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Price discovery of cross-listed firms

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ABSTRACT

This paper examines the contribution of cross-listing to price discovery for a unique and comprehensive sample of firms listed abroad. Using an extended measure of the common factor weight, we find that foreign market contribution to price discovery is more important for multiple-listed firms compared to cross-listed ones. Our results also show that US exchanges are more conductive to price discovery than do foreign European markets. On a univariate regression, we find new evidence that order driven markets and those which are more integrated with the world contribute significantly to price discovery of stocks listed abroad. On a multivariate regression, information asymmetry measures seem to have the most important effect on foreign market contribution to price determination.

1. Introduction

With the enhanced globalization of financial markets, an increasing number of companies are listed and traded in overseas markets. When a firm is cross-listed (or cross-traded),[1] a great competition for order flows can occur, and an important question that arises is about the contribution of each market to the price discovery defined as the process by which markets attempt to find equilibrium prices (Harris, McInish, Shoesmith, & Wood, 1995).

In this paper we address the issue of the dynamic of price discovery for firms listed abroad. Dynamic of price discovery has been studied extensively (e.g., Alhaj-Yaseen, Lamb, & Barkoulas, 2014; Chang, Luo, & Ren, 2013; Chen, Choi, & Hong, 2013; Eun & Sabherwal, 2003; Frijns, Gilbert, & Tourani-Rad, 2010; Grammig, Melvin, & Schlag, 2005; Korczak & Phylaktis, 2010; Lok & Kalev, 2006; Otsubo, 2014; Pascual, Pascual-Fustera, & Climent, 2006). In general, the findings indicate that the domestic market is dominant in terms of price determination.

While much research has been carried out on the price discovery of cross-listed firms, some gaps exist in the literature. A first gap arises because most previous research (and even all studies) investigates only stocks listed on two countries or cross-listed stocks (firms with local and one foreign listing), and no attention has been given to price discovery for multiple-listed stocks[2] despite the fact that a substantial number of company shares are traded in multiple overseas markets (You, Lucey, & Shu, 2013). Further, and despite the importance of major European exchanges in attracting foreign companies, little attention has been given to evaluate the competitiveness of these exchanges in terms of price discovery of cross-listed stocks. In fact, most of the earlier studies have concentrated on cross-listing in the US.

In this paper, we try to overcome these gaps by creating a new analytical framework, and contribute to the existing literature in the following areas. Firstly, unlike prior studies which consider only cross-listed firms our sample further includes multiple-listed firms, including listing and admitting to trading in major US and European exchanges. Our second contribution stems from the fact that while part of our analysis is done using error-correction models based on those developed by Harris et al. (1995) and Eun and Sabherwal (2003), our new analytical framework allows us to extend and modify the methodology to take into account the possibility of multiple cointegrating relations in the error correction model. Thus, we propose a new measure to assess the

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[1] It is important to distinguish between cross-listing and cross-trading. Both, cross-listing and cross-trading are in addition to the home market listing and they make a firm's stock accessible to foreign investors. However, cross-listing is different from cross-trading in the way that it is initiated by the company's decision to cross-list its shares on a foreign market and involves a company meeting listing and disclosure requirements of the host foreign stock exchange. A firm is cross-traded when it is admitted to trade on a foreign stock market without meeting the stock exchange's disclosure and listing requirements.

[2] In this study, multiple-listed stocks may be: stocks with multiple foreign listing; stocks with multiple foreign trading; or stocks with at least one foreign listing and one foreign trading.

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contribution of international cross-listing/trading to price discovery of multiple-listed stocks.

Another objective of our study is to analyze the factors that affect the foreign market's contribution to price discovery. Earlier literature concentrates on transaction costs and trading volume measures (see for example Chen et al., 2013; Eun & Sabherwal, 2003; Frijns et al., 2010). Our study further investigates the effect of market structure and market integration. In addition, very few studies investigate the effect of information asymmetry while it was well demonstrated that information asymmetry determines equity prices (see Chan, Menkveld, & Yang, 2008). The only exception is Chen and Choi (2012) who show that market contribution to price discovery of Canadian cross-listed stock is affected by the probability of informed trading. In this study we consider different measures of information asymmetry to analyze their effect on foreign market contribution to price discovery of stocks listed abroad.

Our sample consists of highly traded European and Canadian firms with 45 foreign presences in US exchanges (NASDAQ and NYSE) and European exchanges (Euronext Amsterdam, Euronext Brussels, Euronext Lisbon, Euronext Paris, Frankfort stock exchange and London stock exchange). Using a high frequency intraday data for a short period of trading overlap we find the following results. First, regarding the foreign market contribution to price discovery, we find different results that vary across firms. For cross-listed firms, and consistent with prior literature, we show that the home market is dominant. For the subset of multiple-listed firms, we document a more important role for foreign markets which become dominant in price discovery process. However, we reach the same conclusion for the two subsets of firms regarding the competitiveness of foreign exchanges. Our results show that the US markets are the most important foreign destinations in terms of price discovery compared to the European ones. Finally, the regression analysis shows the following results. On a univariate basis, we find that foreign market's contribution to price discovery is negatively related to transaction costs, and positively related to the duration of foreign listing or admitting to trading. In addition, we provide new empirical evidence and show that order driven markets are more transparent and provide more efficient prices. We also show that foreign markets contribute more to price discovery when they are more integrated with the world. Regarding information asymmetry factors, we find that the probability of informed trading measured by the price impact and the adverse selection component of the bid–ask spread play a significant effect. This effect is far more statistically significant than the other factors on a multivariate regression analysis.

This paper is organized as follows. In Section 2 we review the literature and develop our testable hypothesis. Section 3 describes the data, the methodology and the variables. In Section 4, we discuss the empirical results. Finally, Section 5 concludes.

2. Theories and hypothesis

In this section, we develop our testable hypothesis. First, we analyze foreign market contribution to price discovery of cross-listed and multiple-listed stocks. We then investigate possible determinants of this contribution.

2.1. Assessing market contribution to price discovery

Price discovery is concerned with the adjustments to inter-market information flows and is defined by the process by which markets attempt to incorporate new information. Therefore, the market with more information on the security and which adjust less to a deviation from the equilibrium should contribute more to the price discovery process. Local market is then more likely to be dominant in terms of price discovery as it is the security's home market where substantial information is expected to be produced (Eun & Sabherwal, 2003).

Several studies have tested this hypothesis in the standard setting of cross-listed stocks. The general finding is that both markets contribute to price discovery, that the local market is generally dominant. For instance, Eun and Sabherwal (2003) examine the price discovery process of Canadian firms cross-listed on the US and show that price series are cointegrated and mutually adjusting. Frijns et al. (2010) investigate the dynamic of price discovery for a sample of four Australian stocks cross-listed in New Zealand and five New Zealand stocks cross-listed in Australia and find that the home market is dominant in both cases. More recent studies like Chen et al. (2013) and Otsubo (2014) show that foreign markets significantly contribute to price discovery of cross-listed stocks.[3] Chang et al. (2013) strongly support the informational role played by the foreign share price in pricing the Chinese A-share. However, this informational role is limited in a context of segmented markets. Alhaj-Yaseen et al. (2014) examine the case of firms with foreign US IPOs that subsequently cross-listed in their domestic market and find evidence supporting the dominance of local markets in price discovery. Accordingly, we have the following hypothesis:

H1a. The local market is dominant in price discovery of cross-listed firms.

Studying the contribution of cross-listing in price discovery process becomes more motivating for international stocks with multiple foreign presences. By making the decision to cross-list on a foreign exchange, a company commits to higher levels of disclosure. As a result, enhanced disclosure reduces information asymmetry (Brown & Hillegeist, 2007). Compared to cross-listing, the stock does not commit to additional disclosure requirements after cross-trading. However, cross-traded stocks attract more market participants who try to profit from informed trading and consequently increase the production of stock-specific information and therefore decrease information asymmetry (Glosten & Milgrom, 1985). The reduction in information asymmetry, both for cross-listing and for cross-trading, may be therefore driven by increased stock-specific information production and also by intensified inter-market competition. Consequently, we conclude that, when a stock is cross-listed or cross-traded, more information is generated and lower information asymmetry is created. These benefits are therefore expected to be more important when the firm has additional foreign listing or trading. We have so the following expectation:

H1b. Foreign markets contribute more to price discovery for firms with multiple foreign presences compared to cross-listed firms given that more information are available for market participants.

2.2. Determinants of foreign market's contribution to price discovery

In this section we set our hypotheses regarding the possible determinants of foreign market's contribution to price discovery. We relate these determinants to trading costs, liquidity, duration of cross-listing/trading, market structure, market integration and information asymmetry.

The trading cost hypothesis predicts that price discovery occurs in the market with the lower trading costs. This argument is consistent with earlier studies such as Fleming, Ostdiek, and Whaley (1996) and Frino and West (2003) who show that markets with the lower trading costs attract informed traders and contribute more to price discovery. Harris et al. (1995) find that the NYSE contribution to price discovery is negatively related to its spreads relative to the regionals. Eun and Sabherwal (2003), Frijns et al. (2010) and Korczak and Phylaktis (2010) find that the foreign market's contribution to price discovery of cross-listed firms increases when its transaction costs relative to the local market decline. Thus, we expect foreign market's contribution to price discovery to be inversely related the relative foreign trading costs. As reported by Eun and Sabherwal (2003), the bid–ask spread

[3] Otsubo (2014) examines price discovery in non-overlapping market setting.

represents a major portion of the trading costs. Therefore, our testable hypothesis is the following:

H2a. Foreign market's contribution to price discovery is negatively related to its spread relative to the remaining listing/trading markets.

Hasbrouck (1995) finds a positive and significant relation between the NYSE contribution to price discovery and its market share in trading volume for a sample of 30 Dow stocks trading in the NYSE and the regional exchanges. In the context of cross-listed/traded stocks, and based on the findings of Chen et al. (2013), Eun and Sabherwal (2003) and Frijns et al. (2010), we expect the following relationship:

H2b. Foreign market's contribution to price discovery is positively related to its liquidity on the stock relative to the remaining listing/trading markets.

Eun and Sabherwal (2003) suggest that the duration for which the firm has been listed in the foreign market could affect factors such as analyst coverage and media attention. We have so the following hypothesis:

H2c. Foreign market's contribution to price discovery is positively related to the duration of foreign listing/trading.

Theoretical analyses of comparative advantages of different types of market structures are presented in the models developed by Biais, Thierry, and Franiois (1998), Malinova and Park (2013), Pagano and Roell (1996), and Viswanathan and Wang (2002). Biais et al. (1998) show that prices in order driven markets represent equilibrium prices that equal the marginal valuation of the asset. Similarly, Malinova and Park (2013) show that order driven markets generate more efficient prices. Pagano and Roell (1996) show that transaction costs are generally lower in order driven markets. Empirically, Jain (2003) and Theissen (2000) show that transaction costs are lower and prices are more efficient on order driven markets. Therefore, market structure affects significantly its performance in terms of liquidity, transaction costs and informational efficiency. Informational efficiency measures the speed of convergence toward an efficient price that reflects all available information (Madhavan, 1992). It is a measure of rapprochement of the price to the fundamental value of an asset (Malinova & Park, 2013; Theissen, 2000). Thus, we expect that the contribution to price discovery is affected by market structure. Based on the literature cited above, we set the following hypothesis:

H2d. Order driven market plays a greater role in the price discovery of firms with foreign(s) listing/trading.

It is worth highlighting that market integration and price discovery have remained separate subjects in cross-listing studies. One vein of the literature investigates the issue of market integration for internationally cross-listed securities (Hupperets & Menkveld, 2002; Jithendranathan, Nirmalanandan, & Tandom, 2000; Lok & Kalev, 2006), and another branch in the existing literature relates to the price discovery, and more particularly to market's contribution to price discovery process of cross-listed stocks. Jithendranathan et al. (2000) investigate the effect of market segmentation on the pricing of cross-listed securities using Indian Global Depositary Receipts (GDRs) and find that when markets are segmented, cross-listed securities may trade at different prices. They also find that GDR prices are affected by both domestic and international factors. Using data from 49 countries, Hooy and Lim (2013) show that markets which are more integrated with the world are also more efficient. This implies that stock returns are determined by both local and global factors with the importance of the latter increasing with the degree of world integration. In a similar line, Hsin and Tseng (2012) use a sample of listed common stocks in 29 emerging markets and show that greater market segmentation leads to greater price synchronicity. Therefore, we expect that for cross-listed/traded firms, stock prices are affected by global information, and that foreign market's contribution to price discovery is related to the degree of world market integration. More precisely, if a foreign market is integrated with the world market, its prices respond promptly to global information leading to a faster incorporation of information and greater role in price discovery process. Our hypothesis is provided as follows:

H2e. Foreign market's contribution to price discovery is positively related to its level of integration with world markets.

One possible determinant factor of the foreign market's contribution to price discovery is the informational disadvantage that foreign investors might have on the cross-listed stock. This informational disadvantage affects significantly the investor's reluctance to trade in foreign securities (Brennan & Cao, 1997; Grinblatt & Keloharju, 2001). Chan et al. (2008) show that information asymmetry is priced in international equity markets in that it significantly explains the cross-sectional variation in foreign share discounts. Chen and Choi (2012) find similar results and show that information asymmetry proxy plays an important role in the valuation of Canadian stocks cross-listed in the US. The authors also show that informed trading is more important in the local market resulting in higher Canadian market contribution to price discovery. We have thus the following expectation:

H2f. Foreign market with more informed trades contributes more to price discovery of cross-listed and multiple-listed stocks.

3. Data, methods, and variables

3.1. Data

The intraday data used in this study are from Tickdatamarket. The dataset provided by Tickdatamarket includes the best bid and ask quotes, transaction prices, volume traded along with the time to the nearest even second. For the intraday exchange rate, we use the data collected by Dukascopy Switzerland. Each quote contains a bid and an ask price. Market price index and firm's capitalization are from Datastream. Information about cross-listed and multiple-listed stocks is from stock exchange web sites, bank of New York web site and Datastream.

The aim of this study is to investigate the dynamic of price discovery of stocks listed and traded on US and European exchanges from August 2013 to October 2013.[4] The study period has 64 days for which data are available on Tickdatamarket. We begin our sample selection with those Canadian and European firms that traded on their local markets and cross-listed or cross-traded on US exchanges (NASDAQ and NYSE) and on European exchanges (Euronext Amsterdam, Euronext Brussels, Euronext Lisbon, Euronext Paris, Frankfort stock exchange and London stock exchange). In order to avoid data hole problem and provide sufficient observations for the intraday analysis, we consider the most heavily traded firms in the local as well as in the foreign(s) market(s). Our final sample consists of 33 firms, 7 from the UK, 5 from Canada, 2 from France, 4 from Netherlands, 3 from Spain, 2 from Italy, 2 from Ireland, 2 from Luxembourg, 2 from Switzerland, 1 from Germany, 1 from Greece, 1 from Norway and 1 from Sweden. Table A.1 in Appendix A describes the sample stocks.

3.2. Methodology

In this section, we present our methodology to assess the relative contribution of markets to the price determination process.

The two most established econometric models for testing the contribution to price discovery in multimarket trading setting are the Gonzalo and Granger (1995) and the Hasbrouck (1995) approaches. Hasbrouck (1995) calls the measure of market's contribution to price discovery

[4] The markets do not appear to be particularly noteworthy during this sample period, and results are not subject to specific events in the global financial markets.

process the market's information share which he defines as the portion of the variance of the common efficient price that can be attributed to the market. In the framework of an error correction model, Gonzalo and Granger (1995) formally justify the market's common factor weight that equals the relative magnitude of error correction coefficients. The Gonzalo and Granger model is the most suitable for our analysis as it can be performed without high frequency data required for properly running the Hasbrouck model. Moreover, as discussed in Eun and Sabherwal (2003), the information share computed from the Hasbrouck approach is not unique since they depend on the ordering of the prices. Therefore, they cannot be used to perform our regression analysis.

Our approach to assess the contribution of cross-listing to price discovery is based on an error correction model as follows:

$$\Delta p_t = \alpha_0 + \alpha\beta' p_{t-1} + \sum_{i=1}^{p} A_i \Delta p_{t-i} + e_t \tag{1}$$

where: p_t is a $(n, 1)$ vector of cointegrated price series, n is the number of listing markets, β' is a (r,n) matrix of r cointegrating vectors, α is a (n,r) matrix of error correction coefficients, p is the number of lags and $\alpha = \begin{pmatrix} \alpha_{1_1} & \alpha_{1_2}\cdots & \alpha_{1_r} \\ \vdots & \ddots & \vdots \\ \alpha_{n_1} & \alpha_{n_2}\cdots & \alpha_{n_r} \end{pmatrix}$.

Eun and Sabherwal (2003), Gonzalo and Granger (1995) and Schwarz and Szakmary (1994) were based on the Gonzalo and Granger (1995) approach, and propose to use the relative magnitude of the error correction coefficients to assess the contribution of each market to the price discovery process in the standard case of cross-listed firms, i.e. $n = 2$. According to these earlier studies, the estimate of alphas indicates the extent to which price series respond to deviation from the equilibrium relationship. Similar earlier studies measure the contribution of one foreign market, E, to the price discovery, as the proportion of the total adjustment that occurs at the local market, L, estimated as follows:

$$CM_{L/E} = \frac{|\alpha_l|}{|\alpha_l| + |\alpha_E|}. \tag{2}$$

This measure, given by Eq. (2), is called the common factor weight. A higher value of this ratio reflects a greater contribution of the foreign market E. Our study is different from previous papers, in that our sample includes stocks with multiple foreign market presences ($n>2$) and, possibly, more than one cointegrating vector for the same stock may be detected ($r>1$). Rittler (2011) asserts that the sum of the error correction coefficients measures the total adjustment that occurs in one market. For a *j.th* listing market, this sum is given by:

$$\alpha_j = \sum_{i=1}^{r} \alpha_{ji}. \tag{3}$$

We therefore construct a suitable extension of the common factor weight given by Eq. (2) as follows:

$$SM_j = \frac{\sum_{i=1}^{r} |\alpha_{ji}|}{\sum_{t=1}^{n} \sum_{i=1}^{r} |\alpha_{ti}|}. \tag{4}$$

A low value of this ratio reflects a low price adjustment and therefore a greater contribution of the *j.th* market to the price discovery process.

3.3. Variables

In this section, we describe the dependent and the explanatory variables used in the regression analysis.

3.3.1. Dependent variable

The dependent variable used in the regression analysis is $\boldsymbol{SM_j}$ given by Eq. (4) and which measures the proportion of the total adjustment that occurs at the foreign market j due to the trading of the security in the remaining listing/trading markets (including the local market). A lower value of this ratio reflects a greater feedback or contribution of the foreign market j to the price discovery process.

3.3.2. Explanatory variables

Similar to Eun and Sabherwal (2003), we measure trading costs by the variable Spread as follow: Spread = (Ask − Bid) / ((Ask + Bid) / 2). Our explanatory variable *SpreadRatio* is the ratio of the foreign spread to the remaining market's spreads.

To test the liquidity hypothesis, and similar to Eun and Sabherwal (2003), we measure liquidity by the number of shares traded in the market. Our explanatory variable, *LiquidityRatio* is measured as the number of shares traded in the foreign listing market as a percentage of the total number of shares traded in that stock on the remaining listing/trading markets during our sample period.

To test the duration hypothesis, we use an explanatory variable, *Duration*, measuring the number of years for which a firm has been listed in the foreign market until our sample period.

We investigate the effect of market structure through a dummy variable that equals 1 if the foreign market is order driven and equals 0 if the foreign market is quote driven market. New York stock exchange is a hybrid market, i.e., an order driven with the presence of a broker. In this case, the dummy variable takes the value of 1.

The degree of integration between foreign and world markets is measured by the correlation between foreign index returns and world index returns 3 years preceding our sample period. We use this explanatory variable to test the market integration hypothesis.

Glosten and Harris (1988) report that asymmetric information effect is more likely to be captured by the price impact of a trade. Chan et al. (2008) show that information asymmetry measured by the price impact and the adverse selection component of the bid–ask spread in the A- and B-share markets, are the most important factors that explain the variation in B-share discounts. We use these two measures as explanatory variables in the regression models to test the information asymmetry hypothesis. These measures reflect the extent of private information that is available in the market (Chan et al., 2008). They therefore reflect the intensity of informed traders. A higher price impact and adverse selection for a stock on one exchange reflects a greater proportion of informed traders.

Based on market microstructure models, Chan et al. (2008) construct information asymmetry's measures as follows:

(i) Price impact:

This approach is based on the theoretical models of Easley and O'Hara (1987), Glosten (1987) and Kyle (1985). According to Chan et al. (2008), the change in transaction price is given by:

$$\Delta p_t = \gamma Q_t V_t + \varphi(Q_t - Q_{t-1}) + e_t \tag{5}$$

where:

- p_t is the transaction price at time t.
- γ is the price impact parameter.
- φ is the gross profit component associated with an order.
- Q_t is the trade sign at time t. We use Lee and Ready (1991) algorithm to determine trade sign. A transaction is classified as buyer (seller) initiated if its price is above (below) the prevailing quote midpoint. If a transaction occurs exactly at the quote midpoint, the tick test is employed, i.e. a transaction is initiated by a buyer if its current price is higher than the price of the previous trade, and vice versa. Following Chan et al. (2008), trade sign equals +1 for a buyer-initiated trade and −1 for a seller-initiated trade.

- V_t is the trade size at time t.
- e_t is a public information signal.

Our explanatory variable is $PI = \gamma$, which represents the price impact in the foreign market.

(ii) The adverse selection component of the bid–ask spread:

Chan et al. (2008) assume that the adverse selection and the gross profit components vary over time and are written respectively as follows:

$$\gamma_t = z_0 + z_1 V_t \tag{6}$$

$$\varphi_t = c_0 + c_1 V_t. \tag{7}$$

According to Chan et al. (2008), the change in transaction price is therefore given by:

$$\Delta p_t = c_0(Q_t - Q_{t-1}) + c_1(Q_t V_t - Q_{t-1} V_{t-1}) + z_0 Q_t + z_1 Q_t V_t + e_t. \tag{8}$$

c_0,c_1, z_0 and z_1 are constant parameters. The adverse selection component, AS, is given by:

$$AS = z_0 + z_1 V^* \tag{9}$$

where $V^*$is the median order size.

Our explanatory variable is *AS* given by Eq. (9), and represents the adverse selection component in the foreign market.

4. Empirical results

4.1. Preliminary results

In this section, we first provide details of price series used in our intraday analysis. We then perform a unit root test for prices for each stock to check for non-stationarity. Afterward, we use the Johansen (1988) method to confirm for the cointegration relationship between price series. The presence of cointegrating vectors allows us to estimate error correction models and investigate the dynamic of price discovery.

4.1.1. Price series construction

To perform our intraday analysis, we need to form intraday price series for each stock in each listing market. Our study is typically conducted for short periods during which trading hours overlap.[5] Price discovery analysis can be based on either transaction or quote prices. Using transaction prices instead may suffer from autocorrelation problem induced by infrequent trading. Since quotes can be updated even if there is no trading, we form our price series of the basis of regularly-spaced midpoint of the best bid and ask quotes within 1 min interval and the final quote in each minute is chosen to represent all the quotes during that minute. If no change of the best quotes is reported within the interval, the observation represents the last available quotes. We then convert all prices to the same currency (US $) using the appropriate exchange rate. To do this, we form a series of exchange rates by selecting the midpoint of the last bid and ask quotes at every 1 min interval. Finally, if the firm is cross-listed via American Depositary Receipts (ADRs), stock prices are multiplied by the appropriate ADR ratio. Fig. B.1 in Appendix B depicts graphically price series for selected sample firms.

4.1.2. Unit root test

We use the augmented Dickey–Fuller test on each of the price series to check for the presence of a unit root. The test is based on three specifications, i.e. without constant, with a constant, and with a constant and trend. The results of the ADF test indicate that price series are $I(1)$ for all sample firms.[6]

4.1.3. Cointegration test

As price series are non-stationary and are the prices of the same security, we do not expect them to diverge without bound from each others. We therefore expect that price series are cointegrated. Harris, McInish, Shoesmith, and Wood (2002) employ Gonzalo and Granger (1995) common factor component and show that when price series are cointegrated, they share a common factor as an implicit efficient price that links the stochastic process in the cointegrated markets. In other words, with the arrival of new information that causes a divergence from the law of one price, there will be an inter-market price adjustment due to arbitrage activities that force prices to converge toward an implicit efficient price or a common factor. Therefore, in our case, since we investigate the price behavior of the same security, we expect prices to converge toward a common efficient price. This means that price series of each stock are cointegrated with *r* cointegrating vectors such as $r = n - 1$, where the number 1 represents a one equilibrium efficient price.

We use the Johansen (1988) method to perform cointegration test. Results reported on Table 1 show that for every stock in our sample, the null hypothesis that there is no cointegrating relation between price series is rejected. For cross-listed stocks, the results show that there is one cointegrating vector, which is consistent with prior literature. For multiple-listed stocks, cointegrating vectors are more than one. More precisely, for *n* markets, there is $(n - 1)$ cointegrating vector(s). For example, the stock's price series of the Spanish company "Banco Santander", which is cross-listed on three foreign markets, there is 3 cointegrating vectors. Overall, cointegration test shows that prices of stocks listed abroad converge toward a common equilibrium efficient price.

The fact that there is cointegration relation(s) between price series validates the use of the error correction model, which represents our approach to evaluate foreign market's contribution to price discovery process.

4.2. Main results

In this section, we present our empirical results about market's contributions to price discovery and the regression analysis.

4.2.1. Market's contribution to price discovery

4.2.1.1. Error correction coefficient estimation. The coefficients of main interest measure the total adjustment of the local and foreign exchange(s) to a deviation from the equilibrium relationship. We note α_l, α_E, α_{us} and α_{Eu} the total adjustment that occurs respectively at the local market, all foreign markets, US markets and foreign European markets.

In Table 2, we provide a summary of descriptive statistics of the estimated coefficients for the error correction terms.

The differences in local market's adjustments between cross-listed firms and firms with multiple foreign presences are statistically significant implying different local price adjustments for both firm's groups. For the subset of cross-listed firms, the median value of $|\alpha_E|$ is 0.012 as compared to 0.008 for $|\alpha_l|$, implying that the local market adjust less to a deviation from the equilibrium. For the subset of multiple-listed firms, Table 2 shows that the median value of $|\alpha_l|$ is less than that of $|\alpha_{Eu}|$ but greater than that of $|\alpha_{us}|$. This implies that price determination occurs in the US exchanges, and prices in the remaining markets adjust to American ones. Consequently, we conclude that local

[5] Table A.2 in Appendix A depicts trading times in all markets considered in our study.

[6] Results regarding unit root test can be provided upon request.

Table 1
Cointegration test.

Symbol	ABX	AGN	ALU	APAM	BAMA	BBVA	BIR	BLT	BP	EAD	ENI
First cointegrating vector	[1, −1]	[1, −1]	[1, −1]	[1, −1]	[1, −1]	[1, 0, −1]	[1, 0, −1]	[1, −1]	[1, 0, −1]	[1, −1]	[1, −1]
Second cointegrating vector						[0, 1, −1]	[0, 1, −1]		[0, 1, −1]		
Third cointegrating vector											
Test of r = 0 against r = 1	9.93*	99.3*	56.2*	3035*	107.2*	313.3*	911*	65.5*	379.3*	388.1*	34.5*
Test of r = 1 against r = 2	0.34	0.01	0.94	1.48	0.67	59.6*	102.6*	0.33	82.6*	1.14	1.24
Test of r = 2 against r = 3						3.13	2.99		2.6		
Test of r = 3 against r = 4											

Symbol	ERICB	ETE	G	GSK	INGA	K	MT	NOVN	RBS	RDSA	RIO
First cointegrating vector	[1, −1]	[1, −1]	[1, −1]	[1, −1]	[1, 0, −1]	[1, −1]	[1, 0, −1]	[1, −1]	[1, −1]	[1, 0, −1]	[1, −1]
Second cointegrating vector					[0, 1, −1]		[0, 1, −1]			[0, 1, −1]	
Third cointegrating vector											
Test of r = 0 against r = 1	122.5*	58.5*	64.4*	59.5*	1288*	147.1*	3803*	55.1*	77.9*	226.8*	29.5*
Test of r = 1 against r = 2	0.024	1.28	0.03	0.01	67.1*	0.012	46.3*	0.59	1.21	70.1*	0.63
Test of r = 2 against r = 3					1.14		2.01			0.16	
Test of r = 3 against r = 4											

Symbol	RY4B	SAN	SANT	SIE	STL	STM	TEF	UBS	UNA	VOD	YRI
First cointegrating vector	[1, 0, −1]	[1, −1]	[1, 0, 0, −1]	[1, 0, −1]	[1, −1]	[1, 0, −1]	[1, −0.98]	[1, −1]	[1, −1]	[1, 0, −1]	[1, −1]
Second cointegrating vector	[0, 1, −1]		[0, 1, 0, −1]	[0, 1, −1]		[0, 1, −1]				[0, 1, −1]	
Third cointegrating vector			[0, 0, 1, −1]								
Test of r = 0 against r = 1	40.8*	24.1*	364.6*	135.9*	87.2*	669.1*	51.7*	6.03*	36.6*	152.1*	108*
Test of r = 1 against r = 2	5.9*	0.12	140.8*	57.9*	1.38	91*	0.11	0.024	0.05	44*	0.01
Test of r = 2 against r = 3	0.001		24.4*	1.91		0.56				1.59	
Test of r = 3 against r = 4			2.5								

This table reports the results of the Johansen (1988) cointegration test. All firms are presented by their symbols. For each firm, we present results of the Trace statistic test of r = 0 against r = 1, r = 1 against r = 2, r = 2 against r = 3 and r = 3 against r = 4.
* Denotes the rejection of the null hypothesis at 5% level.

price adjustments are higher for firms with multiple foreign presences compared to cross-listed firms.

4.2.1.2. Measures of market contribution to price discovery. Table 3 provides a summary of descriptive statistics for our new measure of market contribution to price discovery, *SM*.[7] Table 3 shows that the differences in foreign market's contributions to price discovery between cross-listed firms and firms with multiple foreign presences are statistically significant implying different roles of foreign markets in price discovery for the two firm's subsets.

For cross-listed firms, the median value of SM_E is 59.75% as compared to 40.25% for SM_l. This implies that considerable price discovery takes place in foreign markets. However, the local markets are dominant. Results in Table 3 also show that the median value of SM_{US} is lower than SM_{Eu}, implying that US exchanges are more important than their European counterparts in determining security prices. For multiple-listed firms, the median value of SM_l is 38.4% as compared to 17.3% for SM_{US} and to 35.3% for SM_{Eu}. This result shows a more important role for foreign markets in price discovery compared to cross-listed firms. We particularly document the dominance of US markets in price determination for firms with multiple foreign presences.[8] Therefore, our results lead us to accept our hypotheses H1a and H1b. This result may be explained by the fact that US is a leading financial center in the world (Eun & Sabherwal, 2003).[9]

4.2.2. Regression results

To investigate what determines the foreign market contribution to price discovery, we run a regression of the dependent variable on several explanatory ones. Although the data set is rather limited (45 observations), it may provides us with some indications. In addition to the explanatory variables described in Section 3.3.2, we further control for the following ones. Our results presented in Section 4.2.1 show that foreign market contribution to price discovery varies across firms and across exchanges. Therefore, we use a dummy variable that equals 1 if the firm is listed/traded in multiple foreign markets and 0 if it is a cross-listed firm. We also use a dummy variable that equals 1 if the foreign market is a US exchange and 0 if it is a European market. We also control for the firm size measured by the firm's market capitalization at the end of the year 2012.[10] Table A.6 in Appendix A reports a correlation matrix of the explanatory and control variables that indicate that the level of correlations between independent variables is within an acceptable range and, thus, should not cause any bias in the estimation of the determinants of foreign market contribution to price discovery.[11]

In the regression analysis, we try to investigate the importance of the explanatory variables by including them one by one in a model containing the variable "*SpreadRatio*" as a measure of transaction costs and the variable "*LiquidityRatio*" measuring stock market liquidity. These latter explanatory variables were the mainly employed by earlier literature. The results are reported in Table 4 and are as follows.

Looking at the estimation results of all the models reported in Table 4, the coefficients of "*SpreadRatio*" are positive and statistically significant, which is consistent with earlier empirical evidences and with the argument that lower transaction costs in the foreign market attract informed traders resulting in a lower adjustment to a deviation from the equilibrium and therefore a greater contribution to the price discovery process. This result leads us to accept hypothesis H2a. However, we do not find any significant results on the effect of liquidity on

[7] Table A.3 in Appendix A reports the estimation results of market's contribution to price discovery measured by the proportion of the total price adjustment, *SM*.

[8] Our sample is mainly based on cross-listed stocks rather than cross-traded stocks. Therefore, we compute market's contribution to the price discovery measured by *SM*, by excluding stocks which are traded at least in one foreign market. The results remain unchangeable and our conclusion is the same.

[9] To check for the suitability of our new measure of market's contribution to the price discovery *SM*, we compute the standard one $CM_{L/E}$ used by earlier studies. In other words, we re-estimate, for each firm, an error correction model describing the dynamic of prices in the local and only a one foreign market. We do not find any differences in results and our conclusion regarding foreign market contribution to price discovery is the same.

[10] Table A.4 in Appendix A presents definitions and data sources for all the explanatory variables. Table A.5 in Appendix A provides a summary of the explanatory variables.

[11] We also use the variance inflation factor (VIF) criterion and find that the level of correlations among the variables is sufficiently low for multivariate analysis.

Table 2
Summary of error correction terms.

	$\lvert\alpha_l\rvert$	$\lvert\alpha_E\rvert$	$\lvert\alpha_{US}\rvert$	$\lvert\alpha_{Eu}\rvert$
Cross-listed firms				
Mean	0.017	0.059	0.019	0.31
Median	0.008	0.012	0.011	0.1
Max	0.132	0.839	0.08	0.84
Min	0.00026	0.00024	0.00024	0.01
Standard deviation	0.028	0.17	0.022	0.45
Multiple-listed firms				
Mean	0.136	0.081	0.057	0.1
Median	0.028	0.018	0.011	0.0285
Max	0.538	0.49	0.488	0.474
Min	0.0001	0.0001	0.001	0.0001
Standard deviation	0.18	0.15	0.13	0.15
Test (means)	2.9***	0.51	1.22	1.88*
Test (median)	2.3**	0.86	0.34	1

This table provides descriptive statistics of absolute values of the error correction coefficients $\lvert\alpha_l\rvert$,$\lvert\alpha_E\rvert$,$\lvert\alpha_{US}\rvert$ *and* $\lvert\alpha_{Eu}\rvert$ which are the error correction coefficients measuring the total adjustment that occurs respectively in the local market, all foreign listing markets, US markets, and European markets. 'Test" tests whether α for cross-listed firms are different from multiple-listed firms.
*** Denotes significance at 1%.
** Denotes significance at 5%.
* Denotes significance at 10%.

foreign market contribution to price discovery; the coefficients of the variable "*LiquidityRatio*" are statistically insignificant. Therefore, hypothesis H2b cannot be accepted. While this latter result contradicts those of the majority of earlier studies, it is in line with the finding of Korczak and Phylaktis (2010). Our finding may also be explained by the nature of our sample which is mainly concentrated on heavily traded stocks. The first model in Table 4 shows that the coefficient of "*Duration*" variable is negative and statistically significant, implying that the greater the number of foreign listing years, the greater the price discovery in foreign market. Hypothesis H2c is therefore accepted.

Turning to our new explanatory variables, results in Table 4 model 2 show a negative and statistically significant coefficient of the variable "*INTEGG*". This means that a higher level of integration with the world is associated with greater contribution to price discovery. Model 3 also shows a negative and statistically significant coefficient of "*Marketstructure*" variable. This means that differences in market

Table 3
Summary of market contributions to price discovery.

	SM_l	SM_E	SM_{US}	SM_{Eu}
Cross-listed firms				
Mean	38.34	61.65	58.94	78.8
Median	40.25	59.75	58	85.5
Max	86	94	94	86.4
Min	6	14	14	64.7
Standard deviation	0.2	0.2	0.2	0.12
Multiple-listed firms				
Mean	40.76	27.54	16.56	37.6
Median	38.4	22.2	17.3	35.3
Max	81.2	68	35.3	68
Min	3	3	3	12
Standard deviation	0.25	0.19	0.1	0.2
Test (means)	0.3	5.7***	6.6***	3.6***
Test (median)	0.21	4.2***	3.9***	2.4**

This table reports descriptive statistics for SM_l,SM_E,SM_{US},SM_{Eu} which are the contribution to price discovery for respectively the local market, all foreign listing markets, US markets, and European markets. *SM* is given by Eq. (4) and is expressed in percentage. The column "Test" tests whether *SM* for cross-listed firms are different from multiple-listed firms.
*** Denotes significance at 1%
** Denotes significance at 5%.

organizations affect its performance. More particularly, order driven markets are more conductive to price discovery. We can thus accept hypotheses H2d and H2e.

Models 4 and 5 in Table 4 show negative and statistically significant effects of information asymmetry measures on the dependent variable leading us to accept hypothesis H2f. An increase in the proportion of foreign informed traders has a positive impact on foreign market contribution to price discovery process of cross-listed and multiple-listed stocks.

The last column of Table 4 shows the results when we include all the explanatory variables mentioned above and by substituting "*Firm*" and "*Exchange*" dummy control variables. Coefficients of the main variables remain of similar magnitudes and significances. However, information asymmetry measures are far more statistically significant than the others variables.

Regarding the control variables "*Firm*" and "*Exchange*", estimated coefficients are negative and significant which corroborate our finding in the previous section that foreign markets, particularly US exchanges, play a more important role in price discovery for firms with multiple foreign presences. The coefficients on the "*Capitalization*" variable are not significant in all the regressions.

4.3. Robustness tests

In this section, we examine if the results of the regression analysis are robust. One may argue that market reactions to information are different in the period immediately after the USexchange opening and before the European market closing (e.g., Ghadhab & Hellara, 2015; Miller & Morey, 1996). We then re-estimate our new measure of market contribution to price discovery, *SM*, excluding the first and the last 15 min of the trading overlap of each trading day. We find little qualitative difference in our results. We also re-run the regressions by using the standard measure of foreign market contribution to price discovery, *CM*, as a dependent variable. The regression results remain unchangeable. Frijns et al. (2010) and Korczak and Phylaktis (2010) use other measures of liquidity to test the effect of this variable on foreign market contribution to price discovery. As a robustness test, we use the number of trades and volume in value to measure market liquidity. We again do not find any change in regression results. As an alternative information asymmetry measure, we use the volume-synchronized PIN (VPIN) per Easley, Lopez de Prado, and O'Hara (2012) as an explanatory variable, and we don't find any significant effect. Chen, Choi, and Kim (2008) show that trading time differences have a significant effect on the speed of price convergence for cross-listed stocks. Thus, we use a dummy explanatory variable equals 1 if the home and the foreign market are in the same time zone, and 0 otherwise. We don't find any significant effect in the regression analysis. Our regression results are also robust to volatility measures which do not appear as economically and statistically significant. Eun and Sabherwal (2003) show that foreign market contribution to price discovery of cross-listed stocks is positively related to the proportion of its shares traded in the medium-sized lots. As robustness, we check for this effect in the regression analysis but we don't find any significant result. Our results are also robust to the use of the Newey–West robust covariance matrix.

5. Conclusion

In this study, we reconsider the issue of the dynamic of price discovery of firms listed abroad. We use a sample of 33 firms from European and Canadian markets cross-listed/traded on the US and European exchanges. Unlike previous studies, our sample includes cross-listed firms as well as multiple-listed firms. We find that price series are cointegrated and converge toward a common equilibrium efficient price. This result allows us to estimate an error correction model to investigate the contribution of foreign markets to the price discovery of stocks listed abroad. By constructing a suitable extension of the

Table 4
Regression results.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
SpreadRatio	0.012	0.012	0.014	0.012	0.013	0.005
	(5.77)***	(1.99)*	(2.11)**	(5.39)***	(5.69)***	(1.97)*
LiquidityRatio	0.002	0.001	0.001	0.001	0.002	0.001
	(1.65)	(0.62)	(0.63)	(0.76)	(1.34)	(0.79)
Duration	−0.01					−0.004
	(−2.5)**					(−1.75)*
INTEGG		−0.26				−1.15
		(−2.3)**				(−1.8)*
Market structure			−0.09			−0.13
			(−2.01)**			(−1.9)*
PI				−4.88		−5.05
				(−2.54)**		(−5.11)***
AS					−1.22	−1.42
					(−5.42)***	(−3.51)***
Firm						−0.41
						(−8.27)***
Exchange						−0.01
						(−1.9)*
Capitalization	0.022	0.01	0.01	0.012	−0.006	0.01
	(0.66)	(0.35)	(0.36)	(0.33)	(−0.18)	(0.64)
Constant	0.3	0.29	0.19	0.25	0.43	0.77
	(0.8)	(0.83)	(0.54)	(0.63)	(1.06)	(3.23)***
N	45	45	45	45	45	45
R squared	0.3	0.2	0.25	0.15	0.18	0.75
Adjusted R squared	0.2	0.1	0.17	0.1	0.12	0.67

This table provides regression results. The dependent variable is the foreign market contribution to price discovery *SM* given by Eq. (4), "*SpreadRatio*" is the ratio of the foreign spread to the remaining listing/trading market's spreads where Spread = (Ask − Bid) / ((Ask + Bid) / 2). "*LiquidityRatio*" is the number of shares traded in the foreign listing market as a percentage of the total number of shares traded in that stock on the remaining listing/trading markets during our sample period. "*Duration*" is the number of years for which a firm has been listed in the foreign market until the end of 2012. "*INTEGG*" presents the level of integration between foreign and world markets measured by returns market index correlation 3 years preceding our sample period. "*Market structure*" is a dummy variable equals 1 if the foreign market is order driven and equals 0 if the foreign market is quote driven. "*Capitalization*" is the logarithm of the market capitalization of the company at the end of the year 2012. *PI* is the price impact in the foreign market. *AS* is the adverse selection component in the foreign market. "*Firm*" is a dummy variable that equals 1 if the firm is listed/traded in multiple foreign markets and 0 if it is a cross-listed firm. "*Exchange*" is a dummy variable that equals 1 if the foreign market is a US exchange and 0 if it is a European market. **N** is the number of observations. t-statistics are in parentheses below the corresponding parameter estimates.
*** Denotes significance at 1%.
** Denotes significance at 5%.
* Denotes significance at 10%.

common factor weight, we find that both local and foreign markets contribute to price discovery. However, the results differ across firms. For cross-listed stocks, our results show that the local market is dominant. For multiple-listed firms, foreign markets contribute more to price discovery compared to cross-listed stocks and play a dominant role. In addition, we find that the contribution of US exchanges to price discovery is more important compared to the European foreign markets.

We also examine the factors that affect the extent to which the foreign markets contribute to price determination. Consistent with earlier literature, we find that foreign market's contribution to price discovery is greater when its trading costs are lower. Moreover, we find new empirical evidence showing a statistically significant effect of market structure and global integration. Our results further show a greater significant effect of information asymmetry measures compared to the other factors.

The findings of this paper represent international perspectives as they are based on the experience of companies from various countries that are cross-listed/traded in various international stock markets. The sample is also significant in that it represents a substantial portion of stocks with multiple foreign presences. Our analysis also allows an evaluation of the relative competitiveness of European and American exchanges in terms of price discovery of stocks listed abroad.

Our study focuses essentially on developed markets. Thus it would be useful to consider further emerging countries in order to learn more about price discovery of firms listed abroad. We leave this analysis for future research.

Appendix A

Table A.1
Sample description.

Firm's name	Symbol	Local and foreign listing	Cross-listed/cross-traded	Cross-listing/traded type[a]
Cross-listed firms:				
Aegon	AGN	Amsterdam NYSE	Cross-listed	ADR
Alcatel-Lucent	ALU	Paris NYSE	Cross-listed	ADR
Aperam	APAM	Luxembourg Amsterdam	Cross-listed	Direct

Table A.1 (*continued*)

Firm's name	Symbol	Local and foreign listing	Cross-listed/cross-traded	Cross-listing/traded type[a]
Barrick Gold	ABX	Toronto NYSE	Cross-listed	Direct
BHP Billiton plc	BLT	London NYSE	Cross-listed	ADR
Brookfield Asset Management	BAMA	Toronto NYSE	Cross-listed	Direct
ENI	ENI	Milan NYSE	Cross-listed	ADR
Ericsson	ERICB	Stockholm NASDAQ	Cross-listed	ADR
European Aeronautic Defense & Space	EAD	Amsterdam Frankfort	Cross-listed	Direct
Glaxosmithkline	GSK	London NYSE	Cross-listed	ADR
Goldcorp	G	Toronto NYSE	Cross-listed	Direct
Kinross Gold	K	Toronto NYSE	Cross-listed	Direct
National Bank of Greece	ETE	Athens NYSE	Cross-listed	ADR
Novartis	NOVN	Swiss NYSE	Cross-listed	ADR
Rio Tinto	RIO	London NYSE	Cross-listed	ADR
Royal Bank of Scotland	RBS	London NYSE	Cross-listed	ADR
Sanofi	SAN	Paris NYSE	Cross-listed	ADR
Statoil	STL	Oslo NYSE	Cross-listed	ADR
Telefonica	TEF	Madrid London	Cross-listed	Direct
UBS	UBS	Swiss NYSE	Cross-listed	ADR
Unilever NV	UNA	Amsterdam NYSE	Cross-listed	ADR
Yamana Gold	YRI	Toronto NYSE	Cross-listed	Direct
Multiple-listed firms:				
Arcelormittal	MT	Luxembourg Amsterdam NYSE	Cross-listed Cross-listed	Direct ADR
Banco Bilbao Vizcaya Argentaria	BBVA	Madrid London NYSE	Cross-listed Cross-listed	Direct ADR
Banco Santander	SANT	Madrid London Lisbon NYSE	Cross-listed Cross-listed Cross-listed	Direct Direct ADR
Bank of Ireland	BIR	Irish London NYSE	Cross-listed Cross-listed	Direct ADR
BP plc	BP	London Frankfort NYSE	Cross-traded Cross-listed	Direct ADR
ING Groep	INGA	Amsterdam Brussels NYSE	Cross-listed Cross-listed	Direct ADR
Royal Dutch Shell A	RDSA	London Amsterdam NYSE	Cross-listed Cross-listed	Direct ADR
Ryanair Holding	RY4B	Irish London NYSE	Cross-listed Cross-listed	Direct ADR
Siemens	SIE	Frankfort London NYSE	Cross-listed Cross-listed	Direct ADR
StMicroelectronics	STM	Milan NYSE Paris	Cross-listed Cross-listed	ADR Direct
Vodafone	VOD	London Frankfort NASDAQ	Cross-traded Cross-listed	Direct ADR

[a] Company's shares may be listed or traded in foreign markets either directory or by issuing Depositary Receipts (DR) which represents a specified number of company's shares. American Depositary Receipts (ADR) are Depositary Receipts issued in US markets.

Table A.2
Opening hours of stock exchanges under consideration.

GMT	08:00	14:30		16:30	19:00	21:00
Athens	10:00	16:30	17:30			
Euronext	09:00	15:30		17:30		
Frankfort	09:00	15:30		17:30		
Ireland	08:00	14:30		16:30		
London	08:00	14:30		16:30		
Luxembourg	09:00	15:30		17:30		
Madrid	09:00	15:30		17:30		
Milan	09:00	15:30		17:30		
Oslo	09:00	15:30		17:30		
Stockholm	09:00	15:30		17:30		
Swiss	09:00	15:30		17:30		
NASDAQ, NYSE		09:30		11:30		16:00
Toronto		09:30		11:30		16:00

Table A.3
Market contributions to price discovery.

Symbol	ABX	AGN	ALU	APAM	BAMA	BBVA	BIR	BLT	BP	EAD	ENI
SM_I	52	43	58	13.6	44.5	62	81.2	13.4	25	35.3	30
SM_{US}	48	57	42		55.5	15.8	3	86.8	17.3		70
SM_{Lon}						22.2	15.8				
SM_F									57.7	64.7	
SM_{Ams}				86.4							
SM_{Pa}											
SM_{lis}											

Symbol	ERICB	ETE	G	GSK	INGA	K	MT	NOVN	RBS	RDSA	RIO
SM_I	44	86	22	47.6	50	15	36	38.5	85	38.4	28.6
SM_{US}	56	14	78	52.4	4.3	85	32	61.5	15	23	71.4
SM_{Lon}											
SM_F											
SM_{Ams}							32			38.6	
SM_{Pa}											
SM_{Lis}											
SM_{Br}					57.7						

Symbol	RY4B	SAN	SANT	SIE	STL	STM	TEF	UBS	UNA	VOD	YRI
SM_I	3	42	16.4	11.8	39	68	14.5	44	41.5	56.6	6
SM_{US}	11.6	58	3.6	35.3	61	18.7		56	58.5	17.6	94
SM_{Lon}	55.4		68	52.9			85.5				
SM_F										25.8	
SM_{Ams}											
SM_{Pa}						13.3					
SM_{Lis}			12								

This table reports the estimation results of the market's contribution to price discovery measured by the relative total price adjustment. SM_I,SM_{US},SM_{Lon},SM_F,SM_{Ams},SM_{Pa},SM_{Lis} and SM_{Br} are the contribution for respectively the local market, the US markets, the London stock exchange, the Frankfort stock exchange, Euronext Amsterdam, Euronext Paris, Euronext Lisbon and Euronext Brussels. *SM* is given by Eq. (4) and is expressed in percentage. All firms are presented by their symbols.

Table A.4
Explanatory variables.

Variable	Definition	Data source
SpreadRatio	The ratio of the foreign spread to the remaining listing/trading markets spread where Spread = (Ask − Bid) / ((Ask + Bid) / 2)	Dataset from Tickdatamarket
LiquidityRatio	The number of shares traded in the foreign listing market as a percentage of the total number of shares traded in that stock on the remaining listing/trading markets during the sample period	Dataset from Tickdatamarket
Duration	The number of years for which a firm has been listed in the foreign market until the end of 2012.	Stock exchange web sites, bank of New York web sites and Datastream.
INTEGG	The level of integration between foreign and world markets measured by returns market index correlation 3 years preceding our sample period.	Datastream
Marketstructure	Dummy variable equals 1 if the foreign market is order driven and equals 0 if the foreign market is quote driven	Dataset
PI	The price impact in the foreign market	Dataset from Tickdatamarket
AS	Adverse selection component in the foreign market	Dataset from Tickdatamarket
Firm	Dummy variable that equals 1 if the firm is listed/traded in multiple foreign markets and 0 if it is a cross-listed firm.	Sample dataset
Exchange	Dummy variable that equals 1 if the foreign market is a US exchange and 0 if it is a European market.	Sample dataset
Capitalization	The logarithm of the market capitalization of the company at the end of the year 2012	Datastream

Table A.5
Descriptive statistics of the dependent and the explanatory variables.

	SM	*Spread ratio*	*Liquidity ratio*	*Duration*	*INTEGG*	*Market structure*	*PI*	*AS*	*Firm*	*Exchange*	*Capitalization*
Mean	0.44	2.3	22.58	13.2	−0.07	0.84	−0.001	0.006	0.51	0.66	10.4
Median	0.52	0.72	12.5	13	−0.09	1	2.26E−6	−3.4E−7	1	1	10.8
Max	0.94	41.5	83	39	0.03	1	0.001	0.26	1	1	12.08
Min	0.03	0.003	0.001	1	−0.11	0	−0.033	−0.002	0	0	7.06
Standard deviation	0.26	6.55	23.9	7.1	0.04	0.36	0.005	0.03	0.5	0.47	1.28

This table provides descriptive statistics of the dependent and the explanatory variables. The dependent variable, *SM*, is the foreign market contribution to price discovery. "*SpreadRatio*" is the ratio of the foreign spread to the remaining listing/trading market's spreads where spread = (Ask − Bid) / ((Ask + Bid) / 2). "*LiquidityRatio*" is the number of shares traded in the foreign listing market as a percentage of the total number of shares traded in that stock on the remaining listing/trading markets during our sample period. "*Duration*" is the number of years for which a firm has been listed in the foreign market until the end of 2012. "*INTEGG*" presents the level of integration between foreign and world markets measured by returns market index correlation 3 years preceding our sample period. "*Market structure*" is a dummy variable equals 1 if the foreign market is order driven and equals 0 if the foreign market is quote driven. *PI* is the price impact in the foreign market. *AS* is the adverse selection component in the foreign market. "*Firm*" is a dummy variable that equals 1 if the firm is listed/traded in multiple foreign markets and 0 if it is a cross-listed firm. "*Exchange*" is a dummy variable that equals 1 if the foreign market is a US exchange and 0 if it is a European market. "*Capitalization*" is the logarithm of the market capitalization of the company at the end of the year 2012.

Table A.6
Correlation matrix.

	Spread ratio	*Liquidity ratio*	*Duration*	*INTEGG*	*Market structure*	*PI*	*AS*	*Firm*	*Exchange*	*Capitalization*
SpreadRatio	1	−0.18	−0.01	−0.15	−0.44	0.004	−0.015	−0.12	−0.29	0.11
LiquidityRatio		1	0.13	0.17	0.13	0.14	−0.13	−0.2	−0.29	0.11
Duration			1	0.13	−0.02	−0.17	−0.1	0.26	−0.09	0.12
INTEGG				1	0.36	−0.12	−0.14	0.15	−0.53	−0.003
Marketstructure					1	−0.29	−0.07	−0.29	0.47	−0.04
PI						1	0.02	−0.14	0.2	0.01
AS							1	0.14	−0.22	0.11
Firm								1	−0.4	0.12
Exchange									1	0.02
Capitalization										1

This table describes a correlation matrix of the explanatory variables. "*SpreadRatio*" is the ratio of the foreign spread to the remaining listing/trading market's spreads where spread = (Ask − Bid) / ((Ask + Bid)/2). "*LiquidityRatio*" is the number of shares traded in the foreign listing market as a percentage of the total number of shares traded in that stock on the remaining listing/trading markets during our sample period. "*Duration*" is the number of years for which a firm has been listed in the foreign market until the end of 2012. "*INTEGG*" presents the level of integration between foreign and world markets measured by returns market index correlation 3 years preceding our sample period. "*Market structure*" is a dummy variable equals 1 if the foreign market is order driven and equals 0 if the foreign market is quote driven. *PI* is the price impact in the foreign market. *AS* is the adverse selection component in the foreign market. "*Firm*" is a dummy variable that equals 1 if the firm is listed/traded in multiple foreign markets and 0 if it is a cross-listed firm. "*Exchange*" is a dummy variable that equals 1 if the foreign market is a US exchange and 0 if it is a European market. "*Capitalization*" is the logarithm of the market capitalization of the company at the end of the year 2012.

Appendix B

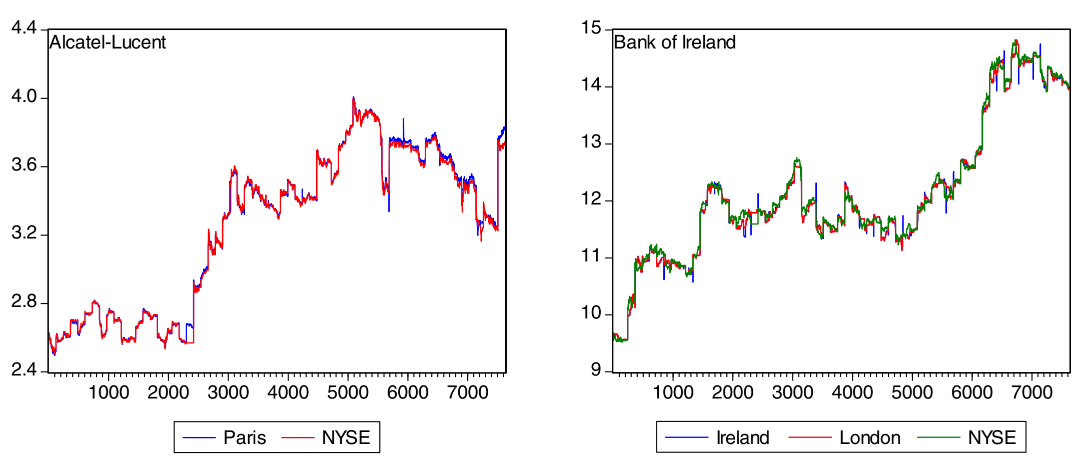

Fig. B.1. Price series. This figure depicts graphically price series for selected sample firms: Alcatel-Lucent and Bank of Ireland.

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