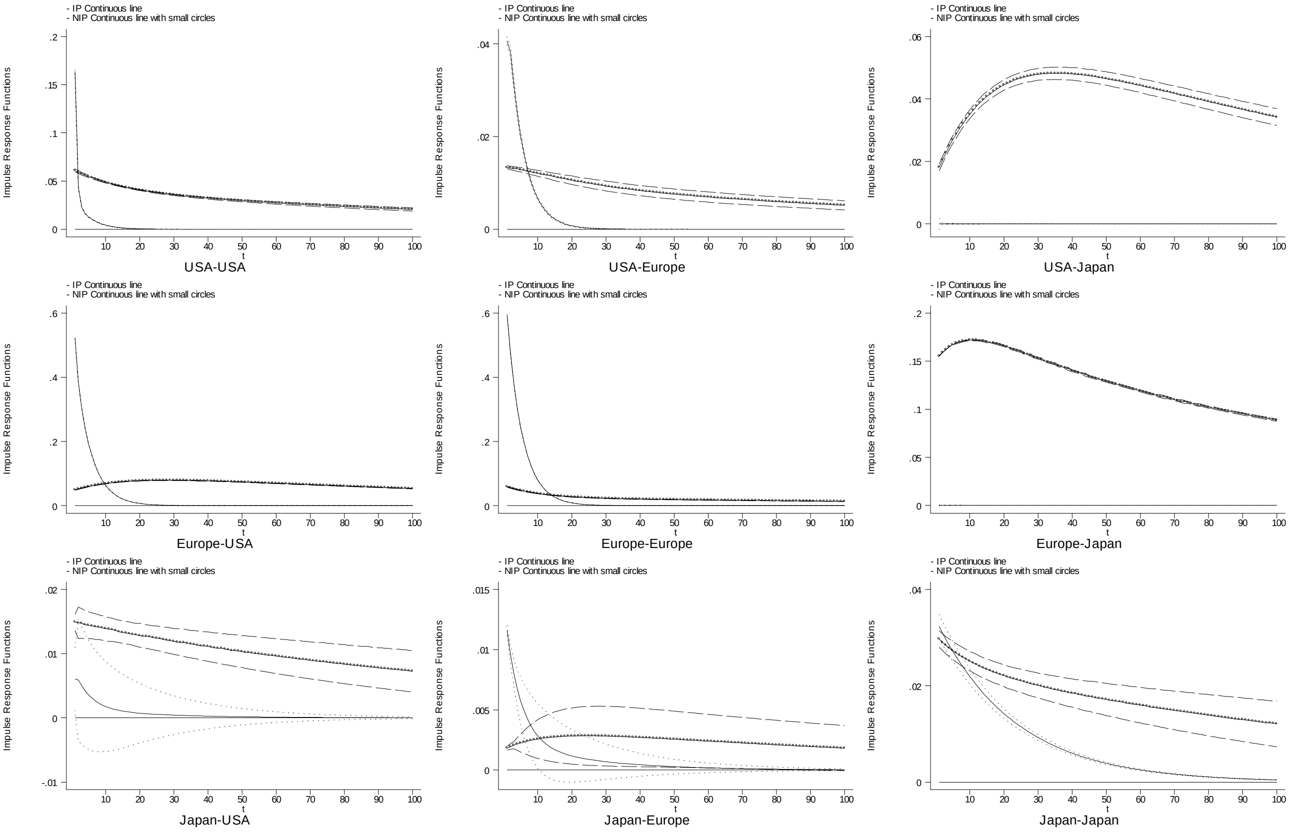


Figure A5: Case 1 (with Toyota): Extended time series sample

The graph entitled USA-USA represents the impulse response functions in the variance of US volatility shocks on posterior US volatility. The graph entitled USA-Japan represents the impulse response functions in the variance of US volatility shocks on posterior Japanese volatility. In each graph the continuous line represents the impulse response function in the variance for the IP, and the continuous line with small circles, that for the NIP. The non-continuous lines represent the upper and lower bounds of the confidence intervals for these impulse response functions, with small dots for the IP and long dashes for the NIP. Under the assumed probability distribution, the true value of the impulse response function in the variance is in the confidence interval with a probability of 95%.



USA-USA

USA-Europe

USA-Japan

Europe-USA

Europe-Europe

Europe-Japan

Japan-USA

Japan-Europe

Japan-Japan

Acknowledgements

The authors are grateful to an anonymous referee and to the participants in the "XXX Simposio de Análisis Económico" (Murcia, Spain) for helpful comments. The authors are also grateful for the financial support of DGICYT (Spain) projects SEJ2004-07530-C04-04/ECON and BEC2001-3777. All errors are the authors' responsibility.

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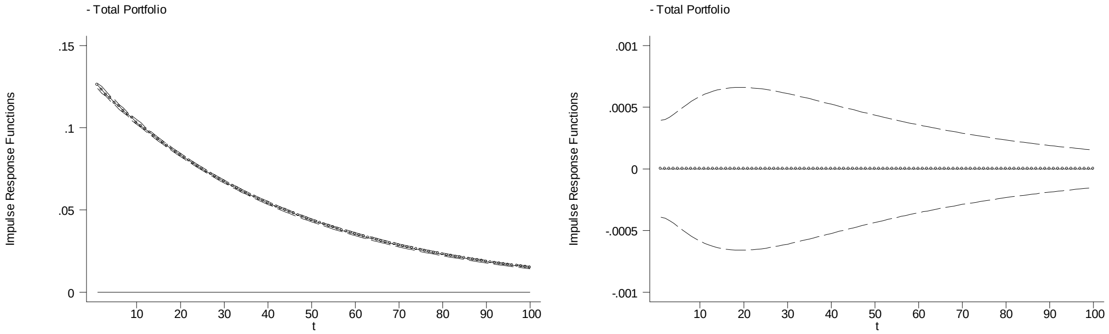
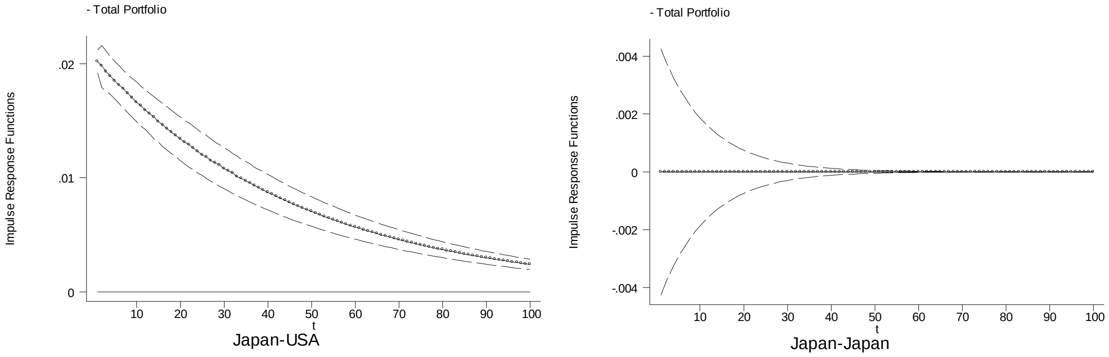
Figure 1: Total Portfolio

For an equally weighted portfolio composed of the 12 stocks in the sample, the graph entitled USA-USA represents the impulse response function in the variance of US volatility shocks on posterior US volatility. The graph entitled USA-Japan represents the impulse response function in the variance of US volatility shocks on posterior Japanese volatility. In each graph the continuous line with small circles represents the impulse response function in the variance, and the non-continuous lines represent the upper and lower bounds of the confidence intervals for this function. Under the assumed probability distribution, the true value of the impulse response function in the variance is in the confidence interval with a probability of 95%.



USA-USA

USA-Japan

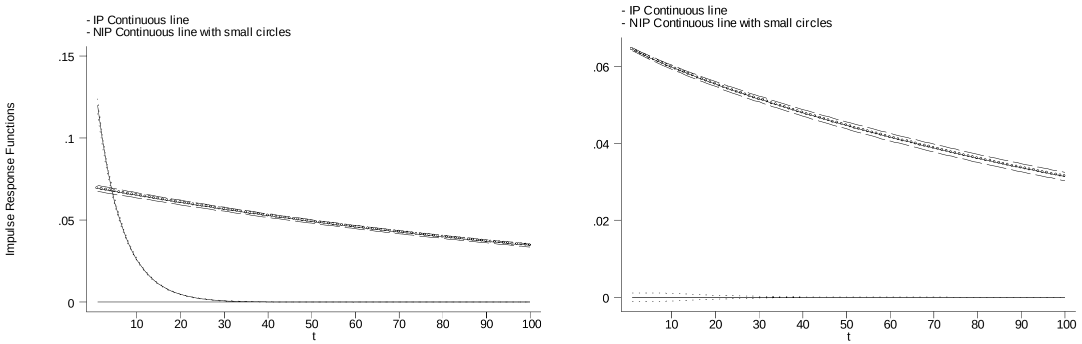


Japan-USA

Japan-Japan

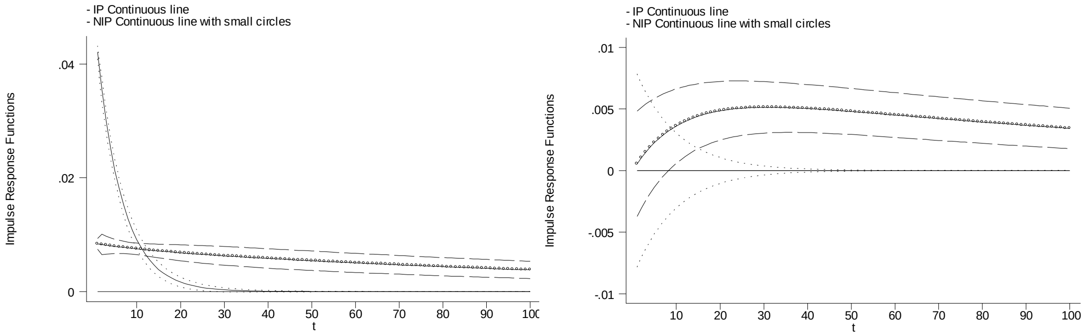
Figure 2: Case 1 (with Toyota)

The graph entitled USA-USA represents the impulse response functions in the variance of US volatility shocks on posterior US volatility. The graph entitled USA-Japan represents the impulse response functions in the variance of US volatility shocks on posterior Japanese volatility. In each graph the continuous line represents the impulse response function in the variance for the IP, and the continuous line with small circles, that for the NIP. The non-continuous lines represent the upper and lower bounds of the confidence intervals for these impulse response functions, with small dots for the IP and long dashes for the NIP. Under the assumed probability distribution, the true value of the impulse response function in the variance is in the confidence interval with a probability of 95%.



USA-USA

USA-Japan



Japan-USA

Japan-Japan

Figure 3: Case 2 (without Toyota)

The graph entitled USA-USA represents the impulse response functions in the variance of US volatility shocks on posterior US volatility. The graph entitled USA-Japan represents the impulse response functions in the variance of US volatility shocks on posterior Japanese volatility. In each graph the continuous line represents the impulse response function in the variance for the IP, and the continuous line with small circles, that for the NIP. The non-continuous lines represent the upper and lower bounds of the confidence intervals for these impulse response functions, with small dots for the IP and long dashes for the NIP. Under the assumed probability distribution, the true value of the impulse response function in the variance is in the confidence interval with a probability of 95%.

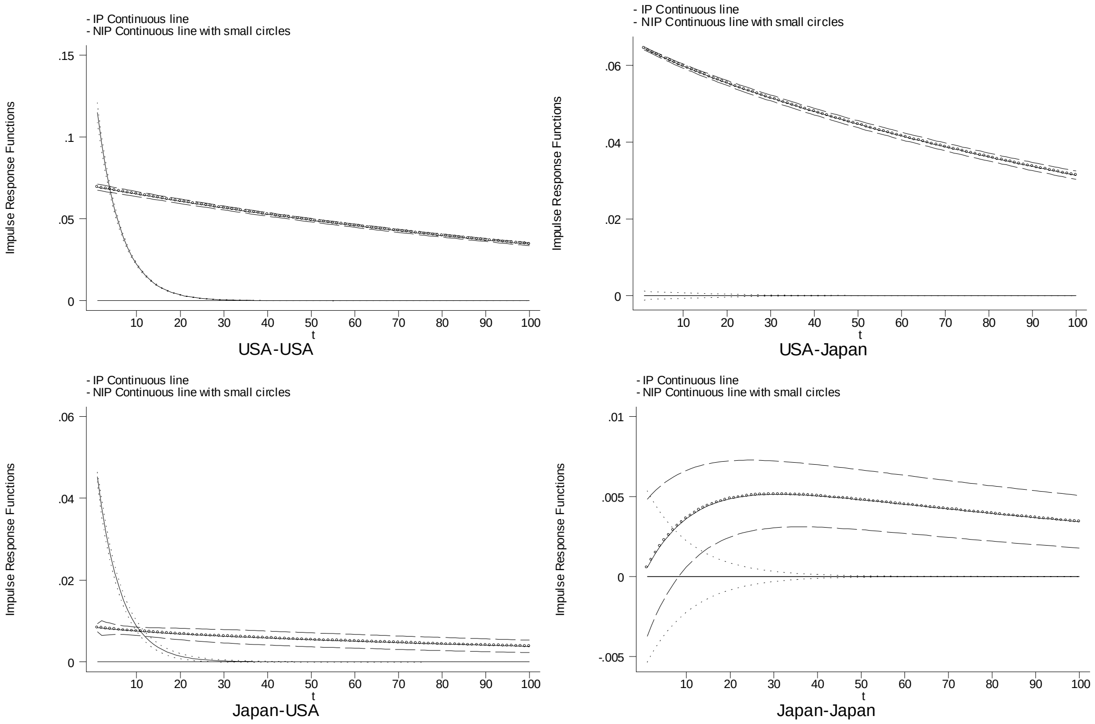
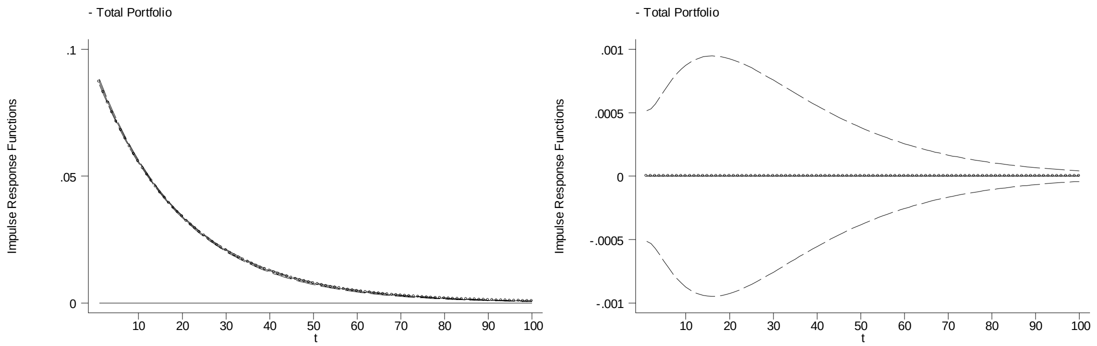


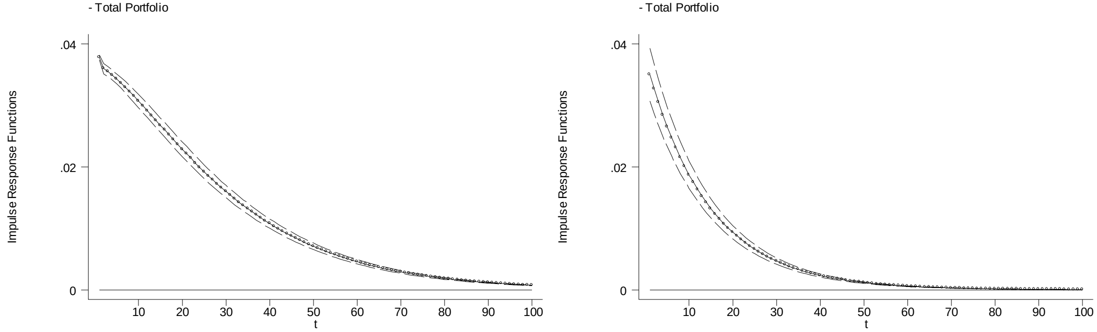
Figure 4: Total Portfolio: Expanded time series sample

For an equally weighted portfolio composed of the 11 stocks in the sample, the graph entitled USA-USA represents the impulse response function in the variance of US volatility shocks on posterior US volatility. The graph entitled USA-Japan represents the impulse response function in the variance of US volatility shocks on posterior Japanese volatility. In each graph the continuous line with small circles represents the impulse response function in the variance, and the non-continuous lines represent the upper and lower bounds of the confidence intervals for this function. Under the assumed probability distribution, the true value of the impulse response function in the variance is in the confidence interval with a probability of 95%.



USA-USA

USA-Japan

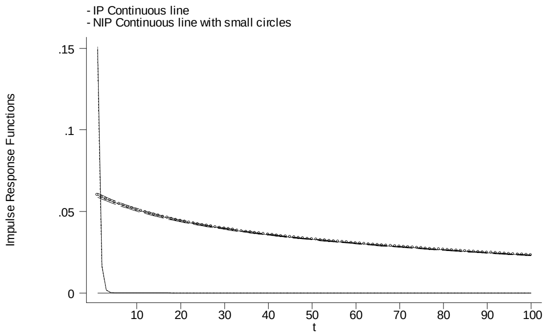


Japan-USA

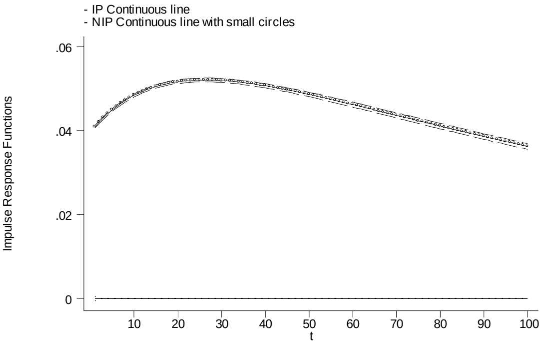
Japan-Japan

Figure 5: Case 1 (with Toyota): Expanded time series sample

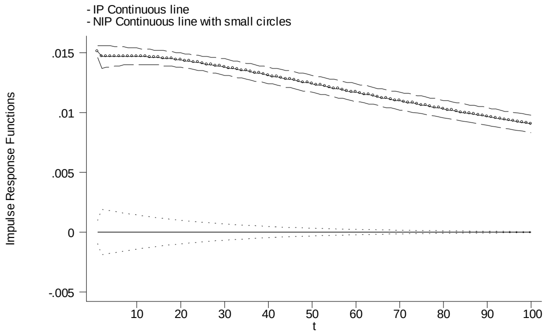
The graph entitled USA-USA represents the impulse response functions in the variance of US volatility shocks on posterior US volatility. The graph entitled USA-Japan represents the impulse response functions in the variance of US volatility shocks on posterior Japanese volatility. In each graph the continuous line represents the impulse response function in the variance for the IP, and the continuous line with small circles, that for the NIP. The non-continuous lines represent the upper and lower bounds of the confidence intervals for these impulse response functions, with small dots for the IP and long dashes for the NIP. Under the assumed probability distribution, the true value of the impulse response function in the variance is in the confidence interval with a probability of 95%.



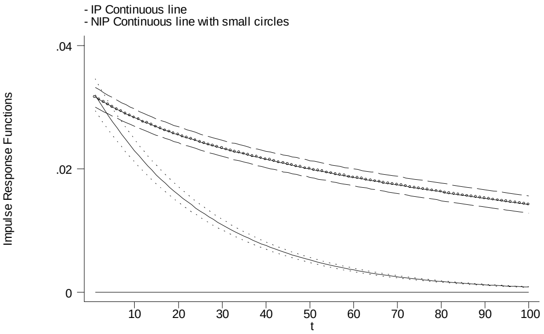
USA-USA



USA-Japan



Japan-USA



Japan-Japan

Table 1. The Sample

This table contains the initial sample of firms, composed of all the Japanese firms listed on the NYSE or on the Nasdaq at the end of 2000. This list was obtained from the NYSE and Nasdaq web pages. The NYSE list was updated in October 2000, and the Nasdaq list in September 2000. This table also contains the criteria used to exclude some firms. Criteria I reports the initial criteria implemented on the sample; 1. Firms non-listed on the Tokyo Stock Exchange; 2. Firms that started the US market listing during the sample time period; 3. Stocks with a percentage of missing closing or opening daily transaction prices higher than 10% in the US, the European or the Japanese markets (the table shows the percentages exceeding this limit); 4. Firms where there is non-available data on its business geographical distribution. Criteria II and III are used to expand the number of analyzed firms. Criteria II is as Criteria I but the third criterion does not take into account the European market. Criteria III is as Criteria II but in the third criterion, the limit in the percentage of missing values is 20%. Whenever the percentage of missing values in the opening price is different from that in the closing price, we take the maximum value.

Company name	Criteria I	Criteria II	Criteria III
Bank of Tokyo-Mitsubishi, Limited *	3. 56% Europe		
Canon, Inc. *			
Hitachi, Ltd. *			
Honda Motor Co., Ltd. *			
Kubota Corporation *	3. 27% USA, 85% Europe	3. 27% USA	3. 27% USA
Kyocera Corporation			
Matsushita Electric Industrial Co., Ltd. *	3. 51% Europe		
Nippon Telegraph and Telephone Corp. *	4. No FOREIGN	4. No FOREIGN	4. No FOREIGN
Orix Corporation *	2. USA listing 16/9/1998	2. USA listing 16/9/1998	2. USA listing 16/9/1998
Pioneer Corporation *			
Sony Corporation *			
TDK corporation *			
Toyota Motor Corporation *			
Crayfish Co., Ltd.	2. USA listing 8/3/2000	2. USA listing 8/3/2000	2. USA listing 8/3/2000
Crosswave Communications Inc.	1. No Tokyo listing	1. No Tokyo listing	1. No Tokyo listing
CSK Corporation	3. 75% USA, 83% Europe	3. 75% USA	3. 75% USA
Dai'ei, Inc.	3. 79% USA, 81% Europe	3. 79% USA	3. 79% USA
Fuji Photo Film Co., Ltd.			
Internet Initiatives Japan	1. No Tokyo listing	1. No Tokyo listing	1. No Tokyo listing
Ito-Yokado Co., Ltd.			
Japan Airlines Company, Ltd.	3. 18% USA	3. 18% USA	4. No FOREIGN
Kirin Brewery Company, Limited	3. 13% USA, 56% Europe	3. 13% USA	4. No FOREIGN
Makita Corp.	3. 14% USA, 73% Europe	3. 14% USA	
Mitsui & Company, Ltd.	3. 63% USA	3. 63% USA	3. 63% USA
NEC Corporation			
Nissan Motor Co., Ltd.			
Sanyo Electric Co., Ltd.	3. 38% USA	3. 38% USA	3. 38% USA
Sawako Corporation	1. No Tokyo listing	1. No Tokyo listing	1. No Tokyo listing
Tokio Marine & Fire Insurance Co., Ltd	3. 89% Europe	4. No FOREIGN	4. No FOREIGN
Trend Micro Incorporated	2. USA listing 8/7/1999	2. USA listing 8/7/1999	2. USA listing 8/7/1999
Wacoal Corp.	3. 77% USA, 94% Europe	3. 77% USA	3. 77% USA

* Firms listed on the NYSE

Table 2. Description of the sample

This table presents the characteristics of the firms that comprise our sample. This information is calculated with the data of the shorter time period sample. The firms' characteristics calculated with the data of the longer time period sample do not present relevant differences and are not reported in order to save space. This information is available on request. In the analysis for the longer time series sample, Fuji Photo Film and Bank of Tokyo-Mitsubishi are not included in the sample of firms.

Company name	FOREIGN	Mean market capitalization in millions of $	US beta	Japan beta	Europe beta	% Vol. US***	% Vol. Japan
NEC	9%	24524.81	0.5942	1.0987	0.6103	1.47%	98.53%
Hitachi	14%	31019.10	0.6819	1.0096	0.5482	7.07%	92.93%
Ito-Yokado	25%	24702.23	0.2581	0.8793	0.3368	1.89%	98.11%
Matsushita Elect. Ind*	29%	41438.43	0.4051	0.7519	0.2352	2.42%	97.58%
Kyocera	31%	16141.50	0.6766	1.1486	0.5923	4.71%	95.29%
TDK	31%	12203.28	0.3367	1.0924	0.5605	0.97%	99.03%
Fuji Photo Film	41%	19215.24	0.5050	0.7731	0.4773	3.53%	96.47%
Bank of Tokyo-Mits.*	42%	41555.43	0.7242	0.8865	0.6324	5.85%	94.15%
Nissan Motor	42%	14998.50	0.5172	0.7767	0.4196	4.12%	95.88%
Toyota Motor	43%	120145.20	0.3816	0.9301	0.5157	1.66%	98.34%
Makita**	45%	1765.66	0.1936	0.4698	0.2938	5.01%	94.99%
Pioneer	51%	3988.54	0.5210	1.1886	0.7174	0.53%	99.47%
Sony	53%	52152.92	0.7437	1.2190	0.6941	10.53%	89.47%
Honda Motor	58%	34913.13	0.4708	0.7732	0.5318	3.05%	96.95%
Canon	61%	25216.27	0.5641	1.1689	0.5945	3.46%	96.54%

* Firms incorporated into the sample when the European data is not taken into account.

** Firms incorporated into the sample when the European data is not taken into account and the limit in the percentage of missing values is relaxed.

*** Percentage of shares traded on the US stock market over the sum of shares traded on the Japanese and the US markets. The conversion rate between ADRs and shares is taken into account.

Table 3. Two markets models

This table presents the results of the two markets models for the period 12/12/1996-31/12/2000. The results are for the total portfolio, the NIP and the IP constructed with three different criteria (Criteria I, II and III). For Criteria II and III, we just present the results of Case 1 (including Toyota) since there are no significant differences with Case 2 (without Toyota), as is shown in the analysis with Criteria I.

		Criteria I				**Criteria II**			**Criteria III**		
		Total portfolio	**NIP**	**IP Case 1**	**IP Case 2**	**Total portfolio**	**NIP**	**IP Case 1**	**Total portfolio**	**NIP**	**IP Case 1**
USA mean	Constant	0.00104 [a]	0.00136 [a]	0.00062 [b]	0.00066 [b]	0.00125 [a]	0.00157 [a]	0.00092 [a]	0.00116 [a]	0.00157 [a]	0.00070 [a]
	$R_{2,t}$	0.18280 [a]	0.12780 [a]	0.16518 [a]	0.20838 [a]	0.12360 [a]	0.17390 [a]	0.24760 [a]	0.13480 [a]	0.17390 [a]	0.22180 [a]
	$R_{1,t-1}$	0.03740 [b]	0.03310	0.01991	0.01459	0.03770 [a]	0.02890	0.00716	0.04180 [a]	0.02890	0.01280
	$R_{2,t-1}$	-0.01270	-0.02630	-0.02682	-0.02424	-0.02180	-0.03060 [c]	-0.02240	-0.01400	-0.03060 [c]	-0.02320
	$R_{1,t-2}$	0.00748	0.01850	-0.00200	-0.00034	0.02120	0.02350	0.00266	0.02350	0.02350	0.00454
	D_{11}	0.12890 [a]	0.02680 [a]	0.27595 [a]	0.33119 [a]	0.11040 [a]	0.02650 [a]	0.24370 [a]	0.10110 [a]	0.02650 [a]	0.21600 [a]
	D_{12}	-0.01970 [a]	-0.03150 [a]	-0.18269	-0.14759	-0.01030 [a]	-0.02890 [a]	-0.08460 [a]	-0.00878 [a]	-0.02890 [a]	-0.07720 [a]
JAP mean	Constant	-0.00054 [c]	-0.00020	-0.00048	-0.00046	-0.00050 [c]	-0.00031	-0.00066 [c]	-0.00062 [b]	-0.00031	-0.00077 [b]
	$R_{1,t-1}$	-0.01400	0.00492	-0.00597	-0.00064	-0.00752	0.00452	-0.00304	-0.01090	0.00452	-0.00436
	$R_{2,t-1}$	-0.07240 [a]	-0.05650 [c]	-0.07338 [a]	-0.07365 [a]	-0.06230 [b]	-0.04900 [c]	-0.06460 [b]	-0.05830 [b]	-0.04900 [c]	-0.04720 [c]
	$R_{1,t-2}$	-0.01310	-0.04020	0.00513	0.00612	-0.01360	-0.02500	0.00602	-0.00176	-0.02500	0.00932
	$R_{2,t-2}$	0.00992	0.00905	0.01497	0.02958	0.00806	0.02740	-0.01070	0.00205	0.02740	-0.00339
	D_{21}	0.03730 [a]	0.03790 [a]	0.04582 [a]	0.04340 [a]	0.04050 [a]	0.03760 [a]	0.04910 [a]	0.03690 [a]	0.03760 [a]	0.04020 [a]
	D_{22}	-0.04030 [a]	-0.04150 [a]	-0.04244 [a]	-0.04267 [a]	-0.03520 [a]	-0.03940 [a]	-0.03900 [a]	-0.03390 [b]	-0.03940 [a]	-0.03680 [a]
USA variance	Constant	0.00000	0.00000	0.00000 [a]	0.00001 [b]	0.00000 [c]	0.00000	0.00000 [b]	0.00000	0.00000	0.00000 [b]
	$h_{1,t-1}$	0.85310 [a]	0.91610 [a]	0.72409 [a]	0.71805 [a]	0.85720 [a]	0.93690 [a]	0.82520 [a]	0.85790 [a]	0.93690 [a]	0.85470 [a]
	$e_{1,t-1}^{2}$	0.12560 [a]	0.06930 [a]	0.11966 [a]	0.11511 [a]	0.13170 [a]	0.05210 [a]	0.10660 [a]	0.13440 [a]	0.05210 [a]	0.09600 [a]
	$e_{2,t}^{2}$	0.02020 [a]	0.00838 [a]	0.04206 [a]	0.04527 [a]	0.01710 [a]	0.00711 [a]	0.02000 [a]	0.01550 [a]	0.00711 [a]	0.01570 [a]
JAP variance	Constant	0.00001	0.00001 [c]	0.00001	0.00001 [c]	0.00001	0.00000	0.00001	0.00001	0.00000	0.00001 [c]
	$h_{2,t-1}$	0.91240 [a]	0.92200 [a]	0.89982 [a]	0.90723 [a]	0.89680 [a]	0.92940 [a]	0.86490 [a]	0.89370 [a]	0.92940 [a]	0.87600 [a]
	$e_{2,t-1}^{2}$	0.02120	0.00659	0.01293	0.02356	0.00971	0.00849	0.01370	0.01420	0.00849	0.02660
	$e_{1,t-1}^{2}$	0.00500	0.06450 [c]	0.02935	0.02321	0.01160	0.06250 [c]	0.03830	0.01600	0.06250 [c]	0.03780 [c]
Correlation	ρ_{12}	-0.08960	-0.02350	-0.04156	-0.07339	0.03800	-0.08980	-0.14120 [b]	0.00020	-0.08980	-0.10740
Log L		9046.19	9121.15	8736.34	8604.95	9119.69	9237.33	8805.29	9188.04	9237.33	8706.45
Meteor Showers (I)[1]		6.85 [b]	17.66 [a]	22.4 [a]	21.39 [a]	13.74 [a]	16.36 [a]	12.84 [a]	11.74 [a]	16.36 [a]	13.97 [a]
Meteor Showers (II)[2]		39.15 [a]	29.26 [a]	45.09 [a]	2007.26 [a]	128.48 [a]	16.73 [b]	1863.25 [a]	92.68 [a]	16.73 [b]	2194.8 [a]
World Wide News[3]		1412.26 [a]	408.23 [a]	2647.95 [a]	2727.68 [a]	1201.67 [a]	459.44 [a]	2289.37 [a]	1033.27 [a]	459.44 [a]	2593.69 [a]

Notes: For reasons of space, residual diagnostic tests are not reported, though they are available on request. However, the Ljung-Box Q statistics suggest that the selected specifications explain the data fairly well. These Q statistics are calculated for 1 to 24 lags, on the standardized residuals, their squares and their cross-products. a. Significant at the 1% level. b. Significant at the 5% level. c. Significant at the 10% level. 1. Likelihood Ratio test where the null is that transmission parameters in volatility are null ($c_{21} = c_{12} = 0$ in [2]). 2. Likelihood Ratio test where the null is that transmission parameters in volatility and mean are null ($\beta_{211} = \beta_{121} = \beta_{212} = \beta_{122} = c_{21} = c_{12} = 0$ in [1]-[2]). 3. Likelihood ratio test where the null is a univariate GARCH model on a time series obtained by stacking the Japanese and the US returns sequentially ($a_{10} = a_{20}$, $\beta_{21k} = \beta_{12k}$, $\beta_{11k} = \beta_{22k}$, $a_1 = a_2$, $b_1 = b_2$, $c_{21l} = c_{12l}$, $c_{22l} = c_{11l}$, and $\rho_{12} = 0$ in [1]-[2]). See Engle *et al.* (1990) for further details.

Table 4. NIP and IP portfolio characteristics

Panel A shows the characteristics of the IP and NIP portfolios analyzed in each sample of firms obtained under three different criteria in the shorter time series sample (12/12/1996-31/12/2000). The characteristics of the IP and the NIP in the extended time series sample (12/12/1996-31/12/2003) are similar to those presented and are not reported, in order to save space. Panel B shows the composition of the IP and NIP portfolios in the shorter time series sample. Case 1 includes all the firms in each sample. Case 2 excludes Toyota Motors in order to obtain smaller differences in capitalization between the IP and the NIP. The composition of the IP and NIP in the extended time series sample is as in the shorter time series sample except for two firms (Fuji Photo Film and Bank of Tokyo-Mitsubishi), which are excluded.

PANEL A

Company Name		**FOREIGN**	**Mean market capitalization in millions of $**	**US beta**	**Japan beta**	**Europe beta**	**% Vol. US****	**% Vol. Japan**
Criteria I								
Case 1								
	Mean for NIP	25%	21301.03	0.508	1.000	0.520	3.27%	96.73%
	Mean for IP	51%	41902.43	0.533	1.009	0.578	3.89%	96.11%
Case 2								
	Mean for NIP	25%	21301.03	0.508	1.000	0.529	3.27%	96.73%
	Mean for IP	53%	26253.87	0.563	1.025	0.591	4.34%	95.66%
Criteria II								
Case 1								
	Mean for NIP	26%	24177.80	0.493	0.964	0.480	3.15%	96.85%
	Mean for IP	50%	41852.86	0.560	0.991	0.586	4.17%	95.83%
Case 2								
	Mean for NIP	26%	24177.80	0.493	0.964	0.480	3.15%	96.85%
	Mean for IP	51%	28804.13	0.590	1.002	0.598	4.59%	95.41%
Criteria III								
Case 1								
	Mean for NIP	26%	24177.80	0.493	0.964	0.480	3.15%	96.85%
	Mean for IP	49%	36841.96	0.514	0.926	0.549	4.28%	95.72%
Case 2								
	Mean for NIP	26%	24177.80	0.493	0.964	0.480	3.15%	96.85%
	Mean for IP	50%	24941.49	0.533	0.926	0.554	4.65%	95.35%

PANEL B

	Criteria I		**Criteria II**		**Criteria III**	
	Case 1	**Case 2**	**Case 1**	**Case 2**	**Case 1**	**Case 2**
NEC	NIP	NIP	NIP	NIP	NIP	NIP
Hitachi	NIP	NIP	NIP	NIP	NIP	NIP
Ito-Yokado	NIP	NIP	NIP	NIP	NIP	NIP
Matsushita El. Ind.			NIP	NIP	NIP	NIP
Kyocera	NIP	NIP	NIP	NIP	NIP	NIP
TDK	NIP	NIP	NIP	NIP	NIP	NIP
Fuji Photo Film*	NIP	NIP	NIP	NIP	NIP	NIP
Bank of Tok-Mits*			IP	IP	IP	IP
Nissan Motor	IP	IP	IP	IP	IP	IP
Toyota Motor	IP		IP		IP	
Makita					IP	IP
Pioneer	IP	IP	IP	IP	IP	IP
Sony	IP	IP	IP	IP	IP	IP
Honda Motor	IP	IP	IP	IP	IP	IP
Canon	IP	IP	IP	IP	IP	IP

* These firms are not included in the extended time series sample.

** Percentage of shares traded on the US stock market over the sum of shares traded on the Japanese and the US markets.

Table 5. Two markets models: Extended time series sample

This table presents the results of the two markets models for the period 12/12/1996-31/12/2003. The results are for the total portfolio, the NIP and the IP constructed with three different criteria (Criteria I, II and III). Only the results of Case 1 (including Toyota) are presented, since there are no significant differences with Case 2 (without Toyota).

		Criteria I			**Criteria II**			**Criteria III**		
		Total portfolio	**NIP**	**IP Case 1**	**Total portfolio**	**NIP**	**IP Case 1**	**Total portfolio**	**NIP**	**IP Case 1**
USA mean	Constant	0.00090 ^{a}	0.00125 ^{a}	0.00047 ^{c}	0.00108 ^{a}	0.00149 ^{a}	0.00047 ^{c}	0.00098 ^{a}	0.00149 ^{a}	0.00067 ^{a}
	$R_{2,t}$	0.15500 ^{a}	0.04890	0.13820 ^{a}	0.17010 ^{a}	0.10500 ^{a}	0.13820 ^{a}	0.14460 ^{a}	0.10500 ^{a}	0.18510 ^{a}
	$R_{1,t-1}$	0.05230 ^{b}	0.03340	0.04360 ^{c}	0.06190 ^{b}	0.02530	0.04360 ^{c}	0.05540 ^{b}	0.02530	0.04120 ^{b}
	$R_{2,t-1}$	-0.02040	-0.01360	-0.04340 ^{b}	-0.02160	-0.02000	-0.04340 ^{b}	-0.01510	-0.02000	-0.03640 ^{c}
	$R_{1,t-2}$	0.01340	-0.02290	-0.00437	0.02150	-0.02180	-0.00437	0.02170	-0.02180	0.01270
	D_{11}	0.10710 ^{a}	0.03370 ^{a}	0.21330	0.08970 ^{a}	0.03130 ^{a}	0.21330	0.08490 ^{a}	0.03130 ^{a}	0.18290 ^{a}
	D_{12}	0.00057	-0.03390 ^{a}	-0.10480 ^{a}	-0.08040 ^{a}	-0.03470 ^{a}	-0.10480 ^{a}	-0.07990 ^{a}	-0.03470 ^{a}	0.01050 ^{a}
JAP mean	Constant	-0.00065 ^{b}	-0.00034	-0.00064 ^{b}	-0.00074 ^{a}	-0.00056 ^{b}	-0.00064 ^{b}	-0.00077 ^{a}	-0.00056 ^{b}	-0.00077 ^{a}
	$R_{1,t-1}$	-0.04740 ^{c}	-0.04100	-0.01030	-0.05280 ^{c}	-0.03310	-0.01030	-0.05380 ^{c}	-0.03310	-0.01670
	$R_{2,t-1}$	-0.04790 ^{b}	-0.01550	-0.04570 ^{b}	-0.03500	-0.00966	-0.04570 ^{b}	-0.02840	-0.00966	-0.04320 ^{c}
	$R_{1,t-2}$	0.01540	0.00075	-0.00379	0.02870	0.01740	-0.00379	0.03220	0.01740	0.00645
	$R_{2,t-2}$	-0.00303	0.00520	0.01370	-0.00373	0.00057	0.01370	-0.00548	0.00057	-0.01490
	D_{21}	0.04710 ^{a}	0.05520 ^{a}	0.04660 ^{a}	0.04520 ^{a}	0.05220 ^{a}	0.04660 ^{a}	0.04230 ^{a}	0.05220 ^{a}	0.04020 ^{a}
	D_{22}	-0.03980 ^{a}	-0.05480 ^{a}	-0.04120 ^{a}	-0.03940 ^{a}	-0.05000 ^{a}	-0.04120 ^{a}	-0.03770 ^{a}	-0.05000 ^{a}	-0.03980 ^{a}
USA variance	Constant	0.00000 ^{a}	0.00000 ^{c}	0.00008 ^{a}	0.00000 ^{a}	0.00000 ^{b}	0.00008 ^{a}	0.00000	0.00000 ^{b}	0.00000
	$h_{1,t-1}$	0.86440 ^{a}	0.90990 ^{a}	-0.04050 ^{a}	0.85250 ^{a}	0.92270 ^{a}	-0.04050 ^{a}	0.85150 ^{a}	0.92270 ^{a}	0.88340 ^{a}
	$e_{1,t-1}^{2}$	0.08720 ^{a}	0.05990 ^{a}	0.15030 ^{a}	0.09880 ^{a}	0.04920 ^{a}	0.15030 ^{a}	0.09650 ^{a}	0.04920 ^{a}	0.06560 ^{a}
	$e_{2,t}^{2}$	0.03780 ^{a}	0.01510 ^{a}	0.00050	0.03800 ^{a}	0.01430 ^{a}	0.00050	0.03460 ^{a}	0.01430 ^{a}	0.03400 ^{a}
JAP variance	Constant	0.00001 ^{b}	0.00000 ^{b}	0.00000 ^{b}	0.00001 ^{b}	0.00000 ^{b}	0.00000 ^{b}	0.00001 ^{a}	0.00000 ^{b}	0.00000 ^{b}
	$h_{2,t-1}$	0.89790 ^{a}	0.93660 ^{a}	0.93160 ^{a}	0.89290 ^{a}	0.93640 ^{a}	0.93160 ^{a}	0.89460 ^{a}	0.93640 ^{a}	0.92650 ^{a}
	$e_{2,t-1}^{2}$	0.03500 ^{a}	0.03100 ^{a}	0.03200 ^{a}	0.03540 ^{a}	0.02800 ^{a}	0.03200 ^{a}	0.03710 ^{a}	0.02800 ^{a}	0.03340 ^{a}
	$e_{1,t-1}^{2}$	0.00741	0.04090 ^{a}	0.00092	0.01110	0.04560 ^{b}	0.00092	0.01200	0.04560 ^{b}	0.00143
Correlation	ρ_{12}	0.00189	0.14750 ^{a}	0.01700	-0.01990	0.05830	0.01700	0.01380	0.05830	-0.03030
Log L		15361.78	15107.65	14948.21	15443.46	15311.35	14948.21	15593.44	15311.35	15278.16
Meteor Showers (I)[1]		69.634 ^{a}	42.3526 ^{a}	10.45886 ^{a}	66.9768 ^{a}	42.9986 ^{a}	10.45886 ^{a}	55.3372 ^{a}	42.9986 ^{a}	87.7818 ^{a}
Meteor Showers (II)[2]		140.058 ^{a}	61.6586 ^{a}	589.8364 ^{a}	127.21 ^{a}	62.2666 ^{a}	589.8364 ^{a}	86.88 ^{a}	62.2666 ^{a}	801.0146 ^{a}
World Wide News[3]		1743.886 ^{a}	1636.4926 ^{a}	1782.5572 ^{a}	1735.786 ^{a}	1332.1366 ^{a}	1782.5572 ^{a}	1653.6028 ^{a}	1332.1366 ^{a}	2003.2478 ^{a}

Notes: For reasons of space, the results of the residual diagnostic tests are not reported, though they are available on request. However, the Ljung-Box Q statistics suggest that the selected specifications explain the data fairly well. These Q statistics are calculated for 1 to 24 lags, on the standardized residuals, their squares and their cross-products. a. Significant at the 1% level. b. Significant at the 5% level. c. Significant at the 10% level. 1. Likelihood Ratio test where the null is that transmission parameters in volatility are null ($c_{21} = c_{12} = 0$ in [2]). 2. Likelihood Ratio test where the null is that transmission parameters in volatility and mean are null ($\beta_{211} = \beta_{121} = \beta_{212} = \beta_{122} = c_{21} = c_{12} = 0$ in [1]-[2]). 3. Likelihood ratio test where the null is a univariate GARCH model on a time series obtained by stacking the Japanese and the US return sequentially ($a_{10} = a_{20}$, $\beta_{21k} = \beta_{12k}$, $\beta_{11k} = \beta_{22k}$, $a_1 = a_2$, $b_1 = b_2$, $c_{21l} = c_{12l}$, $c_{22l} = c_{11l}$, and $\rho_{12} = 0$ in [1]-[2]). See Engle *et al.* (1990) for further details.