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We investigate the transmission of idiosyncratic and systematic risks between U.K. ADRs and their underlying stocks.

We defined idiosyncratic and systematic risks as volatility ratios and standardized beta ratios, respectively.

We found that stock variation tends to revert to idiosyncratic variation, while stock variation tends to persist to systematic variation.

We also found that the systematic transmission tends at the stock level to be stronger from the ADRs to the underlying stocks, whereas the idiosyncratic transmission tends at the portfolio to be stronger from the underlying stocks to the U.K. ADRs.

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Volatility links between the home and the host market for U.K. dual-listed stocks on U.S. markets

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March 20, 2014

Abstract

We investigate how idiosyncratic and systematic effects impact the volatility risk of U.K. cross-listed stocks. Under the hypothesis that more stock followers enhance information effects on volatility, we examine whether variation in volatility of a cross-listed stock has in a bivariate setting two edges. We establish a two-dimensional volatility variation of different magnitudes for U.K. cross-listed stocks. Specifically, we find that idiosyncratic effects induce volatility reversal, whereas systematic effects induce volatility continuation. Our findings imply that the volatility risk of a cross-listed stock is an integral of intermarket volatility effects.

Keywords: cross-listing, Volatility, ADRs, Information transmission

JEL classification:C32, G11, G15

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1 Introduction

There is a mounting evidence on Merton (1987)'s view that an efficient capital market is a market, where information flow is not hampered by national trading and investment barriers of any kind. In fact, with the successive information technology breakthroughs and the liberalization of capital markets of the last three decades, investors all over the world can virtually trade risk and return globally without leaving the comfort of their home country. Various investment vehicles are available to investors in today's world to trade at home foreign assets. For instance, an American investor can trade at home international funds, Exchange-Traded Funds (ETFs), and American Depository Receipts (ADRs). In this way, the American investor has the opportunity to reduce the "super" national risk premium.

Although, the demand side of home-traded foreign securities would not have been met if the offer side of these securities was not responding as quickly as possible to a strong and an increasing demand for home-made foreign securities. In fact, there is a strong belief that the offer side of home-made foreign securities is driven by firms' search for efficient ways to lower cost of capital (Foerster and Karolyi, 1999), to increase liquidity (e.g., Smith and Sofianos, 1996), to improve shareholder protection (e.g., Doidge et al., 2004), and to signal for quality (e.g., Foucault and Fresard, 2012).

An overview of studies on international cross-listing reveals that the motives and valuation effects of cross-listing are complex in information effects. For instance, Foucault and Fresard (2012) found that prices of cross-listed stocks are more informative than prices of non-listed stocks. It follows from their findings that not only cross-listing enhances the precision of private information but also opens the eyes of managers of cross-listed firms on value-enhancing projects. Lang, Lins and Miller (2003) found that cross-listing increases coverage and forecast accuracy with the result that cross-listing enhances the values of cross-listed stocks. Along

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this line of thought, Hail and Leuz (2009) found that cross-listing reduces the cost of capital, whereas Patro (2000) found that the beta riskiness of a cross-listed stock is a function of both home-market and global market risks.

While Sarkissian and Schill (2009) found that the gains with cross-listing are not permanent, cross-listing is still associated with better information environments. As such international cross-listing is a channel by which asymmetry effects are mitigated through efficient idiosyncratic and systematic transmission of information across trading places. Karolyi (2006) surveyed different aspects of international cross-listing that would suggest that stock value is transformed with international cross-listing. One such aspect that links managerial effects to information (trading) effects is the relative contribution of each trading place to price discovery. In this regard, Eun and Sabherwal (2003) found that Canadian stocks listed in the U.S. show strong leadership in higher total trading volume, whereas focusing on selected German stocks Grammig et al. (2004) found that price discovery in the U.S. is positively related to the liquidity of U.S. trading. Thus, the total variation of a cross-listed stock is conditional on the proportion of actual trading activity that takes place across competing markets. However, it is not clear from these studies what would have been the part of information when liquidity is not a constraint

Recognizing that liquidity is a function of volatility and volatility is a function of information, we investigate how stock variation is related to idiosyncratic and systematic variation from either trading place. We conduct this analysis under the understanding that international cross-listing is associated with better information environment (Fernandes and Ferreira, 2008). If cross-listing is associated with both strong private information signals and improvements in trading environments, then both idiosyncratic and systematic variation should be negatively related to stock variation.

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Against this background, we develop a transmission factor that is a correlation-weighted of volatility ratios. Our factor is different from Hasbrouck (1995)'s factor in that it is a product of volatility ratios and standardized beta ratios. Since by construction these ratios are greater than 1, our factor captures information events and help quantifying stock variation's sensitivity to idiosyncratic and systematic variation from either trading place. We clearly differ from previous studies focusing on the transmission of the total stock variation along these dimensions. While the combined effect of our factor is similar to the effect of stock total variation, the insight of stock variation through both idiosyncratic and systematic channels provide a better understanding of the pricing structure of an ADR and its underlying asset.

We specifically relate our study to Wang, Rui and Firth (2002) examining the transmission of volatility between the London stock Exchange and the Hong Kong stock Exchange. Wang et al. controlled for systematic effects and found that these effects induce a negative volatility spillovers. However, we differ from Wang et al. in that our transmission factor is systematic in beta variation at either trading place. Our study is also related to Werner and Kleidon (1996) showing that information is efficiently transmitted across the U.S. and the U.K. borders within the two hours overlapping daily trading on the two trading places. Werner and Kleidon reached their conclusion on intraday data. We use daily data, which implies that our results is more about price completeness than price discovery.

Using a sample of 76 U.K. stocks cross-listed in the U.S., our findings can be summarized as follows. First, disentangling variance effects into idiosyncratic and systematic effects is more informative than entangling these effects. The direction and the magnitude of the relationships indicate that both investors and managers learn from the ADR and the underlying stock variation (Foucault and Fresard, 2012). However, we could not establish with high level of confidence that more ADR followers lead to higher transmission of idiosyncratic effects from

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the host market to the home market.

Second, stock variation reverts to idiosyncratic effects on the day of information. The negative sign suggests a high level of trading integration between the U.K. and the U.S. market (Werner and Kleidon, 1996).

Third, stock variation is positively related to systematic variation on the day of information. This is an indication that the beta of a cross-listed stock is subject to intermarket variation (Patro, 2000; and Fernandes and Ferreira, 2008).

Fourth, stock variation reverts to systematic effects on the day after information. The one-day lag aligns to some extent with the findings of Rapach et al. (2013) showing that return shocks arising in the United States are only fully reflected in equity prices outside the United States with a lag.

Finally, both idiosyncratic and systematic transmission tend to be stronger from the U.K. market to the U.S. market at the stock level. This may suggest that financial analyst coverage and forecast upon the U.K. ADRs have less impact on stock variation at home than do the combination of insider and private information associated with the underlying stocks on stock variation abroad.

The rest of the paper is organized as follows. Section 2 develops a transmission factor between the home and the host trading place. Section 3 reports our empirical findings. Section 4 concludes the paper.

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2 Empirical Models

This section develops a transmission factor across trading places for a cross-listed stock. The factor captures the part of volatility and risk that spill over from one trading place to another.

2.1 Deriving a transmission factor for a cross-listed stock

Let $P_{ik,t}$ be the stock price at time t for stock i at market k; where $i = 1, ..., N$ for N equals the number of cross-listed stocks, $k = 1, ..., K$ for K equals the number of trading places (markets), and $t = 1, 2, ..., T$ for T equals the number of daily observations over the sample period. Let also M_{kt} be the stock market index at k at t, G_t be the global stock market index at t, rf_{kt} be the risk-free rate of return at k at t, and $\overline{rf}_t$ be $\sum_k^K rf_{kt}/K$, where $\overline{rf}_t$ is a proxy for a global risk-free rate of return. The stock, the local market and the world market excess return are given by $R_{ik,t} = \ln(P_{ik,t}/P_{ik,t-1}) - rf_{kt}$, $R_{kt} = \ln(M_{kt}/M_{kt-1}) - rf_{kt}$ and $R_{wt} = \ln(G_t/G_{t-1}) - \overline{rf}_t$, respectively.

Under partially integrated markets, the stock returns are related partly to the local stock market returns, and partly to the global stock market returns. Following Arouri et al. (2012), the stock excess return ($R_{ik,t}$) is related to innovation in the local stock market excess return residuals (v_{kt}) and the global stock market excess return (R_{wt}) as follows,

$$R_{ik,t} = \alpha_{ik} + \beta_{ik} v_{kt} + \beta_{iw} R_{wt} + \varepsilon_{ik,t}, \qquad (1)$$

$$v_{kt} = (n_{kt} - n_{kt} \times n_{wt}), \qquad (2)$$

where n_{kt} are local stock market innovations, n_{wt} are global stock market innovations, v_{kt} are local stock market innovation in residuals, α_{ik} is the unconditional Jensen alpha, β_{ik} is the

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stock beta associated with the local market excess returns, β_{iw} is the stock beta associated with the global market excess returns, and $\varepsilon_{ik,t}$ is an error term[1]. Under normal pricing conditions, our expectation is that $\alpha_{ik} = 0$, $\beta_{ik} \geq 0$ and $\beta_{iw} \geq 0$.

Equation (1) includes v_{kt} that is an econometric measure for market innovation in residuals. This measure is an expression for market innovation in variances in Arouri et al. (2012). Equations (1) and (2) are given in terms of stock i at market k. A bivariate representation of a stock that trades at both market k and l suggests that stock i at k is identified as stock j at l. It follows that $Ev_{kt}R_{wt} = 0$, $Ev_{kt}\varepsilon_{ik,t} = 0$ and $E\varepsilon_{ik,t}\varepsilon_{jl,t} = 0$ under the independence assumption, and $E\varepsilon^2_{ik,t} = \sigma^2_{\varepsilon ik}$, $E\varepsilon^2_{jl,t} = \sigma^2_{\varepsilon jl}$ and $\sigma^2_{\varepsilon ik} = \sigma^2_{\varepsilon jl}$ under the identical distribution assumption.

The identical distribution assumption implies that both $\varepsilon_{ik,t}$ and $\varepsilon_{jl,t}$ are linked to the same news events. It follows that $\sigma^2_{\varepsilon ik} = \sigma^2_{\varepsilon jl}$, $\beta_{ik} = \beta_{jl}$, and $\beta_{iw} = \beta_{jw}$. However, when markets are partially segmented differences may arise between these parameters because (a) news events originate from both controlled (firm-specific) and private sources, (b) the demand for information and the opportunities to trade can be unbalanced across trading places, (c) liquidity is an attribute of each trading place, (d) time-zone distance is an important determinant of price discovery across trading places, and (e) different markets have different weights in the global economy. As a result, the reaction to both private and public news may differ in time, sign and magnitude for a stock trading in different locations.

Equation (1) is a system of equations for $i \neq j$. We consider a bivariate system involving a stock in terms of i and j. We also take the view that the reaction of a stock to news from $k \neq l$ differs in time, sign and magnitude. Such a reaction could be obtained by including

[1]Both w_t and n_{kt} are residuals of autoregressive models of some order, where R_{wt} and R_{kt} are regressed on a constant and lags of R_{wt} and R_{kt}, respectively. The Akaike Information Criterion (AIC) was used to select the number of optimal lags.

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the stock innovation in terms of j and l into (1). However, since innovations can be positive or negative, they are known to exhibit less persistence. A better alternative is to transform equation (1) into a variance equation as follows,

$$h_{ik,t} = \beta_{iw,t}^2 \sigma_{wt}^2 + \beta_{ik,t}^2 \sigma_{kt}^2 + \sigma_{ik,t}^2, \tag{3}$$

where the interaction terms of (3) are zero[2]. Equation (3) recognizes that idiosyncratic and systematic variations are time-varying and contribute to the total variance, independently. Since idiosyncratic and systematic variations are interdependent, the second moment of equation (1) in terms of co-movements between R_{it} and R_{jt} results into[3]:

$$h_{ij,t} = \beta_{iw,t} \beta_{jw,t} \sigma_{wt}^2 + \sigma_{lk,t} \beta_{ik,t} \beta_{jk,t} + E\left(\varepsilon_{it} \varepsilon_{jt}\right), \tag{4}$$

where $\sigma_{kl,t}$ is the time-varying covariance between R_{kt} and R_{lt}, σ_{wt}^2 is the time-varying global variance, $\varepsilon_{it}\varepsilon_{jt}$ are correlated error terms, and $h_{ij,t}$ is the sum of the three independent time-varying variance-covariance terms[4].

Equation (4) is a crude measure of information transmission across trading places. Given that all the betas of (3) and (4) can be given in the form of $\beta_{ik,t} = \rho_{ik,t} \sigma_{it} / \sigma_{kt}$ and $E\left(\varepsilon_{it} \varepsilon_{jt}\right) = \sigma_{it} \sigma_{jt} \rho_{ij,t}$, the ratio of $h_{ij,t}$ to h_{it} gives a standardized measure of information flow as[5],

$$\frac{h_{ij,t}}{h_{it}} = \frac{\sigma_{jl,t}}{\sigma_{ik,t}} \times \frac{\rho_{ik,t} \times \rho_{jl,t} \times \rho_{kl,t} + \rho_{iv,t} \times \rho_{jv,t} + \rho_{ij,t}}{1 + \rho_{ik,t}^2 + \rho_{iv,t}^2} = \frac{\sigma_{jt}}{\sigma_{it}} \times \frac{\Lambda_{lt}}{\Lambda_{kt}}, \tag{5}$$

where $\rho_{ik,t}$ is the time-varying correlation between stock i and market k, $\rho_{kl,t}$ is the time-

[2]See the appendix showing how equation (3) is obtained.

[3]We drop the market index k whenever only stock i is concerned. We use i and k only if both the market and the stock are concerned. It goes without saying that i is mirrored by j, and k is mirrored by l.

[4]See the appendix showing how equation (4) is obtained.

[5]See the appendix showing how equation (5) is obtained.

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varying correlation between market k and l, $\rho_{vi,t}$ is the time-varying correlation between i and global market v, and $\rho_{vj,t}$ is the time-varying correlation between j and v.

Under the belief that the cross-listed stock returns are linked to the same news events, we set $\rho_{ij,t} = 1$. With $\rho_{ij,t} = 1$, Λ_{lt} involves only correlation between stock (i or j) and a factor (k, l or v). Moreover, the influence of i, k and v is scaled in (5), which implies that the ratio of $h_{ij,t}$ to h_{it} is the part of information that can spillover from one trading place to another. Therefore, we refer to the ratio of Λ_{lt} to Λ_{kt} as the standardized beta ratio, whereas we refer to the ratio of σ_{jt} to σ_{it} as the volatility ratio.

Equation (5) shows that the ratio of $h_{ij,t}$ to h_{it} is the product of volatility ratios and standardized beta ratios. The idiosyncratic and the systematic ratios are two sources of information. These sources can be either mutually exclusive in which case we can separate idiosyncratic variation from systematic variation or dependent in which case equation (5) is an appropriate representation of the transmission magnitude. Clearly, three transmission patterns emerge from equation (5)[6].

The first pattern unfolds when both volatility ratios and standardized beta ratios are greater than 1. Many theories underlie this pattern. First, idiosyncratic variation can be related to the idea that cross-listing enhances the precision of private information and provides a greater opportunity to trade for private information. Foucault and Fresard (2012) argued that as the number of financial analysts increases not only information is more precise but also managers are better informed to make optimal investment decisions. Second, systematic variation can be related to the idea that cross-listing expands the market boundaries of a cross-listed stock. Clearly, a cross-listed stock will have at least one foot of its feet in the lightness of a market economy with better trading environments and market infrastructures.

[6]There is a fourth pattern that we discard. The case where $\sigma_{jt} < \sigma_{it}$ and $\Lambda_{lt} < \Lambda_{kt}$ is irrelevant in our case because our analysis is restricted to the case with ratios greater than 1.

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In his survey, Karolyi (2006) highlighted a number of areas of the host market making a cross-listed firm to grow stronger. In this respect, Patro (2000) found that ADR portfolios have significant exposures to both home-market and global market risk, whereas home-stock portfolios have no exposure to global market risks.

The second pattern unfolds when volatility ratios are greater than 1 and standardized beta ratios are less than 1. Since standardized beta ratios are not informative for the stock at the other trading place, we treat these ratios as constant. This pattern should be a more significant transmission channel for stocks showing a weak correlation with both the global and the local market factor. Since it takes time for a cross-listed stock to be rooted in a certain foreign market, a large number of cross-listed stocks remain in the periphery of the zone of influence of market leaders and contributors. One can argue that transmission through idiosyncratic ratios is by far more important than the transmission by both volatility ratios and standardized beta ratios. In fact, idiosyncratic variation captures both firm-specific effects from the headquarter and private information from followers at home and abroad (Lang, Lins and Miller, 2003).

The third pattern unfolds when standardized beta ratios are greater than 1 and volatility ratios are less than 1. Since volatility ratios are not informative for stock variation at the other trading place, these ratios equal 1 under (5). Following our discussion under the first and the second transmission pattern, the third pattern is a more significant transmission mechanism for stocks showing a strong correlation with both the global and the local market factor. For instance, stocks with a long presence in the host market or competing with rivals that are part of the market index in the host market are expected to show greater stock variation to systematic risk. While the beta of the stocks that fall in the secondary category only changes marginally with systematic variation, the beta of stocks showing greater systematic variation

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may be more sensitive to global and intermarket variation (Patro, 2000).

2.2 An estimator for a time-varying covariance matrix

Equation (5) is the sum of time-varying variance-covariance terms. A parametric multivariate GARCH model can be used to obtain time-varying variances and correlations (e.g., Engle and Kroner, 1995). However, our returns data contain a strong nontrading effect resulting from the fact that a stock at either trading place may not trade for several successive days[7]. Campbell, Lo and MacKinlay (1997) showed that in the presence of the nontrading effect, the return time series is made of simple returns on successive days with trade and sums of returns on successive days without trade. It follows that a time series combining simple and aggregate returns gives rise to spurious multivariate relationships. Since a multivariate GARCH model is based on cross-autocorrelation relationships, we use a nonparametric approach to estimate the conditional variances and correlations.

Our nonparametric approach is built partly on stock price ranges (Parkinson, 1980), partly on realized correlations (Chou, 2005; Brandt and Diebold, 2006). Let t index daily excess returns, τ index monthly estimates, and p_{it} be the logarithmic price at the end of the trading day t. Statistically, identifying the highest and the lowest price over a period of time is a way to obtain a range.

Let p_{it}^h and p_{it}^ι be the highest and the lowest logarithmic price over the month, respectively[8]. It follows that at any point in the month, p_{it} can be p_{it}^h or p_{it}^ι or a price between p_{it}^ι and p_{it}^h.

[7]We gauge illiquidity in stocks by taking the ratio of no price change over the sample period of the stock to the total number of observations of the stock. Our sample shows that change in price at one trading place is not always followed by a change in price at the other trading place. As a result a bivariate representation of the transmission mechanism may be suboptimal if not dealt consequently. Moreover, price evolution at the host trading place tends to discontinue more than at home, which may poorly fit a typical GARCH model. In fact, 26.57% of price changes at the host trading place are zero against 18.03% at the home trading place.

[8]τ could be determined over a shorter or a longer time span. However, a longer time-span has a higher likelihood to include structural breaks or jumps that we are not handling, while a shorter time-span may include noise, which we are attempting to avoid.

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So, the range is given by $p_{it}^{\iota} \leq \overline{p}_{it} \leq p_{it}^{h}$, where $\overline{p}_{it}|p_{it}$.

Assuming that p_{it} can be either high or low with probability δ for p_{it}^{h} and $(1-\delta)$ for p_{it}^{ι}, we can write the range as the sum of weighted deviations as $\delta\left(p_{it}^{h}-\overline{p}_{it}\right)+(1-\delta)\left(p_{it}^{\iota}-\overline{p}_{it}\right)$. Let δ be 1/2 and deviations be $\left(p_{it}^{h}-\overline{p}_{it}\right)=u_{it}$ and $\left(p_{it}^{\iota}-\overline{p}_{it}\right)=d_{it}$. We obtain the following expectation,

$$\begin{array}{c} \frac{1}{2}E\left(u_{it}-d_{it}\right)=0 \\ \frac{1}{4}E\left(u_{it}-d_{it}\right)^{2}=\widehat{\sigma}_{i\tau}^{2} \end{array} \tag{6}$$

where E is an expectation operator, $E\left(u_{it}-d_{it}\right)=0$ under the assumption that there are neither jumps nor structural breaks[9], and $\widehat{\sigma}_{i\tau}^{2}$ is the time-varying variance at τ. Although, for a stock trading on different places, deviations are interdependent across trading places. Therefore, we associate (6) with the following covariance expression

$$\frac{1}{4}E\left(u_{it}-d_{it}\right)\left(u_{jt}-d_{jt}\right)=\widehat{\sigma}_{ij,\tau}. \tag{7}$$

We use (7) to estimate the covariance terms of equation (5).

Equations (6) and (7) give expected variances and covariances at τ. These estimates are obtained at lower frequency. We obtain a measure of stock variation at higher frequency as

$$\widehat{\sigma}_{it}^{2}=\frac{1}{4}\left(u_{it}-d_{it}\right)^{2}, \tag{8}$$

where $\widehat{\sigma}_{it}^{2}$ is more persistent than $\widehat{\sigma}_{i\tau}^{2}$. It follows by the virtue of empirical findings that we can express the ratio of $h_{ij,t}$ to h_{it} in terms of daily volatility ratios and monthly standardized

[9]Given that the market is populated by a pool of buyers and a pool of sellers, u_{it} and d_{it} represent the loss (gain) made by those who bought at high and sold at low, and those who bought at low and sold at high, respectively. However, the market clears at equilibrium as $E\left(u_{it}-d_{it}\right)=0$.

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beta ratios. With idiosyncratic variation at higher frequency we are attempting to capture some elements of trading with private information, whereas with systematic variation at lower frequency we are attempting to capture some elements of information completeness.

2.3 The estimated volatility model

Let the ratio of $h_{ij,t}$ to h_{it} be expressed as TOT_{jt}^X, IDI_{jt}^X and SYS_{jt}^X for total, idiosyncratic and systematic transmission, respectively. The superscript X is either H for transmission from home to host or F for transmission from host to home. Because $h_{ji,t}/h_{it}$ can give ratios that are lower than 1, TOT_{jt}^X, IDI_{jt}^X and SYS_{jt}^X are time series with ratios that are greater than 1. We through TOT_{jt}^X, IDI_{jt}^X and SYS_{jt}^X capture information effects.

We use equation (8) to obtain a measure of stock variation. Let $\widehat{\sigma}_{it}$ be VOL_{it}. We examine the relationship between stock variation and transmission factors as follows,

$$\begin{aligned} vol_{it} = \phi_0 + \textstyle\sum_{q=1}^{Q} \phi_q vol_{it-q} + \vartheta_{10} tot_{jt}^X + \vartheta_{11} tot_{jt-1}^X + \vartheta_{20} idi_{jt}^X + \vartheta_{21} idi_{jt-1}^X \\ + \vartheta_{30} sys_{jt}^X + \vartheta_{31} sys_{jt-1}^X + \vartheta_{40} sig_t + \vartheta_{41} sig_{t-1} + \xi_{it}, \end{aligned} \tag{9}$$

where $vol_{it} = \ln(1 + VOL_{it})$, $tot_{jt}^X = \ln\left(1 + TOT_{jt}^X\right)$, $idi_{jt}^X = \ln\left(1 + IDI_{jt}^X\right)$, $sys_{jt}^X = \ln\left(1 + SYS_{jt}^X\right)$, Q is the number of optimal lags, $\sum_{q=1}^{Q} \phi_q$ is persistence in volatility, ξ_{it} is an error term, $sig_t = \ln(1 + SIG_t)$, $SIG_t = \sqrt{\frac{1}{4}\left(u_{lt}^y - d_{lt}^y\right)^2}$, $u_t^y = \left(\Delta y_{kl,\tau}^h + \Delta y_{lk,t}\right), d_t^y = \left(\Delta y_{kl,\tau}^\iota + \Delta y_{lk,t}\right)$, $\Delta y_{kl,\tau}^h$ is the logarithmic interest rate change between the highest interest rate over τ of market k and l , $\Delta y_{kl,\tau}^\iota$ is the logarithmic interest rate change between the lowest interest rate over τ of market k and l , and $\Delta y_{kl,\tau}$ is the logarithmic interest rate change between the interest rate of market l and k at t.

Equation (9) gives stock variation at one trading place as a function of idiosyncratic and systematic variation at another trading place at time t and $t-1$. Limiting the memory of transmission to $t-1$ is a way to examine whether information is fully transferred at t. There-

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fore, letting the memory to be longer than $t-1$ would not change the fact that information is not fully transferred at t if the transmission at $t-1$ leads to significant transmission effects.

Idiosyncratic variation in (9) is related to private and insider information. Therefore, we will expect ϑ_{10} and ϑ_{20} to be negative on the day of information, while ϑ_{11} and ϑ_{21} to be positive on the day after information. The negative sign is associated with news events. Foucault and Gehrig (2008) argued that cross-listing leads to better investment decisions as cross-listing gives more opportunities to trade on private information. A positive sign is expected because public information should not trigger significant price movements.

Systematic variation in (9) is related to market information. Both theoretical and empirical studies show that a cross-listed stock is exposed to intermarket risk variation (e.g., Alexander et al. 1987). The stock exposure to market risk variation is even greater when one of the trading markets of the cross-listed stock is a member of the leading economies in the world. Looking at the lead-lag relationships among monthly country stock returns, Rapach et al. (2013) found that return shocks arising in the United States are only fully reflected in equity prices outside the U.S. with a lag. Looking at 123 ADRs from 16 developed and emerging countries, Patro (2000) found that ADR portfolios have significant exposures to both home-market and global market risks. Against this background, we will expect ϑ_{30} to be positive and ϑ_{31} to be negative. We expect ϑ_{30} to be positive because the standardized beta ratios are measured at lower frequency. In contrast, we expect ϑ_{10} to be a negative coefficient because cross-listed stocks constitute a channel through which a mistake in one market can be transmitted to another market (King and Wadhwani, 1990).

Equation (9) includes interest rate differential volatility as a control variable. In principle, interest rate variation should be negatively related to stock variation. In fact, markets for equity and markets for fixed-income securities tend to move in opposite directions. For instance,

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Lunde and Timmerman (2004) found that change in interest rates is associated with the end and the beginning of bear and bull states in stock markets. Therefore, we expect ϑ_{40} to be negative and ϑ_{41} to be positive.

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3 Empirical results

In this section, we describe the data and report the estimates of the empirical models presented in the previous section.

3.1 Sample and Data

We started with an original sample of 103 U.K. firms that cross-listed on U.S. stock markets between 1973 and 2011[10]. Although, some stocks ceased their trading activities in both the U.K. and the U.S. market by the time we undertook this research. In fact, 58 stocks were active on September 30, 2011 and the rest of the stocks were either dead or delisted. At the end of 2013 only 23 stocks in our sample were still actively trading as ADR. The fact that many stocks disappeared from the list of the U.K. ADRs we started with is an indication of either a low survival rate in the U.S. market or increased integration between the U.K. and the U.S. Doidge, Karolyi and Stulz (2009) examined the determinants and consequences of cross-listings on the New York and London Stock Exchange and found that the falling in the number of cross-listed stock in both London and New York is more related to changes in firm characteristics than in the benefits of cross-listing.

We considered the group of stocks that were either delisted or dead to identify stocks with sufficient trading activity from the time of their cross-listing in the U.S. to September 30, 2011 when our sample ends. We deleted 27 stocks among the 103 stocks because these stocks have a long sequence of daily price changes at zero. As a rule of thumb, a stock was deleted from our final sample if 40% of its return observations were zero.

[10]Our empirical analysis could be applied on any country with ADRs. The choice of the U.K. is motivated on both historical and economic grounds. Historically, the U.K. has produced more ADRs over the years since the first U.K. ADR in 1927 by JP Morgan than any other country in the world. As a result we have at hand longer daily time series for some of the stocks in our sample. Economically, London is known to be a very attractive financial trading center with the potential to take market share from New York (see Doidge et al. 2009).

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Table 1 gives the name and the trading symbol of the 76 stocks along with indications of trading exchanges and corresponding industries.

[Insert Table about here]

Table 1 also gives the number of daily observations over the sample period. The higher the number of observations, the longer the stock has been cross-listed in the U.S. In fact, there are five stocks with more than 10,000 daily observations. While Table 1 does not give the number of shares received for each ADR, it is worth noting that for a large number of stocks in our sample one ADR corresponds to more than one ordinary share of a stock. Table 1 also shows that 37 stocks traded over the counter (OTC), 28 stocks at NYSE, 10 stocks at NASDAQ and 1 at AMEX. However, these trading locations are only illustrative as many of the firms in our sample are not any longer part of today's U.K. ADRs.

Our data set includes daily stock prices, trading volume, the exchange rate between the U.S. dollar (USD) and the British Sterling (GBP), the 3-month U.S. Treasury bill (US3TB), and the 3-month U.K. bill (UK3TB). These data are obtained from DataStream. For the stock with the longest history of cross-listing in the U.S., the sample period runs from January 4, 1973 through September 30, 2011. We dealt with stock prices and interest rates in the way explained in the previous section.

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3.2 Descriptive statistics

Dealing only with two countries, we refer to the U.K. as the primary or the home (H) market and to the U.S. as the foreign market (F) market for the 76 stocks of Table 1. Table 2 gives some descriptive statistics over stock variation at home and abroad.

[Insert Table 2 about here]

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Table 2 gives the stock average standard deviation at home as $\overline{VOL}_H$ and abroad as $\overline{VOL}_F$. The daily variation at home ranges from 0.051% to 1.388% with an average of 0.227%, while it ranges abroad from 0.054% to 6.093% with an average of 0.445%. There is a clear indication that volatility was higher abroad than at home. We did not test for equality between volatility at home and abroad. Nonetheless, the difference between $\overline{VOL}_F$ and $\overline{VOL}_H$ ranges from −0.01% to 5.791% with an average of 0.218%. A difference of 0.218% gives an indication that stock variation across the two markets is not equal.

Table 2 also gives the correlation between stock variation at home and abroad as $\overline{\rho}_{HF}$. We will expect $\overline{\rho}_{HF}$ to be 1 as stock variation at home and abroad should be linked to the same news events. However, while the underlying information factors are common, the underlying trading factors may differ from one trading place to another. In fact, Table 2 shows that the correlation between stock variation at home and abroad ranges from 4.26% to 86.47% with an average of 61.59%, which suggests that stock variation at home and abroad are not necessarily synchronized in trading events and trading activities[11].

Finally, Table 2 gives two additional statistics related to the historical patterns of vol_{it}, which we refer to as the logarithmic gross volatility. To save space, Table 2 reports only the skewness statistic (sk)of the logarithmic gross volatility , and the optimal number of lags (Q) for an autoregressive model of the logarithmic gross volatility. Indeed, the two statistics are much in line with the unreported statistics. Both sk and Q show a clear deviation of the logarithmic gross volatility from both normality and independence. Because we want to explain stock variation on the basis of idiosyncratic and systematic effects, robust and efficient estimates are obtained only if we can in particular control for historical patterns in

[11]Poshakwale and Aquino (2008) show that the differences in synchronicity of trading between U.S. market and home market of cross-listed stocks do not affect the volatility transmission and information flow between the ADRs and the underlying stocks.

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the logarithmic gross volatility.

Therefore, we estimate equation (9) using a two-stage approach. In the first stage, we obtain uncorrelated residuals by regressing the logarithmic gross volatility on a constant and lags of the logarithmic gross volatility. We do not report the autoregressive estimates of this model as these estimates are not the focus of our paper. In the second stage, we use a GMM estimator under mild conditions.

Prior to showing our GMM equations and estimates, Table 3 gives the averages upon the transmission factors from one trading place to another. Table 3 only shows the averages for the idiosyncratic and the systematic transmission, which are referred to as IDI_H and SYS_H in the sense of the U.K. to the U.S. and as IDI_F and SYS_F in the sense of the U.S. to the U.K.

[Insert Table 3 about here]

The factors of Table 3 are ratios. The idiosyncratic factor is obtained as volatility ratios when standardized beta ratios are held constant, while the systematic factor is obtained as standardized beta ratios when volatility ratios are held constant. Under the belief that information is positively related to stock variation, informed trading is associated with increasing volatility. Therefore, both the idiosyncratic and the systematic factor are by construction greater than 1.

Table 3 shows that the average for idiosyncratic variation ranges from 0.380 to 0.859 with an average of 0.690, and from 0.491 to 0.990 with an average of 0.664 in the sense of home to host and host to home, respectively. Similarly, the average for systematic variation ranges from 0.029 to 0.224 with an average of 0.118, and from 0.059 to 0.236 with an average of 0.143 in the sense of home to host and host to home, respectively. Considering the magnitude of

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these simple statistics, idiosyncratic variation should have a greater impact on stock variation than systematic variation.

3.3 GMM estimates of the transmission factors

Let res_{it}denotes the white noise residual time series . Under mild conditions, we relate stock variation in residuals to factor variation through two basic moment conditions given by

$$\begin{gathered}\xi_{it} = res_{it} - \vartheta_{10} tot^X_{jt} - \vartheta_{11} tot^X_{jt-1} - \vartheta_{20} idi^X_{jt} - \vartheta_{21} idi^X_{jt-1} - \\ \vartheta_{30} sys^X_{jt} - \vartheta_{31} sys^X_{jt-1} - \vartheta_{40} sig_t - \vartheta_{41} sig_{t-1}, \\ \xi_{it}\xi_{it-1} - \rho_0 \xi^2_{it-1}, \\ \xi^2_{it-1} - \delta_0,\end{gathered} \tag{10}$$

where $res_{it} = vol_{it} - \phi_0 - \sum_{q=1}^{Q} \phi_q vol_{it-q}$, vol_{it} is stock i's variation, and $\vartheta_{10}, ..., \delta_0$ are parameters to be estimated given an efficient information filtration related a set of valid instruments.

As instruments for the two moments in equation (10), a constant and lagged values of res_{it} are used. Under rational expectations, ξ_{it} should be orthogonal to the chosen instruments. Since we have three equations for 10 parameters, we use the generalized method of moments (GMM) estimator to identify the 10 parameters. The GMM estimator minimizes the distance of the empirical moments from the theoretical moments through a quadratic form, which depends on a symmetric and positive definite weight matrix (Hansen, 1982).

Table 4 gives the main estimates of the paper, which are $\widehat{\vartheta}_{10}, ..., \widehat{\vartheta}_{31}$. These estimates are robust to serial correlation and heteroskedasticity as a consistent matrix of the standard errors of the estimates is used in determining the level of significance. Since the estimates associated with interest rate volatility are not significant in most cases, these estimates are not reported

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in Table 4. Moreover, Table 4 only shows the 16 first alphabetic ordered stocks for each of the trading place. We give, in the last row of Panels A and B, the average upon the 76 stocks' estimates in order to detect the common trait of the three transmission mechanisms. These averages are robust and tested across a sample of 76 stocks' estimates.

[Insert Table 4 about here]

Panel A gives robust estimates relating factor variation abroad to stock variation at home, whereas Panel B gives robust estimates relating factor stock variation at home to stock variation abroad. These factor variations are given in terms of total, idiosyncratic and systematic variation.

We hypothesized that idiosyncratic transmission should be negatively related to stock variation on the day of information, whereas it should be positively related to stock variation on the day after information. Panel A shows that stock variation at home is negatively related to idiosyncratic variation abroad. On average a one percent factor variation abroad corresponds to a marginal increase of 0.037% of stock volatility at home, whereas Panel B shows that a one percent idiosyncractic variation at home corresponds to a marginal increase of 0.123% of stock volatility abroad.

Comparing the magnitude by which stock volatility reverts to idiosyncratic variation, the underlying stocks show leadership in idiosyncratic transmission. The home leadership in idiosyncratic transmission may suggest that (a) the combination of insider and private information produces a greater impact on stock variation than does financial analyst forecast and coverage alone (Foucault and Fresard, 2012), (b) investors show greater trading sentiment for the underlying stocks (Chen et al., 2009), and (c) the notion of home and host market becomes anecdotal for highly integrated markets (Lowengue and Melvin, 2002).

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On the day after information, stock variation at home is positively related to idiosyncratic variation abroad at the rate of 0.056%. Positive coefficients imply that idiosyncratic information is fully transferred on the news day. As previously documented in Werner and Kleidon (1996), the two hours during which London and New York overlap, there is a significant amount of both private and public information that is transmitted across the two trading places. However, Panel B shows that on the day after information, stock variation at the host market increases marginally at the rate of 0.062%. The negative sign suggests that the transmission from the U.K. to the U.S. is not completed on the day of information. An explanation is that the two hours during which the two markets overlap may be too short to exhaust all private information at home. Another explanation is that liquidity is scarce for small ADRs in particular (Silva and Chavez, 2008).

We also hypothesized that systematic transmission should be positively related to stock variation on the day of information, but negatively related to stock variation on the day after information. Panel A shows that systematic variation from the U.S. market is positively related to stock variation in the U.K. on the news day, but negatively related to variation in the U.K. on the day after the news day. Panel B shows that systematic variation from the U.K. is positively related to stock variation in the U.S. both on the day of information and the day after the news day. The negative sign may be aligned with Rapach et al. (2013) showing that information from U.S. markets get impounded into other market places of the world with a lag.

Both Panels A and B show that volatility linkages across trading places are significant. Stock variation on either trading place is negatively related to idiosyncratic variation. However, the magnitude of the transmission tends to be greater from the home trading place to the host trading place. Moreover, Panels A and B show that both the U.S. and the U.K.

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market are integrated to some extent as most of idiosyncratic information is transmitted on the day of news events.[12]

3.4 Estimating the portfolio effect of stock variation

We partially reported our estimates of equation (10) as averages. The reason for averaging our estimates is that investors hold and trade portfolios, and an average is one of the statistics of interest in portfolio management. We follow Patro (2000) and examine the idiosyncratic and systematic effect of a portfolio including the 76 cross-listed stocks.

Let assume that an American investor holds a portfolio of all the U.K. ADRs. With 76 stocks in our sample from different industries, the investor holds a well-diversified portfolio. Let also assume that the investor constructs a corresponding portfolio on ADRs' underlying stocks. He uses the U.K. portfolio as a benchmark portfolio.

Let VOL_{pt}^{X}, TOT_{pt}^{X}, IDI_{pt}^{X}, and SYS_{pt}^{X} stand for portfolio volatility, total transmission, idiosyncratic transmission, and systematic transmission, respectively. In constructing these portfolios, the weights are given by the ratio of stock market value to the total market value at time t, and perfect positive correlation is assumed. Table 5 gives the estimates of equation (10) in terms of these value-based portfolios.

[Insert Table 5 about here]

The standard errors of the coefficients are HAC standard errors with Newey-west Barlett window and 26 lags for the model of Panel A and 22 lags for the model of Panel B. The level

[12]There is a possibility that our findings are subject to the day of the week effects. We examine this possibility by multiplying both idiosyncratic and systematic transmission factor with an indicator for the day of the week. We do not find that the day effect alters the transmission mechanism across the trading places. Our results indicate that both idiosyncratic and systematic effects are randomly spread across the days of the week.

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of significance of the J-specifications suggests that the coefficients are identified at the points where the orthogonal conditions are statistically equal to zero.

Panel A gives the estimates of the home volatility equation including stock and market variation abroad, while Panel B gives the estimates of the host volatility equation including stock and market variation at home.

Panels A and B report a number of other estimates, which we are not reported in Table 4. First, both Panels A and B show that interest rate volatility is not significantly related to stock variation. Second, both Panels A and B show that volatility is persistent looking at $\widehat{\rho}_0$. Third, both Panels A and B show that the estimates are obtained under normal conditions as the J-statistics are statistically zero.

Our hypothesis that idiosyncratic variation is negatively related to stock variation on the day of information and positively related to stock variation on the day after information cannot be completely verified for any of the two equations. At the portfolio level, the relationship between stock variation and factor variation is stronger in terms of systematic variation than in terms of idiosyncratic variation.

Specifically, Panel A shows that stock portfolio variation in the U.K. is negatively related with a lag to systematic variation, whereas Panel B shows that stock portfolio variation in the U.S. is not significantly related to systematic variation. Since systematic variation in the ADRs is significantly related with a lag to stock variation in the underlying stocks, we interpret this relationship under a broader view on the impact of the U.S. economy on the rest of the world economy. In fact, Rapach et al. (2013) found that lagged U.S. returns predict returns of several industrialized countries.

In a nutshell, Table (5) shows that (a) both idiosyncratic and systematic transmission are stronger from the U.S. to the U.K., (b) variation in the ADR portfolio is more sensitive to the

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combined effects of systematic and idiosyncratic variation, and (c) variation in the portfolio of the underlying stocks is distinctively sensitive to idiosyncratic and systematic variation in the ADR portfolio.[13]

[13]Patro (2000) found that cross-listed stocks are exposed to both home market and global risks. Our transmission factors do control for global risk variation. Nonetheless, our estimates may still fail to capture shocks related to global news events. In fact, a large number of studies look at stock price reaction to cross-listing decisions (see Karolyi, 2006). Similarly, global shocks or market shocks in either trading place may lead to more intensive information transmission. Therefore, we examine the abnormal information effect on days when global shocks are revealed either at the home or at the host trading place. Following Marin and Olivier (2008), we define crashes and jumps in terms of J_{wt}, which is an indicator taking 1 when the absolute residual shock in the world stock market index is greater than 1.95 times the world stock market GARCH volatility, and 0 otherwise. Subsequently, our transmission factors were given as $TOT_{jt}^{X} \times J_{wt}$, $IDI_{jt}^{X} \times J_{wt}$, and $SYS_{jt}^{X} \times J_{wt}$. Considering global shocks does not qualitatively change our findings. Only the home effect is magnified with global shocks and a large number of stocks showing a weak response to the induced global transmission factors.

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Concluding remarks

We investigated the information flow between the U.K. and the U.S. market by developing a transmission factor that is a combination of volatility ratios and standardized beta ratios. Our factor is able to separate idiosyncratic and systematic effects from total variation effects. Our findings support the decomposition as stock variation is differently related to idiosyncratic and systematic effects. In general, we found that stock variation at either market is negatively related to idiosyncractic variation at either market, while it is positively related to systematic variation at either trading place.

Our results have implications for institutional investors holding global portfolios. Indeed, we construct a portfolio of U.K. ADRs and their corresponding underlying stocks to show how such investors can build trading portfolios that are subject to idiosyncratic and systematic risk effects. The estimates of these trading portfolios show that increased volatility linkage across markets enhances price informativeness in terms of stock variation. Clearly, we believe that holding a virtual portfolio on the ADRs of a given country gives an information advantage on the ADRs' underlying stocks that can be bought or sold quicker than otherwise.

Our findings provide an understanding of the volatility dynamics and how different channels contribute to the variation of asset's return. Moreover, the results are important for cross-listed and potential cross-listed firms that are concerned about their cost of capital. One of the main reasons for these firms to cross-list is to raise external finance at lower cost of capital. Disentangling the idiosyncratic and systematic channels that affect volatility transmission is useful for these firms when assessing the impact of cross-listing on their stock returns and thus their cost of capital.

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Appendix: Derivation of equations (3), (4) and (5)

Equation (3) is obtained as follows,
Start with

$$R_{it} = \alpha_i + \beta_{ik} v_{kt} + \beta_{iw} R_{wt} + \varepsilon_{it}, \tag{11}$$

Take the second moment of (11) and get:

$$\begin{gathered}(R_{it})^2 = (\alpha_i + \beta_{ik} v_{kt} + \beta_{iw} R_{wt} + \varepsilon_{it})^2 = \alpha_i^2 + 2\alpha_i R_{wt}\beta_{iw} + 2\alpha_i v_{kt}\beta_{ik} + 2\alpha_i \varepsilon_{it} + \\ R_{wt}^2 \beta_{iw}^2 + 2R_{wt} v_{kt} \beta_{ik} \beta_{iw} + 2R_{wt}\varepsilon_{it}\beta_{iw} + v_{kt}^2 \beta_{ik}^2 + 2v_{kt}\beta_{ik}\varepsilon_{it} + \varepsilon_{it}^2.\end{gathered} \tag{12}$$

Take the expectation of (12) and consider time-variation in the parameters to obtain:

$$\begin{gathered}E\left(R_{it}\right)^2 = E\alpha_i^2 + 2\alpha_i E R_{tw}\beta_{iw} + 2\alpha_i E v_{kt}\beta_{ik} + 2\alpha_i E\varepsilon_{it} + ER_{wt}^2\beta_{iw}^2 + \\ 2ER_{wt}v_{kt}\beta_{ik}\beta_{iw} + 2ER_{wt}\varepsilon_{it}\beta_{iw} + Ev_{kt}^2\beta_{ik}^2 + 2Ev_{kt}\beta_{ik}\varepsilon_{it} + E\varepsilon_{it}^2 \\ h_{it} = \beta_{iw,t}^2\sigma_{wt}^2 + \beta_{ik,t}^2\sigma_{kt}^2 + \sigma_{it}^2 \blacksquare\end{gathered} \tag{13}$$

Equation (4) is obtained as follows,
Start with

$$\begin{gathered}R_{it} = \alpha_i + \beta_{ik} v_{kt} + \beta_{iw} R_{wt} + \varepsilon_{it}, \\ R_{jt} = \alpha_j + \beta_{jl} v_{lt} + \beta_{jw} R_{wt} + \varepsilon_{jt},\end{gathered} \tag{14}$$

Take the product of R_{it} and R_{jt} and get:

$$\begin{gathered}\alpha_j\varepsilon_{it} + \alpha_i\varepsilon_{jt} + \alpha_i\alpha_j + \varepsilon_{it}\varepsilon_{jt} + R_{wt}^2\beta_{iw}\beta_{jw} + R_{wt}\varepsilon_{it}\beta_{jw} + R_{wt}\varepsilon_{jt}\beta_{iw} + \\ v_{kt}\beta_{ik}\varepsilon_{jt} + v_{lt}\beta_{jl}\varepsilon_{it} + \alpha_j R_{wt}\beta_{iw} + \alpha_i R_{wt}\beta_{jw} + \alpha_j v_{kt}\beta_{ik} + \alpha_i v_{lt}\beta_{jl} + \\ R_{wt}v_{kt}\beta_{ik}\beta_{jw} + R_{wt}v_{lt}\beta_{jl}\beta_{iw} + v_{kt}v_{lt}\beta_{ik}\beta_{jl}.\end{gathered} \tag{15}$$

Take the expectation of (15) and consider time-variation in the parameters to obtain:

$$\begin{gathered}\alpha_j E\varepsilon_{it} + \alpha_i E\varepsilon_{jt} + E\alpha_i\alpha_j + E\varepsilon_{it}\varepsilon_{jt} + ER_{wt}^2\beta_{iw}\beta_{jw} + \\ ER_{wt}\varepsilon_{it}\beta_{jw} + ER_{wt}\varepsilon_{jt}\beta_{iw} + Ev_{kt}\beta_{ik}\varepsilon_{jt} + Ev_{lt}\beta_{jl}\varepsilon_{it} + \alpha_j ER_{wt}\beta_{iw} + \\ \alpha_i ER_{wt}\beta_{jw} + \alpha_j Ev_{kt}\beta_{ik} + \alpha_i Ev_{lt}\beta_{jl} + ER_{wt}v_{kt}\beta_{ik}\beta_{jw} + \\ ER_{wt}v_{lt}\beta_{jl}\beta_{iw} + Ev_{kt}v_{lt}\beta_{ik}\beta_{jl} = \\ h_{ij,t} = \beta_{iw,t}\beta_{jw,t}\sigma_{wt}^2 + \sigma_{lk,t}\beta_{ik,t}\beta_{jl,t} + E\left(\varepsilon_{it}\varepsilon_{jt}\right) \blacksquare\end{gathered} \tag{16}$$

Equation (5) is obtained as follows,
Start with

$$\begin{gathered}\frac{h_{ijt}}{h_{it}} = \frac{\sigma_{wt}^2\beta_{iwt}\beta_{jwt} + \sigma_{lkt}\beta_{ikt}\beta_{jlt} + E(\varepsilon_{it}\varepsilon_{jt})}{\sigma_{wt}^2\beta_{iwt}^2 + \sigma_{kt}^2\beta_{ikt}^2 + \sigma_{i\varepsilon t}^2}, \\ \beta_{iw,t} = \rho_{iw,t}\frac{\sigma_{it}}{\sigma_{wt}}, \beta_{jw,t} = \rho_{jw,t}\frac{\sigma_{jt}}{\sigma_{wt}}, \beta_{ik,t} = \rho_{ik,t}\frac{\sigma_{it}}{\sigma_{kt}}, \beta_{jl,t} = \rho_{jl,t}\frac{\sigma_{jt}}{\sigma_{lt}}, \\ \sigma_{lk,t} = \rho_{klt}\sigma_{kt}\sigma_{lt}, E\left(\varepsilon_{it}\varepsilon_{jt}\right) = \rho_{ij,t}\sigma_{it}\sigma_{jt}.\end{gathered} \tag{17}$$

Rewrite (17) in terms of relative betas, simplify and obtain:

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$$\frac{h_{ijt}}{h_{it}} = \frac{\sigma^2_{wt}\rho_{iwt}\frac{\sigma_{it}}{\sigma_{wt}}\rho_{iwt}\frac{\sigma_{jt}}{\sigma_{wt}}+\rho_{klt}\sigma_{kt}\sigma_{lt}\rho_{ikt}\frac{\sigma_{it}}{\sigma_{kt}}\rho_{jlt}\frac{\sigma_{jt}}{\sigma_{lt}}+\rho_{ij,t}\sigma_{it}\sigma_{jt}}{\sigma^2_{wt}\rho^2_{iwt}\frac{\sigma^2_{it}}{\sigma^2_{wt}}+\sigma^2_{kt}\rho^2_{ikt}\frac{\sigma^2_{it}}{\sigma^2_{kt}}+\sigma^2_{i\varepsilon t}} = \frac{\rho_{jwt}\rho_{iwt}\sigma_{it}\sigma_{jt}+\rho_{jlt}\rho_{klt}\rho_{ikt}\sigma_{it}\sigma_{jt}+\rho_{ij,t}\sigma_{it}\sigma_{jt}}{\rho^2_{iwt}\sigma^2_{it}+\rho^2_{ikt}\sigma^2_{it}+\sigma^2_{i\varepsilon t}} = \frac{\sigma_{it}\sigma_{jt}\left(\rho_{jwt}\rho_{iwt}+\rho_{klt}\rho_{ikt}\rho_{jlt}+\rho_{ij,t}\right)}{\sigma^2_{it}\left(\rho^2_{iwt}+\rho^2_{ikt}+1\right)} = \frac{\sigma_{jt}}{\sigma_{it}} \times \frac{\left(\rho_{jw,t}\rho_{iw,t}+\rho_{kl,t}\rho_{ik,t}\rho_{jl,t}+\rho_{ij,t}\right)}{\left(\rho^2_{iwt}+\rho^2_{ikt}+1\right)} \blacksquare \tag{18}$$

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Table 1: An overview of selected UK ADRs between 1973 and 2011

	syl	ind/exc	nobs		syl	ind/exc	nobs
Abbey National	aby	bks/otc	2449	Lastminutecom	lmt	hot/nas	1156
Allied Domceq	ald	vev/otc	2035	Legal&General	lgg	ins/otc	4246
Amercham	ahm	dru/nyse	1681	Lloyds Banking	lyg	bks/nyse	2916
Assoc Brit Foods	adb	fod/otc	4370	Lonmin	lnm	met/otc	4374
Astrazeneca	azn	dru/nyse	4780	Mark&Spencer	mas	mer/otc	2484
Autonomy Corp	aut	cmp/otc	2844	Merant	mrn	com/nas	3156
Bae Systems	bae	aer/otc	3365	Mitchells&Butlers	mbp	hot/otc	597
Barclays	bcs	bks/nyse	6535	National Westm	nwb	bks/nyse	3524
BG	brg	utiI/nyse	6406	National Grid	ngg	uti/otc	4090
BHP Billiton	blt	min/otc	3695	Pearson	prs	pub/otc	4242
BOC Group	box	chm/nyse	2594	Premier Farnell	pfp	eei/nyse	2301
Bookham Tec	bkh	ppp/otc	1148	Prudential	ppl	ins/otc	4369
BP	bpa	ogs/nyse	10105	Rank Group	ran	hot/nas	8522
British Am Tob	bti	tob/amex	3402	Reed Elsevier	ruk	med/nyse	4416
British Land	btl	svs/otc	2029	Rentokil Initial	rto	svc/otc	4360
BT Group	bt	tel/nyse	6661	Rexam	rex	ppp/nas	10109
Bunzl	bnl	ppp/nyse	3368	Rio Tinto	rtp	min/nyse	3310
Carlton Comms	cct	med/nas	4429	Rolls-Royce	ryc	ear/otc	4362
Carnival	cuk	lrp/nyse	2850	Royal B of Sctl	rbs	bks/nyse	1037
Centrica	cpy	ogs/otc	3314	Royal D Shell B	rds	ogs/nyse	10109
Compass Group	cms	fod/otc	2486	RSA Insurance	rsa	ins/otc	2043
Cordian Comm	cda	pub/nyse	5124	Sabmiller	sbm	bev/otc	3284
Corus Group	cga	ist/nyse	4583	Sainsbury (J)	jsn	ret/otc	4740
Diageo	deo	bev/nyse	5362	Sottish Power	spi	uti/nyse	1243
Dixons Retail	dcs	aer/nyse	4374	Shire	shp	dru/nas	3528
ebookers	ebk	svs/otc	1005	Signet Group	sig	mer/nas	6058
eidos	eid	csn/nas	2299	Six Continents	six	hot/nyse	3436
Gallaher Group	glh	tob/nyse	2577	Skyepharma	sky	dru/nas	3446
GKN	gkn	aut/otc	2439	SLG Real.	slg	cmp/otc	1811
Glaxosmithkline	gsk	dru/otc	10109	Smith&Nephew	snn	dru/nyse	3099
Hanson	han	mul/nyse	5428	Spirent Co	spm	ele/otc	3236
HSBC Holding	hsb	bks/otc	4374	Tate&Lyle	tat	fod/otc	3847
ICAP	iap	fis/otc	1692	Telewest Co	tws	com/otc	2514
Intern Power	ipr	ele/otc	4355	Tesco	tsc	ret/otc	3869
Invensys	ivn	ppp/otc	4374	Unilever	ul	mul/nyse	10109
Johnson Matthey	jmp	tec/otc	3325	United Utilities	uu	uti/nyse	3980
Kingfisher	kng	mer/otc	2591	Vodafone G	vod	telL/nyse	4369
Ladbrokes	ldb	hot/otc	4374	WPP	wpp	pub/nas	6199

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Table 2: Some descriptive statistics of the stock variation at home and abroad

	$\overline{VOL}_H$	$\overline{VOL}_F$	$\overline{\rho}_{HF}$	sk	Q		$\overline{VOL}_H$	$\overline{VOL}_F$	$\overline{\rho}_{HF}$	sk	Q
aby	0.0016	0.0015	0.751	3.776	10	lmt	0.0067	0.0089	0.770	3.059	1
ald	0.0007	0.0135	0.378	4.111	2	lgg	0.0015	0.0085	0.583	9.019	26
ahm	0.0016	0.0014	0.669	3.952	6	lyg	0.0030	0.0037	0.688	9.738	26
adb	0.0006	0.0052	0.475	3.753	14	lnm	0.0021	0.0023	0.779	5.622	39
azn	0.0008	0.0007	0.640	4.629	17	mas	0.0010	0.0011	0.653	5.144	4
aut	0.0034	0.0037	0.592	7.169	10	mrn	0.0045	0.0042	0.739	5.618	4
bae	0.0011	0.0011	0.645	9.817	14	mbp	0.0005	0.0006	0.481	3.023	2
bcs	0.0020	0.0020	0.649	15.094	19	nwb	0.0006	0.0005	0.583	4.474	18
brg	0.0008	0.0008	0.590	5.690	17	ngg	0.0012	0.0010	0.628	5.524	18
blt	0.0009	0.0011	0.558	4.709	17	prs	0.0011	0.0010	0.688	3.974	18
box	0.0018	0.0014	0.644	3.874	11	pfp	0.0028	0.0024	0.780	3.635	2
bkh	0.0010	0.0015	0.642	4.370	2	ppl	0.0016	0.0017	0.765	7.925	29
bpa	0.0009	0.0008	0.542	3.692	1	ran	0.0014	0.0015	0.643	12.179	23
bti	0.0053	0.0054	0.609	5.443	1	ruk	0.0009	0.0008	0.628	4.132	12
btl	0.0009	0.0009	0.670	10.213	15	rto	0.0015	0.0118	0.592	5.427	12
bt	0.0010	0.0011	0.625	3.607	18	rex	0.0012	0.0016	0.584	8.514	19
bnl	0.0007	0.0006	0.574	3.169	18	rtp	0.0011	0.0009	0.455	3.853	1
cct	0.0023	0.0020	0.692	9.325	22	ryc	0.0120	0.0132	0.865	6.182	13
cuk	0.0018	0.0014	0.664	11.077	22	rbs	0.0009	0.0008	0.689	5.157	13
cpy	0.0008	0.0008	0.553	4.209	18	rds	0.0014	0.0014	0.749	9.644	19
cms	0.0010	0.0014	0.525	5.909	19	rsa	0.0025	0.0023	0.805	4.656	20
cda	0.0050	0.0054	0.647	8.439	24	sbm	0.0009	0.0073	0.605	3.635	1
cga	0.0036	0.0034	0.751	13.698	37	jsn	0.0008	0.0026	0.651	4.333	7
deo	0.0006	0.0043	0.499	4.407	17	spi	0.0008	0.0006	0.632	2.505	1
dcs	0.0030	0.0609	0.551	11.910	32	shp	0.0017	0.0016	0.684	5.817	10
ebk	0.0080	0.0084	0.716	3.637	1	sig	0.0026	0.0034	0.545	6.703	13
eid	0.0067	0.0057	0.137	5.891	5	six	0.0011	0.0009	0.634	5.007	11
glh	0.0009	0.0009	0.601	4.178	1	sky	0.0048	0.0338	0.684	7.783	23
gkn	0.0020	0.0031	0.675	6.248	23	slg	0.0139	0.0145	0.779	4.219	4
gsk	0.0009	0.0009	0.659	11.304	20	snn	0.0008	0.0008	0.671	3.374	4
han	0.0011	0.0016	0.600	8.478	15	spm	0.0051	0.0054	0.766	16.021	24
hsb	0.0010	0.0010	0.611	7.187	20	tat	0.0013	0.0033	0.639	4.798	3
iap	0.0017	0.0037	0.650	7.028	11	tws	0.0075	0.0071	0.786	4.682	23
ipr	0.0014	0.0016	0.697	6.962	21	tsc	0.0006	0.0035	0.042	5.308	4
ivn	0.0044	0.0045	0.810	10.506	22	ul	0.0008	0.0008	0.489	9.294	22
jmp	0.0010	0.0012	0.618	5.038	18	uu	0.0007	0.0020	0.048	5.629	9
kng	0.0011	0.0124	0.223	5.989	19	vod	0.0012	0.0073	0.531	3.514	14
ldb	0.0012	0.0026	0.645	5.445	6	wpp	0.0033	0.0029	0.694	12.062	25

$\overline{VOL}_H$ and $\overline{VOL}_F$ are stock volatilities at home and abroad, respectively; $\overline{\rho}_{HF}$ is the correlation between the stock at home and abroad; sk is the skewness of $\ln(1 + VOL_{it})$; and Q is the optimal number of lags of an autoregressive model of $\ln(1 + VOL_{it})$.

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Table 3: Averages over idiosyncratic and systematic transmission factors

	IDI_H	SYS_H	IDI_F	SYS_F		IDI_H	SYS_H	IDI_F	SYS_F
aby	0.703	0.038	0.652	0.181	lmt	0.641	0.138	0.647	0.175
ald	0.502	0.158	0.588	0.066	lgg	0.649	0.068	0.614	0.142
ahm	0.761	0.099	0.554	0.222	lyg	0.586	0.189	0.671	0.155
adb	0.724	0.083	0.683	0.139	lnm	0.679	0.098	0.580	0.151
azn	0.767	0.102	0.592	0.236	mas	0.652	0.210	0.709	0.124
aut	0.687	0.136	0.622	0.157	mrn	0.714	0.105	0.689	0.197
bae	0.708	0.120	0.568	0.182	mbp	0.791	0.029	0.801	0.116
bcs	0.764	0.086	0.636	0.158	nwb	0.730	0.162	0.701	0.166
brg	0.627	0.224	0.789	0.076	ngg	0.859	0.057	0.574	0.158
blt	0.745	0.094	0.682	0.144	prs	0.751	0.127	0.665	0.099
box	0.839	0.102	0.581	0.228	pfp	0.743	0.074	0.613	0.139
bkh	0.610	0.064	0.688	0.209	ppl	0.741	0.099	0.678	0.137
bpa	0.809	0.104	0.649	0.140	ran	0.667	0.081	0.735	0.122
bti	0.680	0.104	0.639	0.084	ruk	0.825	0.085	0.621	0.149
btl	0.758	0.097	0.653	0.142	rto	0.575	0.129	0.663	0.161
bt	0.753	0.079	0.675	0.119	rex	0.632	0.114	0.738	0.129
bnl	0.774	0.116	0.622	0.116	rtp	0.798	0.100	0.627	0.113
cct	0.756	0.103	0.599	0.219	ryc	0.545	0.191	0.755	0.087
cuk	0.733	0.177	0.656	0.073	rbs	0.738	0.179	0.657	0.182
cpy	0.609	0.156	0.612	0.143	rds	0.747	0.102	0.573	0.179
cms	0.654	0.091	0.795	0.112	rsa	0.732	0.101	0.571	0.215
cda	0.731	0.074	0.671	0.157	sbm	0.632	0.145	0.722	0.174
cga	0.740	0.093	0.628	0.110	jsn	0.667	0.124	0.678	0.142
deo	0.728	0.128	0.654	0.115	spi	0.743	0.033	0.491	0.151
dcs	0.531	0.138	0.598	0.140	shp	0.715	0.141	0.626	0.122
ebk	0.622	0.147	0.677	0.200	sig	0.692	0.137	0.714	0.124
eid	0.662	0.133	0.781	0.111	six	0.778	0.094	0.654	0.120
glh	0.644	0.184	0.722	0.123	sky	0.631	0.177	0.655	0.153
gkn	0.669	0.079	0.689	0.169	slg	0.601	0.168	0.638	0.127
gsk	0.723	0.090	0.675	0.147	snn	0.764	0.123	0.695	0.140
han	0.823	0.087	0.602	0.151	spm	0.614	0.171	0.636	0.196
hsb	0.841	0.084	0.566	0.123	tat	0.686	0.130	0.650	0.172
iap	0.531	0.181	0.718	0.110	tws	0.647	0.194	0.645	0.139
ipr	0.678	0.138	0.723	0.156	tsc	0.380	0.193	0.990	0.059
ivn	0.655	0.136	0.637	0.149	ul	0.727	0.105	0.721	0.101
jmp	0.710	0.041	0.607	0.163	uu	0.641	0.068	0.836	0.085
kng	0.464	0.084	0.659	0.073	vod	0.634	0.107	0.742	0.150
ldb	0.622	0.149	0.693	0.165	wpp	0.754	0.109	0.630	0.136

IDI_H and IDI_F stand for idiosyncratic factors from home to host and from host to home, respectively. SYS_H and SYS_F stand for systematic factors from home to host and from host to home, respectively.

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Table 4: Effects of stock variation across trading places

	$\widehat{\vartheta}_{10}$	$\widehat{\vartheta}_{11}$	$\widehat{\vartheta}_{20}$	$\widehat{\vartheta}_{21}$	$\widehat{\vartheta}_{30}$	$\widehat{\vartheta}_{31}$
	Panel A: From the US trading places to the UK trading place					
aby	-0.005%	-0.012%	-0.022%†	0.031%†	0.105%†	-0.050%
ald	-0.007%	-0.001%	-0.013%†	0.015%†	0.049%	-0.007%
ahm	-0.049%	0.038%	-0.021%†	0.030%†	0.050%	-0.013%
adb	-0.001%	0.000%	-0.016%†	0.015%†	0.056%†	-0.034%†
azn	-0.021%†	0.010%	-0.027%†	0.024%†	0.020%†	-0.004%
aut	-0.050%	0.080%	-0.101%†	0.086%†	0.434%†	-0.273%†
bae	0.019%	0.005%	-0.023%†	0.039%†	0.062%†	-0.037%†
bcs	-0.021%†	0.030%†	-0.019%†	0.052%†	0.023%	-0.010%
brg	0.020%	-0.013%	-0.026%†	0.022%†	0.126%†	-0.074%†
blt	0.000%	0.000%	-0.018%†	0.018%†	0.060%†	-0.038%†
box	-0.048%†	0.043%†	-0.055%†	0.059%†	0.067%†	-0.028%
bkh	0.027%†	0.012%	-0.005%	0.022%†	0.053%†	-0.011%
bpa	-0.002%	0.023%	-0.017%†	0.030%†	0.039%†	-0.021%†
bti	0.088%	0.046%	-0.046%	0.408%†	0.273%	-0.201%
btl	-0.001%	0.003%	-0.022%†	0.028%†	0.045%†	-0.029%†
bt	-0.015%†	0.007%	-0.023%†	0.022%†	0.029%†	-0.019%
	-0.018%†	0.028%†	-0.037%†	0.056%†	0.069%†	-0.027%†
	Panel B: From the UK trading place to the US trading places					
aby	-0.066%†	0.009%	-0.014%†	-0.004%	0.089%	0.187%†
ald	-0.114%	-0.404%†	-0.490%†	-0.263%	-0.172%	-0.106%
ahm	-0.019%	-0.070%†	-0.040%†	-0.018%†	0.122%	0.058%
adb	-0.151%†	-0.197%†	-0.178%†	0.041%	-0.062%	-0.080%
azn	-0.003%	-0.020%†	-0.014%†	-0.006%†	0.076%†	0.023%
aut	-0.076%†	-0.056%†	-0.169%†	-0.159%†	0.151%†	0.111%†
bae	-0.017%	-0.026%†	-0.038%†	-0.012%†	0.088%†	0.051%†
bcs	-0.115%†	-0.029%	-0.050%†	-0.046%†	0.148%†	0.072%
brg	0.006%	-0.032%†	-0.015%†	-0.011%†	0.069%†	0.028%†
blt	-0.023%	-0.036%†	-0.033%†	-0.019%†	0.089%†	0.036%
box	-0.023%	-0.029%	-0.040%†	-0.018%†	0.184%†	0.057%†
bkh	-0.062%	-0.010%	-0.090%†	-0.024%†	-0.078%	0.033%
bpa	-0.029%†	-0.010%	-0.012%†	-0.016%†	0.134%†	0.106%†
bti	-0.303%	0.031%	-0.259%†	0.015%	0.718%	0.445%
btl	-0.020%†	-0.018%†	-0.016%†	-0.012%†	0.063%†	0.045%†
bt	-0.007%	-0.043%†	-0.033%†	-0.020%†	0.172%†	0.025%
	-0.118%†	-0.113%†	-0.123%†	-0.062%†	0.209%†	0.120%

$\xi_{it} = res_{it} - \vartheta_{10} tot^X_{jt} - \vartheta_{11} tot^X_{jt-1} - \vartheta_{20} idi^X_{jt} - \vartheta_{21} idi^X_{jt-1} - \vartheta_{30} sys^X_{jt} - \vartheta_{31} sys^X_{jt-1}$, $res_{it} = vol_{it} - \phi_0 - \sum_{q=1}^{Q} \phi_q vol_{it-q}$. vol_{it} is stock i's volatility. tot^X_{jt}, idi^X_{jt}, and sys^X_{jt} are total, idiosyncratic and systematic variation, respectively. X is either H or F. (†) means significance at 5%.

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Table 5: Portfolio effects of stock variation across trading places

	Coefficient	HAC Standard Errors	T-statistic	prob-value
Panel A: From the U.S. trading places to the UK trading place				
$\widehat{\vartheta}_{10}$	0.222%	0.0031	0.7255	0.4682
$\widehat{\vartheta}_{11}$	-0.911%†	0.0035	-2.5777	0.0099
$\widehat{\vartheta}_{20}$	0.377%†	0.0015	2.5887	0.0096
$\widehat{\vartheta}_{21}$	-0.136%	0.0013	-1.0218	0.3069
$\widehat{\vartheta}_{30}$	1.849%†	0.0095	1.9422	0.0521
$\widehat{\vartheta}_{31}$	-2.432%†	0.0073	-3.3408	0.0008
$\widehat{\vartheta}_{40}$	1.040%	0.0170	0.6135	0.5395
$\widehat{\vartheta}_{41}$	1.900%	0.0186	1.0211	0.3072
$\widehat{\rho}_0$	26.401%†	0.1178	2.2416	0.0250
$\widehat{\delta}_0$	0.003%†	0.0000	2.4290	0.0151
J-Specification(5)	6.6879			0.2449
Panel B: From the U.K. trading place to the US trading places				
$\widehat{\vartheta}_{10}$	-1.062%†	0.0038	-2.8040	0.0050
$\widehat{\vartheta}_{11}$	-0.290%	0.0041	-0.7038	0.4815
$\widehat{\vartheta}_{20}$	0.174%	0.0013	1.3087	0.1906
$\widehat{\vartheta}_{21}$	-0.074%	0.0013	-0.5799	0.5620
$\widehat{\vartheta}_{30}$	0.407%	0.0161	0.2522	0.8009
$\widehat{\vartheta}_{31}$	1.430%	0.0147	0.9703	0.3319
$\widehat{\vartheta}_{40}$	-0.935%	0.0309	-0.3022	0.7625
$\widehat{\vartheta}_{41}$	0.192%	0.0259	0.0743	0.9408
$\widehat{\rho}_0$	76.575%†	0.1263	6.0649	0.0000
$\widehat{\delta}_0$	0.006%†	0.0000	2.5039	0.0123
J-Specification(23)	13.7188			0.9346

(1) $\xi_{pt} = res_{pt} - \vartheta_{10} tot^X_{pt} - \vartheta_{11} tot^X_{pt-1} - \vartheta_{20} idi^X_{pt} - \vartheta_{21} idi^X_{pt-1} - \vartheta_{30} sys^X_{pt} - \vartheta_{31} sys^X_{pt-1} - \vartheta_{40} sig_t - \vartheta_{41} sig_{t-1}$, (2) $\xi_{pt}\xi_{pt-1} - \rho_0 \xi^2_{pt-1}$, and (3) $\xi^2_{pt-1} - \delta_0$; $res_{pt} = vol_{pt} - \phi_0 - \sum_{q=1}^{Q} \phi_q vol_{pt-q}$. vol_{pt} is the stock portfolio volatility. tot^X_{pt}, idi^X_{pt}, sys^X_{pt} and sig_t are total, idiosyncratic, systematic and rate variation, respectively. (†) means significance at 5%.

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