Specialist Trading and the Price Discovery Process of NYSE-Listed Non-US Stocks

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Abstract:

In this paper we examine the contribution of US trading to the price discovery process of 64 British and French companies cross-listed on NYSE. We use our large sample to examine the factors which may affect the US contribution to price discovery, by focusing our analysis on the role of the information environment of NYSE specialists who make market in non-US securities. We find strong evidence that concentration of stocks from a given country in an individual specialist increases the US share in price discovery through the reduction in information asymmetries. The results are robust to controlling for other factors, such as the share of trading in the US relative to home trading, the ADR institutional holdings, the ratio of spreads in the US and home market, and the size of the firm.

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I. Introduction

Price discovery is a core product of a security market and can be defined as the process by which markets impound new information and find the equilibrium price (Hasbrouck, 1995). When a company lists in more than one markets, a question arises of where price discovery for its stocks occurs, and the process for internationally listed companies has been a subject of intensive empirical research over the last years. Studies on both daily (e.g. Lieberman, Ben-Zion and Hauser, 1999; Kim, Szakmary and Mathur, 2000; Wang, Rui and Firth, 2002) and intra-day data (e.g. Pascual, Pascual-Fuster and Climent, 2001; Hupperets and Menkveld, 2002; Eun and Sabherwal, 2003; Grammig, Melvin and Schlag, 2004) find that, on average, the home market is dominant in the pricing process. However, an important finding of the studies is a large variation in the markets' shares in the process across companies.

In an analysis of the cross-sectional differences of the foreign market's share in price discovery, Eun and Sabherwal (2003) find that the process is influenced by relative trading characteristics. Investigating Canadian companies which list in the US, they uncover that the US contribution is directly related to the share of trading in a stock and to the ratio of medium-size trades in the US and in Canada, and inversely related to the ratio of bid-ask spreads. On the basis of their samples of a few US-listed Israeli and German stocks, Lieberman et al. (1999) and Grammig et al. (2004) provide intuitive explanation that there is also greater scope for international discovery for companies with higher foreign sales and larger foreign ownership.

In this paper, we add to the debate on the determinants of foreign market's share in price discovery by focusing on the information environment of NYSE specialists who make market in non-US stocks. The specialists are responsible for maintaining a fair and orderly market in assigned securities. However, as Corwin (1999) notes there are significant differences in performance across specialist firms, which have an impact on execution costs, liquidity and the efficiency of prices. Bacidore and Sofianos (2002) in their empirical evidence on liquidity provision and specialist trading in non-US stocks, document differences in market quality between US and foreign stocks and attribute them to greater information asymmetries associated with trading non-US stocks. They suggest that these asymmetries may be reduced by higher concentration of foreign stocks in a particular specialist, which in turn may encourage closer linkages and associations with local brokers and lead to a better understanding of international stock markets.

In our study we examine whether the concentration of stocks from a given country in both specialist firms and individual specialists affects the US share in price discovery through the reduction in information asymmetries.[1] We identify individual specialists on the basis of their post and panel locations and thus fully address the impact of both specialist firms' policies and actions and individual specialists' personal skills and experience on the price discovery process. We control for the impact of other factors found in previous studies to influence the price discovery process, such as relative trading volumes, the ratio of quoted spreads (Eun and Sabherwal, 2003), the composition of the company's customer and investor base (Lieberman et al., 1999; Grammig et al., 2004), and the firm size and industry classification.

Our sample consists of 64 British and French companies which cross-list on the NYSE. The United Kingdom has the largest number of NYSE cross-listings and the largest NYSE trading value among European countries, and France follows as the second and the fourth most important one, respectively, in the rankings as of 2002. In the analysis we depart from earlier studies and do not confine our sample to a few large and very liquid stocks. In contrast, we explore the price discovery in the breadth of the whole group of NYSE-listed UK and French. Our testing framework is similar to that fo Eun and Sabherwal (2003). However, their results for Canadian stocks may not hold for European companies cross-listed in the US. The United States and Canada are considered to have more integrated markets because of the longer overlap in trading and business hours and higher cultural proximity. All these factors may influence the interest from US investors and could explain different patterns in the US contribution to price discovery. Moreover, Canadian securities are listed in the US as ordinary shares, whereas European companies usually choose listing of American Depository Receipts (ADRs). Although ADRs are close substitutes of underlying ordinary shares, arbitrage transactions involve ADR creation or cancellation fees paid to the depository bank, which may have an impact on the inter-market pricing process.

The remainder of the paper is organised as follows. The role of NYSE specialists and differences in market making of US and non-US are outlined in Section 2. Section 3 describes data sources and the sample of UK and French stocks under investigation. In Section 4, we discuss the methodology of our analysis, which consists of two parts. In the first part, we show how we calculate the contribution to price discovery of each market for each stock based on its speed of adjustment to the long-run relationship between the ADR price and the

[1] Our concentration on individual specialists extends the previous literature on specialist trading, which is dominated by firm-level studies.

home price in the Vector Error Correction model. In the second part, we outline the cross-section analysis, which examines the factors, which may influence the US share to the price discovery process. Section 5 presents the results, while Section 6 concludes the paper.

II. The Role of NYSE Specialist and Market Making in Non-US Stocks

NYSE specialists are responsible for maintaining a fair and orderly market in assigned securities. Every security has a single specialist, who has unique full access to the limit order book, and whose responsibilities include posting firm and continuous bid and ask quotes, committing own capital to supply-short term liquidity in the absence of public bids and offers, and reducing stock price volatility by trading against the market trend. At times of significant information releases or extreme order imbalances, the specialist may halt trading to allow investors to react to new information and adjust their orders. Individual specialists are employed by specialist firms. After ongoing consolidation, there were seven specialist firms making market in common stocks in 2003.

The crucial role in the allocation of stocks to specialist firms is played by the exchange's Allocation Committee. When a new security is going to start trading on the exchange, the committee collects applications from specialist firms. The committee then selects a subset of applicants, and the new listing firm has an option to choose from this pool the specialist firm which will handle its stocks. Prior to March 1997, the decision was solely made by the committee. NYSE's objectives in the allocation process are spreading reward and risk across specialists, rewarding specialist performance, and providing the best possible match between specialist unit and stock. Once the allocation is made, reallocations from one specialist firm to another are very rare.

Despite the regulations and close monitoring by the exchange to promote improved specialist performance, there are significant differences across specialist firms, as found by Corwin (1999). Spreads and depth, as well as transitory volatility and the frequency and duration of trading halts differ significantly and the results suggest that specialist firms strongly affect market quality. They influence execution costs, liquidity and noise in stock prices and the differences may result from differences in specialist firm characteristics such as risk aversion, organisational form, investment motives, and expertise.

There are inherent differences between making market in non-US stocks traded on the NYSE and their US domestic counterparts, which result from different institutional details and flow of information related to the security. The foreign firm's securities may not be fully

fungible across home and US markets, may be subject to different national regulations and their trading may be influenced by language, cultural, and time zone differences between home country and the US. Moreover, foreign stocks are usually actively traded in their home markets and US traders may have limited access to information on trading there. As shown by Domowitz, Glen and Madhavan (1998), the level of information linkages between markets has a direct impact on the market quality. If the markets are not fully integrated and access to information is indeed limited, greater adverse selection increases trading costs when informed arbitrage traders exploit price differences at the expense of less informed liquidity providers.

Bacidore and Sofianos (2002) provide empirical evidence of the importance of information asymmetry and adverse selection in trading behaviour and liquidity provision by NYSE specialist in non-US stocks. Using proprietary data, they find that specialist closing inventories for non-US stocks are closer to zero than for US stocks, and specialist participation and stabilisation rates for non-US developed market stocks are higher that those of US stocks, while for non-US emerging market securities they are significantly smaller. Non-US stocks are also found to have larger spreads, less quoted depth and greater volatility. The authors conclude that higher trading costs reflect additional compensation demanded by the NYSE specialists to compensate for higher adverse selection risks borne in trading foreign stocks.

Based on their findings, Bacidore and Sofianos (2002) suggest that in order to reduce trading costs and increase the competitiveness, NYSE should pursue a policy, which reduces the information asymmetries inherent in trading non-US securities. Since making market in foreign stocks requires an understanding of securities trading in international markets, the improvement may be driven by development of linkages with the listing firms' home markets, possibly by associations with non-US securities firms. The development may be encouraged by concentration of foreign stocks in particular specialists. Such a policy is indeed undertaken, and Corwin (2004) finds that NYSE tends to allocate non-US stocks to specialist firms that already have experience in trading foreign securities.

III. Data and Sample

The data were taken from various sources. NYSE trades and quotes were downloaded from the Trade and Quote (TAQ) database. The London Stock Exchange and the Euronext Paris provided tick data on domestic trading of British and French stocks, respectively. Intra-day exchange rates were obtained from Olsen. Market capitalisation and foreign sales data are

taken from Datastream, while ADR institutional holdings and sector classifications are from JP Morgan ADR web page (www.adr.com). Data on the ratio of ADR and ordinary shares come from The Bank of New York web page (www.adrbny.com), and allocation of stocks across specialists are from the NYSE.

The sample period spans six months from January 2003 through June 2003 and covers 122 trading days in both UK and French subsamples, after exclusion of public holidays in either home or US market. All three stock markets (US, UK and France) followed similar patterns during this period. There was a downward drift with a local minimum of market indices about mid-March, followed by upward trend towards the end of the sample period. There seems to be no single event or day which may be particularly noteworthy over those six months.

The sample includes British and French companies listed on the domestic exchange and cross-listed on the New York Stock Exchange throughout the whole six-month sample period. We exclude two companies which changed ADR ratios, since as documented by Muscarella and Vetsuypens (1996), the action could have a significant impact on liquidity.[2] Any shocks to liquidity and microstructure environment for our sample stocks could lead to discontinuity in comparing the relevant characteristics of the home and US markets throughout the period. We also exclude ADRs representing preferred stocks, as their pricing mechanism may be substantially different from common ADRs and ordinary shares. Unlike Eun and Sabherwal (2003), we do not make any exclusions on the basis of trading intensity and liquidity. We aim to investigate the price discovery process and its determinants in the breadth of the sample, not confining it to the most liquid, and hence conceivably largest companies.[3] Altogether, our sample includes 64 companies, 43 from the UK and 21 from France. Table 1 presents basic characteristics of the sample stocks.

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[2] These are British Energy, which changed the ratio from one ADR representing four ordinaries to one ADR representing 75 ordinaries, effective on March 18, 2003, and P&O Princess Cruises (renamed to Carnival), which merged with Carnival Corporation under a dual-listed corporation structure, accompanied by share consolidation and a change in ADR ratio effective on April 21, 2003.

[3] Additionally, for France Telecom, we exclude the period between March 25, 2003 and April 14, 2003 which was the difference between the date of distribution of warrants to holders of ordinary shares and the date of distribution of cash proceeds from the sale of warrants to holders of ADRs. In this period, the price difference between ADRs and ordinary shares

The market capitalisation of individual firms varies from USD 196 million for France's Compagnie Generale de Geophysique to USD 146,975 million for BP. While there is no clear difference in the average size of UK and French sample companies, UK stocks tend to have larger trading volumes in the home and US market. Liquidity in home markets is overwhelmingly larger than in the US in terms of trading volume and number of trades in both UK and French subsamples. Not reported in the table, the sample mean (median) number of shares traded in the US market as a percent of total number of shares traded in both the home and the US market is 4.0% (1.7%) suggesting thin trading in the US for many of the stocks.[4] For only two stocks, BP and France's STMicroelectronics, the NYSE captures more than 20% of total trading volume.

The London Stock Exchange and the Euronext Paris are automated, electronic markets, and the New York Stock Exchange operates as a floor-based market with specialists acting as market makers. There is a two-hour overlap in trading in the three exchanges. It starts at 14:30 GMT (9:30 EST) when the US market opens and lasts until 16:30 GMT (11:30 EST) when both London and Paris exchanges close. The exact overlap between Paris and London makes possible the joint study of these markets, because the results cannot be influenced by different trading designs. Figure 1 depicts trading times in markets covered by the study. Specifically, since we focus on continuous trading only, our price series from the Euronext Paris end at 16:25 GMT, when continuous trading finishes followed by the closing auction. The closing auction in London starts after 16:30 GMT. Because daylight saving time started in Europe one week earlier than in the US, there was a one-hour overlap (15:30-16:30 GMT) from March 30, 2003 to April 6, 2003.

Following a commonly used approach, we form our price series on the basis of equally-spaced midpoints of the best bid and ask quotes. Using transaction prices instead may suffer from the problem of autocorrelation and, moreover, quotes can be updated even if there is no trading. Supporting evidence for that is reported in Table 1, where differences in the

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depended on the price of warrants. Similarly, for Lafarge we exclude the period after June 19, 2003 which was the date of distribution of rights in the local markets only. Proceeds from the sale of these local rights were distributed to the ADR holders at a later date outside our sample period.

[4] The findings are consistent with findings by Halling, Pagano, Randl and Zechner (2004), who document the widespread presence of flow-back towards the home market and a decline in foreign trading to extremely low levels.

frequency of quoting between home and US market are visibly smaller than discrepancies in trading volume and number of transactions. Similarly to Eun and Sabherwal (2003), we set our interval to ten minutes. Each point in our price series represents the average of the last best bid and ask prices within the 10-minute interval. If no change of the best quotes is reported within the interval, the observation represents the last available quotes.

IV. Methodology

A. Testing for Cointegration and Vector Error Correction Modelling

One should expect that the price of an instrument cross-listed in a foreign market does not deviate from the price in the home market. The law of one price, which prevents any arbitrage opportunities in international cross-listings, implies a cointegrating relation and we expect that log home price, P_t^H and log US price P_t^{US} converted to the same currency are cointegrated with a cointegrating vector $\mathrm{B}' = (1 \quad -1)$. In our analysis, we denominate all price series in US dollars and convert local UK and French prices using intra-day exchange rates.

The first step in testing for cointegration involves determining the order of integration of each series. We apply the commonly used Augmented Dickey-Fuller (ADF) test, with the number of lags determined by the Schwarz Bayesian criterion. If the null hypothesis of a unit root cannot be rejected and the series are found to be I(1), we proceed with the multivariate cointegration tests. We use the method developed by Johansen (1988, 1991) and Johansen and Juselius (1990) which tests for cointegration of the series. We expect to find a cointegrating vector, B, of the form described above.

Having tested for cointegration, we proceed with the modelling of dynamics of the pricing process. Vector Error Correction Model (VECM) allows us to explore how the series react to deviations from the long-run equilibrium described by the cointegrating vector. We estimate the following models, where the lag length, p, is chosen by applying the Schwarz Bayesian information criterion:

$$\Delta P_t^H = \alpha_0^H + \alpha^H \left(P_{t-1}^H + \beta^{US} P_{t-1}^{US} \right) + \sum_{i=1}^{p} \delta_i \Delta P_{t-i}^H + \sum_{i=1}^{p} \vartheta_i \Delta P_{t-i}^{US} + \varepsilon_t^H \,, \tag{1}$$

$$\Delta P_t^{US} = \alpha_0^{US} + \alpha^{US}\left(P_{t-1}^{H} + \beta^{US} P_{t-1}^{US}\right) + \sum_{j=1}^{p} \delta_j \Delta P_{t-j}^{H} + \sum_{j=1}^{p} \vartheta_j \Delta P_{t-j}^{US} + \varepsilon_t^{US} . \quad (2)$$

The estimates of α^H and α^{US} provide information on the adjustment of each series to the previous period's deviation from the equilibrium. Either or both home share and ADR prices must respond to departures from the equilibrium to prevent riskless arbitrage opportunities. For instance, if the price in the US market is lower than the price in the home market adjusted for the exchange rate, the US price will increase and the home market price will decrease in the following period to restore equilibrium.[5] Thus, the expected signs of α^H and α^{US} will be negative and positive respectively. The absolute values of α^H and α^{US} show the magnitude of the response of the home and US markets respectively within the first 10-minute interval, and the estimates can be used to infer about the price discovery process by which markets find the new equilibrium price.

We apply a measure of the contribution of each market to price discovery proposed by Schwarz and Szakmary (1994). Intuitively, a market contributes to price discovery if feedback from that market drives prices in the other market. If the total adjustment to restore the equality of prices is reflected by the sum of the absolute values of α^H and α^{US}, then the contribution of a market can be measured by the proportion of the total adjustment which occurs in the other market. Consequently, for every sample company, we define the US market contribution to the pricing process as:

$$\theta = \frac{\left|\alpha^{H}\right|}{\left|\alpha^{H}\right| + \alpha^{US}} . \quad (3)$$

If price discovery occurs in the home market only, there is no feedback provided by the US market and the domestic price does not adjust to prior departures from the equilibrium. Consequently, $\alpha^H = 0$ and $\theta = 0$. On the other hand, if the US market is the exclusively leading one, all the adjustment to the departures takes place in the domestic market and $\theta = 1$.

An alternative approach to the price discovery process is proposed by Hasbrouck (1995). He estimates the market's contribution to the process on the basis of the contribution

[5] It is also possible that i) P^H increases and P^{US} increases more; and ii) P^H decreases but P^{US} decreases less.

of its innovations to total innovations in the common efficient price, represented by the common stochastic trend of the cointegrated system (Stock and Watson, 1988). However, the approach involves Choleski factorisation and leads to non-unique results, as only the upper and lower bounds of the contribution can be estimated. As found by, for example, Hupperets and Menkveld (2002), the range may be substantial. In our analysis we use the Schwarz and Szakmary's (1994) measure, which overcomes this problem and will enable us to proceed with the cross-sectional analysis. Theissen (2002) finds that both measures lead to qualitatively similar conclusions about the markets' contribution to the pricing process.

B. Cross-Sectional Analysis of the US Contribution to Price Discovery

The size of our sample, 64 stocks in total, enables us to examine factors which affect the size of the US market contribution to price discovery by using cross-sectional analysis. Our dependent variable is the logistic transformation of the US market contribution to price discovery, $\ln(\theta/(1-\theta))$. The logistic transformation ensures that the predicted values lie between zero and one, which by definition are the bounds of the contribution. Our main explanatory variables reflect the allocation of non-US stocks to NYSE specialists, since this can affect information asymmetries on the side of specialist and consequently influence the price discovery process. We additionally include a list of control variables which may have an impact on the price discovery process, as have been identified in earlier studies in either formal tests (Eun and Sabherwal, 2003) or intuitively suggested on the basis of limited sample of stocks (Lieberman et al., 1999 and Grammig et al. 2004). The explanatory variables are discussed below.

B.1. Concentration of Foreign Stocks in NYSE Specialists

We expect that the US contribution to price discovery for cross-listed stocks may be influenced by particular allocation of stocks to NYSE specialists. Bacidore and Sofianos (2002) document higher information asymmetry and increased adverse selection risk for market making in non-US stocks. We expect the US market quality to improve and, consequently, the US contribution to the price discovery process to increase as these asymmetries decline. Reduced asymmetries may directly result in posting more competitive bid and offer prices and encourage larger stabilisation rates to dampen noisiness making the prices more informative.

We test the impact of the concentration of stocks in particular specialists on the price discovery, since, according to Bacidore and Sofianos (2002), this may be one of the factors reducing the asymmetries. A specialist with concentrated market making activities in foreign stocks from a given country may have larger incentives to develop better understanding of stock trading in that country by closer linkages with its market and associations with local brokers and dealers. We measure the concentration of non-US stocks on the specialist firm level, as well as on individual specialist level. The associations with local securities firms may be developed by specialist firms, whereas certain understanding, skills and expertise in market making in non-US stocks may be captured by focusing on individual specialists.

The information on allocation of stocks to specialists is provided by NYSE in daily files. The files identify the specialist firm assigned to each security, as well as the trading location of the securities on the floor as described by different posts and panels. There are 18 posts and various alphabetically labelled panels on each post. The individual specialist responsible for each stock is identified by a unique post and panel. On the basis of the file from January 2, 2003, i.e. the beginning of our sample period, we track the number of UK and French companies covered by each of the seven specialist firms and similarly we determine the number of the countries' stocks allocated to each of the individual specialists. We take into account all UK and French stocks traded on the NYSE on that day, including preferred ADRs. In case of multiple issues by the same company, we count them as one.

The identified allocation is presented in Table 2. In the regressions, we use two explanatory variables. One of them stands for the number of companies from the same country handled by the same specialist firm and the other refers to the number of country's stocks covered by an individual specialist. For example, BP is handled by Spear, Leeds and Kellogg Specialists and assigned to individual specialist located in post 1, panel C. Consequently, the variable reflecting the number of companies from the same country covered by the same specialist firm for BP is equal to 16, since Spear, Leeds and Kellogg Specialists make market in 16 UK stocks. The variable reflecting concentration in individual specialist is equal to 4, as the specialist located at 1C handles 4 UK companies.

B.2. Control Variables

B.2.1. Country of Origin

Each regression controls for a company's country of origin by including a dummy variable, which equals to one for British companies and to zero for French ones. There may

be, on average, higher contribution from the US market to pricing of British stocks, because of higher cultural, language and regulatory proximity, which are found to be important determinants of international securities transactions (Tesar and Werner, 1995; Grinblatt and Keloharju, 2001).

B.2.2. Market Capitalisation

We also control for the firm size measured as the logarithm of the average daily market capitalisation (in USD millions) over the sample period. We expect a positive relation between the firm size and US contribution to price discovery, because as found by studies of cross-border stock holdings (e.g. Kang and Stulz, 1997), larger companies tend to be of larger interest to foreign investors. The possible reason for that is increased transparency and limited information asymmetry of such firms.

B.2.3. US Share in Trading Volume

We expect the contribution of the US market to price discovery to be positively related to the share in total trading volume. Higher proportion in total trading is likely to increase efficiency of the market and may indicate informativeness of underlying demand (Stickel and Verrecchia, 1994). As suggested by Foerster and Karolyi (1998), it may also reflect higher competition for order flow by the foreign market, which might make the local market more responsive to the foreign market prices. We define the US market share in total trading volume as the number of shares traded in the US as a percent of the home exchange and US trading volume within the two-hour trading overlap over the whole sample period. Eun and Sabherwal (2003) confirmed the positive relationship.

B.2.4. The Ratio of US and Home Spreads

The price discovery process may also be influenced by relative trading costs in both markets. Since the bid-ask spread represents a major proportion of the trading costs, our attention is focused on the average ratio of quoted spreads in the US to the local exchange bid-ask spreads in the sample period. We expect the US market contribution to the price discovery process to increase when its spreads relative to domestic spreads decline. The lower the spread on the US exchange, the greater the competition from the US market makers and the greater the response of the local markets. Eun and Sabherwal (2003) have found such negative relationship for the Canadian stocks, while Harris et al. (2002) arrived at the same conclusion on the basis of their analysis of the 30 Dow Jones stocks.

B.2.5. ADR Institutional Holdings

In addition to the trading process characteristics of stocks, we include variables which reflect the internationalisation of a company. As suggested by Lieberman et al. (1999) and Grammig et al. (2004), the composition of the shareholders base may be one of the factors. Higher following by institutions based in the US is expected to increase the importance of the US market in the price discovery process, since the larger importance of sophisticated investors may imply more informed trading. We capture this effect by including a variable which is defined as the ratio of ADR holdings by US institutions to the number of shares outstanding.

B.2.6. US Sales

Moreover, we expect the US contribution to price discovery to increase with the US operations of the company. We proxy that with a variable which measures the proportion of US-based sales in total sales of a company, as published in the latest annual report by the end of 2003. A foreign firm which operates in the US market may be better recognised by investors there. Kang and Stulz (1997) document that foreign holdings in Japan are concentrated in export-oriented firms, which are presumably more familiar to foreign investors. Being subject to the competition from rival companies within the US, stock prices of companies with relatively larger US sales are also more likely to incorporate industry wide news on the US exchange and are more sensitive to the US market conditions.

B.2.7. High-Tech Industries

Pagano, Roell and Zechner (2002) suggest that the US analysts and investors have superior expertise in high-tech industries, therefore we can expect more informative trading and higher price discovery in the US for companies from sectors of advanced technologies. We test this by including a high-tech sector dummy which equals to one for electronics, media, pharmaceuticals and healthcare products, telecommunications and semiconductors companies. There are such 21 firms in our sample.

V. Empirical Results

A. Cointegration and Vector Error Correction Models

We perform ADF unit root tests on the levels of two log price series for each sample firm using three different test specifications, i.e. without constant, with a constant and with a constant and time trend. The test in the first specification does not reject the null hypothesis of a unit root at the 5% significance level for any of the firms. We obtain rejections at the 5% level for at least one of the two price series for 6 stocks in the test with a constant, and for 4 stocks in the test with a constant and trend. For differenced series we can reject the null of a unit root at the 1% significance level for all stocks. In the next step we test for cointegration between prices in the home and US market using the Johansen's trace statistic. For all sample stocks, we can reject the null hypothesis of no cointegration.

Cross-sectional descriptive statistics of the estimated cointegrating vectors are presented in Panel A of Table 3. We normalise our estimates by setting β^H equal one. As expected, prices in the home and US market move closely together, and our mean and median estimates of the elements of the cointegrating vector are close to the B vector of the form $\mathrm{B}' = \begin{pmatrix} 1 & -1 \end{pmatrix}$ as indicated by the theory of the law of one price. We find median β^{US} equal to –1.0030. Divergence from the theoretical value of minus one in the case of individual stocks is conceivably caused by transaction costs bounds implying that small divergences cannot be arbitraged away.

Panel B of Table 3 describes estimates of the adjustment coefficients estimated from the Vector Error Correction Models given by formulae (1) and (2). Generally, the average adjustment of home market prices, α^H, is similar in magnitude to the average correction originating in the US market, α^{US}, implying similar contribution of both stock exchanges to the price discovery process. The adjustment of the home market has a negative sign and is significant at the 5% level for 22 out of 64 stocks. α^{US} is significant at the 5% level with a commonly expected positive sign for 31 stocks. For 22 stocks both α^H and α^{US} have the same sign. For eight stocks they are positive and for 14 stocks negative. In those cases one market seems not to be affected by the divergence from equilibrium and does not react to reduce it, and all the correction originates in the other market which makes up for the divergence adjusting more in absolute values.

On the basis of the estimated adjustment coefficient, we calculate the US share in the price discovery process for each of the stocks in our sample as given by formula (3). Since the formula assumes a negative sign of the adjustment coefficient in the home market and positive one for the US, we have to modify it for stocks for which we find adjustment with a sign opposite to the one commonly expected. In those cases we arbitrarily assign 99.9% share

in the price discovery for the non-adjusting market.[6] Descriptive statistics of the US contribution to the pricing process in the whole sample, as well as in various sub-samples are presented in Panel C of Table 3.

On average, the US market contributes nearly a half to the price discovery process. The mean US contribution in our whole sample is 47.3%, with the median of 40.0%. Despite the limited liquidity of the US trading venue compared to the domestic markets as reported in Table 1, feedback from US prices is apparently not negligible. Generally, the US contribution to the pricing process for UK cross-listed stocks is somewhat larger than for French companies. The results may be driven by a set of different trading and fundamental factors though, and any far reaching conclusions cannot be drawn at this stage. We will control for them when we perform multivariate cross-sectional regression analysis. Furthermore, in line with previous studies on different samples, we can observe large cross-sectional variation of the estimated US share in the pricing process. As mentioned earlier, for eight companies we do not find any contribution from the US market. On the other end, virtually all price discovery for 14 originates on the NYSE. The following section focuses on the differences in US market contribution across companies and analyses the impact of stock allocation to NYSE specialists on the pricing process, controlling for determinants identified in earlier studies.

B. Cross-Sectional Determinants of the US Contribution to Price Discovery

Descriptive statistics and correlation coefficients between independent variables of our cross-sectional regressions presented in Table 4 provide further insight into the sample and stock trading characteristics in the home and US market. The findings support the dominant role of the home market in stock trading and document associated narrower spreads on the domestic exchange. We find a strong positive correlation between the US share in total trading volume and ADR institutional holdings, which is not surprising, as one can expect investors in ADRs to induce heavier trading in the US venue. Moreover, the sample companies are found to be export-oriented, with on average about one third of the revenues generated in the US. It is consistent with the finding of Pagano et al. (2002), and may suggest a strong marketing and advertising incentive to cross-list in the US. Considering the relatively

[6] We decide not to assign a 100% share to make it more tractable in further steps involving logistic transformation of the variable.

thin trading in the US, it is presumably a much stronger motivation than the liquidity enhancement.

An important point about the variables reflecting concentration of a country's stocks in a specialist firm and in an individual specialist can be made at this stage. They are negatively correlated with the ratio of quoted spreads in the US and home market. We find that the more UK (French) stocks a specialist trades, the more competitive spreads he quotes, and the reason behind it may be limited adverse selection costs. The finding corresponds with suggestions by Bacidore and Sofianos (2002) of reduced information asymmetries when the firm specialises in companies from given foreign country.

From the technical point of view, high correlations between explanatory variables may lead to multicollinearity when correlated variables are jointly included in regressions. In our sample we find *Log market capitalisation*, *US / Total trading volume*, *US / Home quoted spread* and *DR institutional holdings / shares outstanding* to be correlated between each other with the correlation coefficients in excess of 0.40. Consequently, we run a set of regressions including these variables separately. Additionally, since we have no data on US sales for six companies, we run regressions on the full sample with omitted *US / Total sales* variable and on 58 stocks with available complete data when *US / Total sales* variable is included. The results of alternative regression models are presented in Table 5.

We find support that concentration of foreign stocks in particular NYSE specialists increases the price discovery in the US market relative to the home exchange, also after controlling for various factors which may affect the pricing process. Coefficients of *No. of country's stocks traded by individual specialist* are consistently positive and strongly significant across all model specifications. If information environment has an impact on international stock trading and holdings, as suggested by previous literature, we uncover that it is not only the information on the part of investors which plays a role. We find that the information environment of NYSE specialists is also important and our results lend support that it can be improved by allocating foreign stocks to a specialist who already trades such securities, as mentioned by Bacidore and Sofianos (2002) and Corwin (2004). However, the coefficients of *No. of country's stocks traded by specialist firm* are not different from zero. We interpret this as an indication of the importance of individual skills and understanding of stock trading in international markets, rather than the impact of policies and actions at the specialist firm level. We find that it is the individual NYSE specialist whose personal expertise and experience can lead to better and more informative pricing in the US compared to the home trading venue.

The estimated coefficients of our control variables, *Log market capitalisation*, *US / Total trading volume*, *US / Home quoted spread* and *DR institutional holdings / shares outstanding* are all statistically significant at the 1 percent level and have a priori expected signs. We find strong support that price discovery in the US in relation to Europe increases for larger firms, for companies with larger proportion of trading captured by the US market and with larger share of institutional Depository Receipts holders in the shareholders base. Finally, the negative coefficient of the ratio of quoted spreads in the US and home market indicates that informative trading in the US increases when relative transaction costs decrease. Trading is apparently more informative in liquid markets and in venues where quoted prices are competitive. These findings confirm the results of Eun and Subherwal (2003) for Canadian listings in the US. The significance of size and foreign shareholdings is consistent with the arguments that US markets contributes more to the price discovery when the firm is more transparent and better recognised by US investors. *US / Total sales*, other factor of international exposure, does not yield significant coefficients though. Insignificant coefficients of *UK dummy* and *High-tech sector dummy* variables indicate that, after controlling for other stock and trading characteristics, the firm origin and its sector classification do not impact the price discovery process.

C. Robustness Checks of the Results of Cross-sectional Analysis

We examined whether the results of our cross-sectional analysis are robust by performing various exercises. We tested whether our results depend on the frequency of the sampling interval. We have thus performed the whole analysis using one minute interval instead of ten minutes. Results are shown in Table 6. As it can be seen there are hardly any differences in either the sign or the statistical significance of coefficients. The coefficients relating to the *No. of country's stocks traded by individual specialist* remain statistically significant, in most of the models at the 5 percent level and in a few at the 10 percent level.[7]

We performed another check on our results by explicitly incorporating the exchange rate effects in the pricing process. Grammig, Melvin and Schlag (2004) have pointed out that the bivariate system suffers from a bias towards overstating the information share of the

[7] The results were also invariant to reducing the two hour overlap to one hour by leaving out half an hour at each end to avoid any possible anomalies when the New York market opens and when the European markets close.

market whose price is converted into foreign currency. We thus estimated a trivariate system with an independent role for the exchange rate rather than the bivariate system where the exchange rate is used to convert one price into the same currency as the other price.

We do not find the exchange rate to play an important role in the adjustment process. The average error correction term is small and statistically insignificant, which supports the view that the exchange rate does not respond to inequality of home and foreign prices of individual stocks. There are, however, differences amongst the firms and in some cases the coefficient is statistically significant at the 5% level. The results of the cross-sectional analysis are presented in Table 7. Once again there is no significant change in the results of the variables of main interest.

VI. Conclusions

In this paper, we examine the contribution of the US trading to the price discovery process of non-US stocks. We analyse 64 British and French companies cross-listed on the NYSE over the six-month period from January 2003 through June 2003. The analysis concentrates on the two hour trading overlap between the US and the European exchanges. Our sample is larger than those used in previous studies and its breadth gives us the opportunity to study factors which might affect the contribution of the US market to pricing process. Our main findings are summarised below.

We focus on the impact of concentration of stocks from a given country in NYSE specialists on the price discovery process. As found by Bacidore and Sofianos (2002), making market in non-US stocks is associated with larger information asymmetries and higher adverse selection risk. The concentration may reduce them, since it encourages closer links with non-US stock markets and a better understanding of international stock trading. We find that larger concentration of stocks from a given country at the individual specialist level leads to a larger share of NYSE in price discovery. This we interpret as an indication of the importance of the information environment of specialist traders.

The results remain significant after controlling for other factors which have been found in earlier studies to influence the price discovery process. We confirm that the US market contribution to price discovery is positively related to the share of trading in the US relative to home trading, the ADR institutional holdings and inversely related to the ratio of spreads in the US and home market. Finally, we show that the US market contributes more to price discovery of larger firms. Our findings support the importance of familiarity and

recognition on the side of NYSE specialists and US investors, and the impact of relative liquidity and trading costs. The results have been found to be robust to the frequency of the sampling interval and to the explicit incorporation of the exchange rate in the pricing process.

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Figure 1. Opening Hours of Stock Exchanges under Consideration

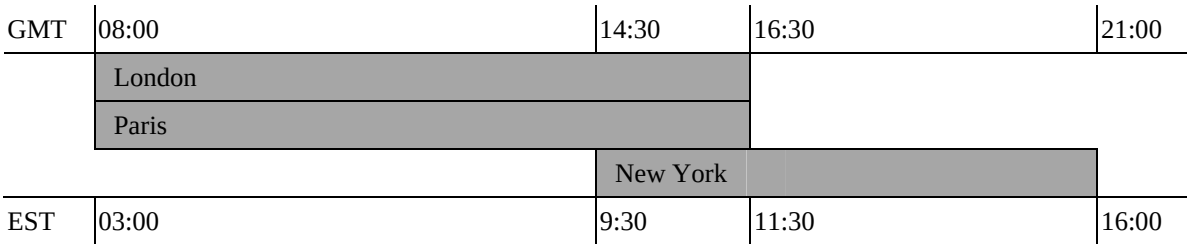

Table 1. Capitalisation of Sample Companies and Main Trading Characteristics within Overlapping Hours

		UK stocks		French stocks		Full sample	
		mean	median	mean	median	mean	median
Capitalisation (USD mil.)		23,471	6,936	17,007	8,525	21,350	7,864
Avg daily trading volume per stock	home	8,606,327	4,231,766	1,293,267	655,134	6,206,729	2,567,093
	US	693,299	66,030	105,804	6,268	500,528	45,488
Avg daily number of trades per stock	home	605	433	1,117	942	773	541
	US	86	30	77	20	83	28
Avg daily number of quotes per stock	home	368	362	563	485	432	388
	US	237	218	256	287	243	224

The sample includes 43 UK and 21 French stocks cross-listed on the New York Stock Exchange from January 1, 2003 through June 30, 2003. All measures are computed for every stock in the sample and then mean and median across the sample and subsamples are calculated. Capitalisation is measured as average daily market capitalisation in the study period. Volume, trades and quotes are counted within the trading overlap between the home and US market. Volume in the US market is adjusted for the ratio of ADR and ordinary shares. Number of quotes is defined as a number of changes in best bid and/or best ask price.

Table 2. Allocation of UK and French Stocks to Specialist Firms and to Posts and Panels on the Trading Floor

Specialist firms	Post & Panel	UK stocks	French stocks
Bear Wagner Specialists, LLC	*Total*	*9*	*0*
	18C	2	0
	18D	3	0
	18E	1	0
	18H	3	0
Fleet Specialist Inc	*Total*	*6*	*6*
	12A	2	0
	12B	0	1
	12C	2	0
	12L	1	0
	12U	1	4
	12V	0	1
LaBranche and Co.	*Total*	*13*	*7*
	6O	0	1
	6R	1	0
	8H	1	2
	8I	2	1
	8J	4	0
	8K	1	1
	9I	1	0
	9N	1	0
	9O	0	1
	9P	2	1
Performance Specialist Group LLC	*Total*	*2*	*0*
	1N	2	0
Spear, Leeds and Kellogg Spec. LLC	*Total*	*16*	*7*
	1C	4	0
	1D	2	3
	1E	3	0
	2F	3	1
	2G	2	0
	2H	0	1
	2J	2	1
	30Y	0	1
Susquehanna Specialists	*Total*	*1*	*1*
	8L	1	1
Van der Moolen Specialists USA LLC	*Total*	*4*	*1*
	10I	3	1
	11A	1	0

The table presents the number of UK and French stocks allocated to specialist firms and to individual specialists within the firms. Individual specialists are identified by unique post and panel locations. The table summarises information on UK and French companies contained in the NYSE *Post & Panel Locations* daily file from January 2, 2003. Given numbers include all companies listing any type or form of equities. Multiple issues by the same company are counted as one.

Table 3. Vector Error Correction Models Coefficients and US Share in Price Discovery

	mean	std deviation	25th percentile	median	75th percentile
A. Cointegrating vector					
β^{H}	1.0000	0.0000	1.0000	1.0000	1.0000
β^{US}	-1.0068	0.0254	-1.0088	-1.0030	-0.9980
B. Adjustment coefficients					
α^{H}	-0.1213	0.1328	-0.2037	-0.0835	-0.0282
α^{US}	0.1232	0.1522	0.0210	0.1193	0.2066
C. US share in price discovery					
UK stocks	0.5143	0.3990	0.1298	0.4911	0.9990
French stocks	0.3878	0.3177	0.1199	0.3020	0.5261
Full sample	0.4728	0.3765	0.1266	0.4004	0.8598

The table presents cross-sectional descriptive statistics of coefficients of Vector Error Correction Models given by formulae (1) and (2) the US share in price discovery estimated on the basis of VECM adjustment coefficients. The sample includes 43 UK and 21 French stocks cross-listed on the NYSE from January 1, 2003 through June 30, 2003.

Table 4. Descriptive Statistics and Correlations between Explanatory Variables

A. Descriptive statistics

	mean	std deviation	25th percentile	median	75th percentile
No. of country's stocks traded by specialist firm	9.4688	4.6937	6.0000	9.0000	13.0000
No. of country's stocks traded by individual specialist	2.3125	1.0522	1.0000	2.0000	3.0000
Log market capitalisation	8.9781	1.5352	7.9791	8.9670	10.0200
US / Total trading volume	0.0399	0.0533	0.0089	0.0165	0.0467
US / Home quoted spread	3.4258	2.4892	1.7622	2.9208	4.4339
DR institutional holdings / shares outstanding	0.0277	0.0301	0.0046	0.0151	0.0490
US / Total sales	0.3386	0.2162	0.1600	0.3300	0.5200

B. Pearson correlation coefficients

	No. of country's stocks traded by spec. firm	No. of country's stocks traded by ind. spec.	Log market cap.	US / Total trading volume	US / Home quoted spread	DR inst. holdings / shares outst.	US / Total sales
No. of country's stocks traded by specialist firm	1.0000	0.3202***	0.1848	0.2481**	-0.3211***	0.3587***	0.2934**
No. of country's stocks traded by individual specialist		1.0000	0.1169	0.0954	-0.2234*	0.2345*	0.1168
Log market capitalisation			1.0000	0.5301***	-0.4773***	0.4125***	-0.3204**
US / Total trading volume				1.0000	-0.4169***	0.7339***	-0.0726
US / Home quoted spread					1.0000	-0.4539***	0.1447
DR institutional holdings / shares outstanding						1.0000	-0.1035
US / Total sales							1.0000

No. of country's stocks traded by specialist firm (individual specialist) for each of the UK (French) sample companies is equal to the total number of UK (French) stocks for which market is made by the same firm (individual specialist) and is calculated as of January 2, 2003. Log market capitalisation is the natural logarithm of the average daily capitalisation (in USD millions) over the sample period. Trading volume is calculated as number of shares traded within overlapping hours over the whole sample period and is adjusted for the ADR:ordinaries ratio. The ratio of US and home quoted spreads is an average in the sample period. Data on ADR institutional holdings come from the 3Q2003 filings. Data on sales come from the latest annual reports published by the end of 2003. ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. The sample includes 43 UK and 21 French stocks cross-listed on the NYSE from January 1, 2003 through June 30, 2003.

Table 5. Determinants of the US Share in Price Discovery with 10-Minute Interval Based on a Bivariate System

	Expected sign	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Constant		-1.81	-3.35***	-3.83***	-16.10***	-4.35***	0.22	-3.94***	-17.14***	-4.31***	-0.36	-4.31***
		(-1.54)	(-3.33)	(-3.32)	(-7.35)	(-3.79)	(0.13)	(-3.31)	(-6.19)	(-3.36)	(-0.22)	(-3.15)
UK dummy	+	0.37	0.56	0.06	0.28	0.84	-1.31	0.02	-0.16	0.59	-1.79	-0.38
		(0.31)	(0.55)	(0.06)	(0.31)	(0.82)	(-1.19)	(0.02)	(-0.17)	(0.54)	(-1.56)	(-0.35)
No. of country's stocks traded by specialist firm	+	0.19		0.11	0.02	-0.03	0.08	-0.02	-0.03	-0.05	0.03	-0.11
		(1.25)		(0.77)	(0.20)	(-0.21)	(0.56)	(-0.12)	(-0.26)	(-0.37)	(0.22)	(-0.71)
No. of country's stocks traded by individual specialist	+		1.38***	1.27***	1.12***	1.20***	1.10**	1.07**	1.53***	1.51***	1.64***	1.44***
			(3.02)	(2.67)	(2.67)	(3.20)	(2.43)	(2.59)	(3.46)	(3.65)	(3.67)	(3.52)
Log market capitalisation	+				1.49***				1.53***			
					(6.09)				(5.43)			
US / Total trading volume	+					39.08***				35.25***		
						(3.75)				(3.31)		
US / Home quoted spread	-						-0.68***				-0.67***	
							(-3.74)				(-3.14)	
DR institutional holdings / shares outstanding	+							61.09***				66.07***
								(4.18)				(4.18)
US / Total sales	+								1.88	-1.23	0.04	0.08
									(0.89)	(-0.60)	(0.01)	(0.04)
High-tech sector dummy	+				-0.17	-0.14	-0.36	0.49	-0.18	0.15	-0.20	1.02
					(-0.17)	(-0.12)	(-0.29)	(0.45)	(-0.17)	(0.13)	(-0.16)	(0.98)
Adjusted R-sq. (%)		2.07	9.92	9.51	35.76	29.54	18.89	23.67	36.92	29.33	22.32	29.84
Number of observations		64	64	64	64	64	64	64	58	58	58	58

The dependent variable is the logistic transformation of the US share in price discovery estimated from the VECM adjustment coefficients. UK dummy is equal to 1 for UK companies and 0 for French companies. No. of country's stocks traded by specialist firm (individual specialist) for each of the UK (French) sample companies is equal to the total number of UK (French) stocks for which market is made by the same firm (individual specialist) and is calculated as of January 2, 2003. Log market cap is the natural logarithm of the average daily capitalisation (in USD millions) over the sample period. Trading volume is calculated as number of shares traded within overlapping hours over

the whole sample period and is adjusted for the ADR:ordinaries ratio. The ratio of US and home quoted spreads is an average in the sample period. Data on ADR institutional holdings come from the 3Q2003 filings. Data on sales come from the latest annual reports published by the end of 2003. High-tech sector dummy is equal to 1 for companies from sectors of advanced technologies, and to 0 otherwise. The sample includes 43 UK and 21 French stocks cross-listed on the NYSE from January 1, 2003 through June 30, 2003. t-statistics of the estimated coefficients based on the heteroskedasticity consistent standard errors are reported in parentheses. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table 6. Determinants of the US Share in Price Discovery with 1-Minute Interval

	Expected sign	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Constant		-2.40***	-2.85***	-3.15***	-9.13***	-3.29***	-0.99	-3.06***	-10.65***	-3.40***	-1.37	-3.39***
		(-4.82)	(-4.33)	(-4.13)	(-4.94)	(-5.02)	(-1.12)	(-4.63)	(-4.97)	(-5.35)	(-1.42)	(-4.86)
UK dummy	+	-0.01	0.19	-0.12	-0.06	0.27	-0.83	-0.20	-0.21	0.24	-1.04*	-0.34
		(-0.01)	(0.41)	(-0.21)	(-0.14)	(0.48)	(-1.51)	(-0.34)	(-0.44)	(0.40)	(-1.80)	(-0.54)
No. of country's stocks traded by specialist firm	+	0.10		0.07	0.04	0.00	0.07	0.01	0.03	0.01	0.07	-0.01
		(1.50)		(1.20)	(0.78)	(0.05)	(1.10)	(0.10)	(0.53)	(0.21)	(0.91)	(-0.15)
No. of country's stocks traded by individual specialist	+		0.53**	0.47*	0.37**	0.40**	0.36*	0.32*	0.49**	0.47**	0.57**	0.44**
			(2.01)	(1.94)	(2.16)	(2.23)	(1.72)	(1.73)	(2.49)	(2.17)	(2.17)	(2.06)
Log market capitalisation	+				0.74***				0.87***			
					(4.01)				(4.02)			
US / Total trading volume	+					21.96***				21.19***		
						(4.68)				(4.05)		
US / Home quoted spread	-						-0.33***				-0.34**	
							(-3.26)				(-2.51)	
DR institutional holdings / shares outstanding	+							35.49***				36.95***
								(3.76)				(3.59)
US / Total sales	+								1.46	-0.26	0.31	0.43
									(1.17)	(-0.19)	(0.17)	(0.31)
High-tech sector dummy	+				-0.60	-0.61	-0.69	-0.26	-0.79	-0.62	-0.76	-0.12
					(-1.18)	(-1.24)	(-1.28)	(-0.56)	(-1.50)	(-1.22)	(-1.31)	(-0.26)
Adjusted R-sq. (%)		1.80	5.30	5.59	34.53	34.49	16.21	27.95	39.08	32.11	17.27	29.15
Number of observations		64	64	64	64	64	64	64	58	58	58	58

Notes: See notes to Table 5.

Table 7. Determinants of the US Share in Price Discovery with 10-Minute Interval Based on a Trivariate System

	Expected sign	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Constant		-1.47	-2.78**	-3.15***	-15.67***	-3.64***	1.20	-3.16***	-17.55***	-3.73***	0.46	-3.71***
		(-1.36)	(-2.64)	(-2.80)	(-7.70)	(-3.65)	(0.74)	(-3.02)	(-6.67)	(-3.24)	(0.28)	(-2.97)
UK dummy	+	-0.27	-0.14	-0.52	-0.34	0.33	-2.00*	-0.61	-0.82	0.06	-2.54*	-1.05
		(-0.22)	(-0.14)	(-0.47)	(-0.36)	(0.32)	(-1.72)	(-0.56)	(-0.80)	(0.05)	(-1.97)	(-0.89)
No. of country's stocks traded by specialist firm	+	0.15		0.09	0.00	-0.07	0.06	-0.05	-0.04	-0.07	0.03	-0.11
		(1.11)		(0.63)	(0.04)	(-0.50)	(0.45)	(-0.31)	(-0.35)	(-0.54)	(0.21)	(-0.80)
No. of country's stocks traded by individual specialist	+		1.14**	1.06**	0.88**	0.96**	0.86*	0.82*	1.31***	1.25***	1.43***	1.22***
			(2.44)	(2.11)	(2.05)	(2.54)	(1.81)	(1.90)	(2.78)	(3.00)	(2.95)	(2.85)
Log market capitalisation	+				1.53***				1.65***			
					(6.19)				(5.82)			
US / Total trading volume	+					44.96***				41.12***		
						(4.39)				(3.82)		
US / Home quoted spread	-						-0.71***				-0.71***	
							(-3.85)				(-3.15)	
DR institutional holdings / shares outstanding	+							65.51***				69.17***
								(5.08)				(4.61)
US / Total sales	+								2.31	-0.94	0.27	0.29
									(1.02)	(-0.42)	(0.09)	(0.13)
High-tech sector dummy	+				-0.55	-0.59	-0.76	0.14	-0.68	-0.38	-0.69	0.59
					(-0.52)	(-0.52)	(-0.58)	(0.12)	(-0.66)	(-0.33)	(-0.53)	(0.53)
Adjusted R-sq. (%)		-0.83	4.98	4.08	32.94	32.44	14.83	21.23	35.84	30.51	18.04	26.21
Number of observations		64	64	64	64	64	64	64	58	58	58	58

Notes: See notes to Table 5.