Multi-market Trading and Liquidity: Evidence from Cross-listed Companies [1]

by

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We examine the relationship between cross-listed stock-pair price differentials and their liquidity for a large sample of international firms whose shares are traded both in their home market and on a U.S. stock exchange through either an American Depository Receipt (ADR) or ordinary shares programs. Using a sample of 650 firms from 18 countries for the period 2 January 1997 to 29 December 2012, we exploit the decimalization (the change in the minimum tick size) as a quasi-natural experiment and find that higher liquidity is associated with lower ADR (ordinaries) premium. Also we document a positive relationship between liquidity and price discovery as well as a liquidity effect on the price convergence between the ADR and the underlying stock. We identify two possible mechanisms through which liquidity affects price convergence: institutional trading and stock's holding costs. The results are consistent with the notion that institutional trading lessens deviations from parity whereas holding costs impede arbitrage.

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Abstract:

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1. Introduction

As of 2013, there are over 500 non-U.S. firms listed on the New York Stock Exchange. It is now a well-documented fact that when a firm's shares trade simultaneously on multiple exchanges, there may be more than one price for the same stock. For example, Kaul and Mehrotra (2007) provide evidence that economically significant price disparities do exist for stocks cross listed in New York and in Toronto. These differentials are net of estimated transaction costs; and traders have opportunities to save money or earn arbitrage profits by sending orders to the foreign market. Gagnon and Karolyi (2010) also report wide-ranging price differentials for cross listed pairs of international firms. This apparent departure from the law of one price has generated considerable interest in both academia and the Finance industry.

Non-U.S. stocks are listed in the US as either American depositary receipts (ADRs) or as ordinary equity[2]. Although considerable number of studies have analyzed the deviations from price parity, the questions of how ADR (ordinaries) premium, price convergence and price discovery change over time and how liquidity affects this change remain largely unexplored. Schultz and Shive (2010) find that one-sided trades correct most of the mispricing of dual-class shares. This is contrary to the conventional perception that arbitrage trading, such as a long-short strategy, is the main driver that corrects price discrepancies between pairs of similar assets. This suggests, in the context of cross-listing, that the shares' home markets and hosting markets (the US markets in our study) may play different roles in the pricing dynamics of the pairs, including the occurrence of mispricing and the subsequent resolution. Schultz and Shive also argue that the more liquid share class is responsible for the mispricing most of the time. However, the relationship between liquidity and ADR premium is less clear. Asset pricing literature[3] suggests that illiquidity depresses asset prices and leads to higher expected returns. Based on this thinking, US and home market liquidities have opposite effects on ADR premium. High liquidity in the US market increases ADR price and its premium, while high illiquidity in the home market

[2] ADRs are negotiable certificates traded in the US market that represent claims against the home-market shares held by a custodian bank. The certificate traded in the United States for a cross-listed ordinary is identical to the one traded in the home market.

[3] For example, Pastor and Stambaugh (2003), Amihud (2002), and Acharya and Pedersen (2005).

depresses home share price, thus increases ADR premium. Alternatively, based on the thinking that trades concentrate in more liquid assets and the trades can be either one-sided or in pairs, high liquidity in both US and home market are associated with lower ADR premium and faster convergence after mispricing.

Our study leads to several interesting findings. Our first set of results examines the determinants of the cross-sectional variation in the ADR (ordinaries) premium. We document a liquidity-ADR premium relationship. We show that a higher premium is associated lower US and home market liquidity. This result is consistent with the notion that illiquidity impedes arbitrage, which is reflected by larger ADR premium but inconsistent with Chan et al (2008) who find that higher US liquidity increases the ADR price and therefore leads to a higher ADR premium.

The question of whether stock liquidity has a positive or negative effect on the ADR premium has been difficult to test due to the simultaneity between liquidity and the ADR premium. Liquidity may affect the premium but the premium could also affect liquidity. To address this simultaneity we run tests during a period surrounding an exogenous shock to liquidity - the decimalization (change in the minimum tick size) - using a difference-in-differences (hereafter, DiD) approach[4]. Previous research has documented evidence that decimalization has narrowed bid-ask spreads and lowered the price impact of trades in the US stock market. We show that firms with a larger increase in liquidity due to decimalization experience a bigger drop in ADR premium than those with a smaller increase in liquidity. For example, firms with an increase in liquidity in the top tercile of the sample due to decimalization experience 12.69% lower ADR premium following decimalization than matched firms of similar characteristics but with an increase in liquidity in the bottom tercile. Overall, our identification tests suggest that stock liquidity has a negative causal effect on the ADR premium.

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[4] We perform the same estimation methods using a provision in the 2003 United States dividend tax cut. Specifically, this provision extends the US dividend tax cut (15%) internationally but only to a subset of dividends from companies located in certain foreign countries. Dividends from companies located in non-tax treaty countries continued to be taxed at the marginal income tax rate (35%). This policy change generated a reallocation of US institutional capital and significantly increased liquidity in dividend-paying stocks domiciled in tax-treaty countries (Desai and Dharmapala (2010)). The results from the DiD estimation based on the 2003 dividend tax cut remain the same as our baseline results. They are available on request.

Our second set of results examines the effect of liquidity on the extent to which the U.S. stock market contributes to the price discovery of cross-listed non-U.S. shares. Previous studies have documented mixed results with respect to whether the price discovery predominantly occurs in the home market, with the prices in the foreign market adjusting to the home market. Su and Chong (2007), for example, examine Chinese firms listed on both the Hong Kong Stock Exchange (SEHK) and the NYSE and find that the average information share is 89.4% for the SEHK. However, Eun and Sabherwal (2003) find that the U.S. stock market plays a significant role in the price discovery process for the Canadian cross-listed stocks. Similarly, Frijns et al. (2010) examine cross-listings in Australia and New Zealand, and find that the larger, Australian, exchange dominates price discovery. We estimate an error-correction model for the stock-pair prices and analyze the factors that affect the extent of the U.S. stock market's contribution to price discovery. For our sample, the U.S. market contributes more to the price discovery than the home market. Our cross-sectional regression analysis shows that there is a positive effect of liquidity on price discovery with the liquidity effect in the U.S. market being much stronger than for the home market. The home country stock market development and shareholder rights also play an important role in explaining the cross sectional variations in the contribution to price discovery.

Our third set of results comes from a duration analysis that examines the impact of liquidity on the conditional probability that cross-listed pair prices converge. We document evidence that the duration of the deviations from price parity, accounting for trading costs, is shorter for more liquid stocks. While there could be many different ways through which liquidity may affect price convergence, we concentrate on examining the effect of institutional ownership and stock's holding costs. Our results show that institutional trading amplifies the effect of liquidity and lessens deviations from parity whereas large holding costs impede arbitrage even for liquid stocks.

Our results remain the same when we control for the effect of the 2008 Financial Crisis and the financials short sale ban in all our regression models. Finally, we compare the liquidity effect for firms cross-listed as ADRs versus those cross-listed as ordinary equity. Our results suggest that the liquidity effect on the ADR (ordinaries) premium is not significantly different for the two types of securities.

Our paper adds to the literature that examines the relationship between cross-listing and market liquidity. Cross-listing is pursued for various reasons such as the improved access to larger capital markets and the lower cost of capital, enhanced liquidity, and better corporate transparency and governance provisions as some of the motives for cross-listing (see Karolyi (2006) for a survey of this literature). As previous studies suggest, however, cross-listing does not guarantee a more liquid trading environment for the firm's shares nor does the new competition for order flow among different markets necessarily improves efficiency and price discovery. Often fragmentation between competing markets can also lead to large deviations from price parity. The literature on the liquidity effects in asset pricing has shed light on the size and variation of the ADR (ordinaries) premium (see Chan et al (2008) and Amihud, Mendelson and Pedersen (2005) for a survey).

Earlier studies also show that the cross-listing decision itself has a liquidity impact although the direction varies across markets and time periods. Noronha et al. (1996) examine the liquidity of NYSE/AMEX listed stocks and find that there are increases in informed trading and trading activity after the stocks are listed overseas. However, spreads do not decrease because the increase in informed trading increases the cost to the specialist of providing liquidity. In contrast, Foerster and Karolyi (1998) find that Toronto Stock Exchange listed stocks have narrower spreads in the domestic market after they are cross-listed on a U.S. exchange. They attribute the decrease in trading costs to the increased competition from the U.S. market makers. Similarly, Moulton and Wei (2010) find narrower spreads and more competitive liquidity provision for European cross-listed stocks due to availability of substitutes. In contrast, Berkman and Nguyen (2010) examine domestic liquidity after cross-listing in the U.S using a matched sample of non-cross-listed firms to control for contemporaneous changes in liquidity and find that there are no improvements in home market liquidity due to cross-listing.

We also contribute to the literature on limits to arbitrage in international equity markets. Gagnon and Karolyi (2010) empirically investigate whether the variation in the magnitude of the deviations from price parity for cross-listed stocks is related to arbitrage costs. Their findings suggest that the deviations are positively related to holding costs, especially idiosyncratic risk, which can impede arbitrage. Their study, however, focuses on the magnitude of the deviation from parity for cross-listed price pairs. It does not identify the determinants of the variations in the persistence and duration of such price deviation.

Domowitz et al. (1998) show that the market quality of cross-listed stocks depends on the degree to which markets are linked informationally. For markets that are sufficiently segmented, trading costs are higher for cross-listed stocks due to greater adverse selection associated with arbitrageurs who exploit pricing differences across these segmented markets at the expense of less-informed liquidity providers. In addition, different trading rules and regulations across markets may have an impact on liquidity providers trading non-U.S. stocks. For example, affirmative and negative obligations imposed upon the NYSE specialist may be particularly burdensome for specialist trading non-U.S. stocks. Also, differences exist between minimum tick sizes, priority rules, and insider trader restrictions and regulations for US and non-US stocks. Our empirical results support the liquidity hypothesis where increases in the US market liquidity are associated with decreases in the ADR (ordinaries) premium.

The reminder of this paper is organized as follows. In Section 2, we describe our data sources, discuss sample details and presents summary statistics. Section 3 examines whether differences in liquidity in the home and US markets have effects on the stock-pair price differentials. Section 4 begins with preliminary data analysis, including unit root and cointegration tests and then presents the estimates from a vector error correction model (VECM). Based on these estimates, we examine the cross-sectional variation in the price discovery process. In Section 6, we carry out a duration analysis of the stock-pair price convergence and examine the mechanisms through which liquidity affect the ADR and the underlying stock price convergence. Section 7 concludes.

2. Data and Summary Statistics

Our data sources are Datastream, CRSP, TAQ Consolidated Trades and Compustat databases; and the sample period is 2 January 1997 to 29 December 2012. We identify the stocks in our sample by searching the complete list of foreign companies listed on their home market as well as on a U.S. stock exchange as of January 2013. The foreign listings include both active and inactive issues at the time of the search, and are either in the form of American Depositary Receipts or in the form of ordinary equities. We remove all issues without home market security code and issues that are described as preferred shares, perpetual capital security, trust, unit, right, or fund. Our analysis includes only listed (Level II and Level III) ADRs and ordinaries.

We collect daily home-market closing prices from Datastream for the sample stocks [5]. We set the home-market price as missing when there is no trading or no price reported for a particular trading day, or when a series becomes inactive in Datastream due to restructuring, delisting, or other events. We match each home-market price with a U.S.-market price. For stocks for which the home market and the U.S. market close at the same time, i.e. Canadian, Mexican and Brazilian stocks, we collect daily U.S.-market closing prices from Datastream. For the majority of the firms in our sample, however, the home market closes before the U.S. markets do. To synchronize the home-market price and the U.S.-market price, we use the TAQ Consolidated Trades database to obtain intraday trading price for the foreign listings on the U.S. market. We use the intraday U.S. price with time ticker closest to and within 30 minutes after the home market closes. The synchronization is imperfect as trading hours of stock markets in Asian Pacific countries and in the U.S. do not overlap with at least 12-hour time difference between the two regions. As stock markets in the Asian Pacific region close before stock markets in the U.S. open, we use the U.S. market trading price closest to and within 30 minutes after U.S. market opens. [6] We adjust all U.S.-market prices by their ADR ratios so that they are comparable to the underlying equity's home-market prices. Finally, we check the Bank of New York Mellon

[5] All variables are in U.S. dollars to avoid currency conversion when comparing the domestic values with the issue's U.S. counterpart. In line with the previous literature, we treat exchange rates as exogenous.

[6] Gagnon and Karolyi (2010) use a similar methodology to synchronize home-market and U.S.-market price pairs.

Corporation's DR Directory and J.P. Morgan adr.com as additional information sources to verify ADRs and fill in ADR ratios when these ratios are missing from Datastream. Since ADR ratios are only available at the end of the sample period, we check the ADR premium/discount for each firm to spot abnormal patterns that indicate possible ratio changes. When we do, we search for news announcements and/or security filings to identify the events of ratio changes and manually correct the old ADR ratios. Finally, we drop 13 firms from the sample as we are not able to identify ratio changing events or due to missing ADR ratios.

We also remove observations from countries with less than five ADRs since we require some within-country cross-sectional variation to estimate the effect of country-level characteristics. We also remove stocks with less than 30 consecutive price observations during our sample period in order to obtain a long enough time series to estimate a vector error-correction model. After removing all stocks with missing price data, our final sample consists of 650 firms from 18 countries for the time period from 2nd January 1997 to 29th December 2012. We use Datastream to collect daily series of equity market index for home market; for example, Argentina Merval Index for Argentina, S&P TSX for Canada, Topix index for Japan, as well as the S&P 500 as the equity index for the US market. Finally, we obtain firm-level accounting data from Compustat, number of price estimates by analysts from I/B/E/S, and institutional holdings from Thomson Reuters 13F. Table A1 in the Appendix to this paper reports the distribution of sample firms by country and presents some county-level characteristics. Table A2 in the Appendix contains the description of all the variables used in our empirical analysis.

Next we discuss some summary statistics for our sample of cross-listed firms. To minimize the effect of outliers, we winsorize all variables at the top and bottom 1% of each variable's distribution. Panel A of Table 1 presents summary statistics of the cross-listed securities. On average, ADRs are traded at a premium of 2.36% percent (the median ARD premium is 0.09%) relative to their underlying home market prices. The mean cross-listed firm in our sample has ADR shares outstanding that represent 17.55% of its home market equity while the median has 3.73%. In terms of trading volume, typically more shares are traded in the U.S. market, although the variation in the ratio of U.S.-market volume over home-market volume is very large.

Panel B presents descriptive for the liquidity measures of the cross-listed stocks for both the US market and the home market. We report descriptive statistics for the four most commonly used liquidity measures: (i) the ratio of the bid-ask spread over the bid-ask midpoint; (ii) the natural logarithm of daily volume over shares outstanding (log turnover); (iii) the natural logarithm of absolute daily return over dollar volume[7] (the Amihud illiquidity measure); and (iv) the number of zero return days over the number of trading days[8]. The p values from the t test for differences in means provide a simple way to compare the US and the home market liquidity. Even though bid-ask spreads are significantly different at 5%, the difference is not large and economically significant with the average spread of 2.37% in the US market and 2.33% in the home market. The t statistic for turnover is consistent with the result on trading volume in Panel A of Table 1, i.e. on average the U.S. market has higher turnover than the home market. The Amihud's illiquidity and zero-return measures, on the other hand, suggest a (statistically and economically) higher liquidity for the home market. The home market is characterised by more consistent trading as for the average cross listed stock, 9.59% percent of the trading days have no trading activity, whereas in the US market, the percentage is 15.70%.

Panel C presents firm-level characteristics. The distribution of the size of the sample cross-listed firms, as measured by both total assets and sales is highly skewed. The average firms have $9,490 million in total assets and $4,857 million in sales; the median firms has $911 million in total assets and $623 million in sales. Also on average the cross-listed firms in our sample has 16.97% leverage as measured by the long-term debt-to-assets ratio and -3.59% profitability as measure by the net income-to-assets ratio. The rest of the paper discusses our formal tests of the effect of liquidity on multi-market trading.

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[7] If the dollar volume is missing, we use closing price multiplied by the number of shares traded to proxy for the value of the dollar volume.

[8] Lesmond, Ogden, and Trzcinka (1999) use the percentage of days with zero returns as a proxy for illiquidity.

3. ADR premium and liquidity

This section presents our first set of results. We examine the cross-sectional variation in ADR (ordinaries) premium and in particular the effect of liquidity on its size. Chan et al (2008) report a positive relationship between the premium and the ADR's liquidity, and a negative relationship between the premium and the liquidity of the underlying share in the home market. The authors argue that high liquidity in the ADR market increases the price of the ADR and its premium. Similarly, high illiquidity in the home market depresses the price of the home share, and thus increases the ADR's premium.

In our baseline model, we examine the cross-sectional differences of the ADR premium and the effect of stock liquidity, firm and country characteristics. Our first regression model is:

$$Premium_{it} = a_i + \gamma_1 Liquidity_{it} + \gamma_2 FX\ premium_{it} + \gamma_3 \Delta Equity\ return_{it}^{Home}$$
$$+ \gamma_4 Firm\ factors_{it} + \gamma_5 Country\ factors_{it} + \varepsilon_{it} \quad (1)$$

where $Premium_{it}$ is i[th]'s stock-pair premium. $Liquidity_{it}$ is a vector of liquidity measures for both the US and the home market discussed in Section 2, $FX\ premium_{it}$ is the one-month forward premium (discount) on the home foreign currency, $\Delta Equity\ return_{it}^{Home}$ is the most recent one month change in the return of the home market equity index[9], $Firm\ factors_{it}$ and $Country\ factors_{it}$ are vectors of firm-specific and country-specific characteristics discussed below[10]. We estimate equation (1) both in level and in differences in order to account for the persistence in our liquidity measures. The results are not materially different.

Investing in an ADR is effectively taking a position in foreign stock markets. Therefore, expectations of future exchange rate changes and foreign equity returns are

[9] We chose not to use the forward equity return as a possible proxy for expectations about the future stock market performance because of the relative stationarity of the interest rates. The proxy will be a scaled version of the spot return.

[10] To estimate (1) with panel data, we note that there is an important difference in the properties of the liquidity measures and firm and country factors. The variables that measure the liquidity of the stock-pairs vary from one month to the next, while the vector of firm characteristics vary annually and the vector of country characteristics do not change very much over the sample period.

potentially important factors in ADR (ordinaries) pricing[11]. We use the 1-month forward premium (discount) to proxy for expected future exchange rate changes. All exchange rates are defined as the number of units of the foreign currency per U.S. dollar, i.e. a positive exchange rate change indicates a depreciation of foreign currency, while a negative change indicates appreciation. We expect that currency appreciation will have a positive effect on the ARD premium.[12] Similarly, increases in the home market equity return will have a positive effect on the ADR premium.

Next, we control for the greater risks of asymmetric information (analysis coverage and institutional holding) and limits to arbitrage (idiosyncratic volatility) associated with ADR investment. We also include the log of ADR size[13], profitability and leverage as additional controls.

Finally, we use country dummy variables as a catch-all variable for all country-specific variables as well as a number of country-level characteristics to account for the home country's openness (as measured by intensity of capital controls, the transparency and credibility of its accounting standards, the efficacy of its judicial system, corporate governance variables such as anti-director rights), as well as its market restrictions (See Tables A1 and A2 for details).

Table 2 reports the results from the estimation of equation (1). We estimate OLS regressions with standard errors clustered at the firm level. The coefficients of the liquidity measures have the expected sign and is statistically significant even when we control for firm and country level characteristics. An increase in the US market liquidity results in a decrease in the ADR (ordinaries) premium. The effect is large and economically significant. For example from column (II), one standard deviation increase in the US bid-ask spread results in 2.64% increase in the ADR premium, which is large compared to the mean of 2.36% and the median of 0.09%. Although, the effect is not so strong for the home market liquidity,

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[11] This argument presumes some transaction costs, currency restrictions or other frictions that make it costly or difficult to speculate directly or hedge the risk of exchange rate movements.
[12] This means that the sign for the forward premium measure is expected to be negative.
[13] Size has been widely accepted as an important factor in most liquidity based asset pricing models. See Pastor and Stambaugh (2003) and Acharya and Pedersen (2005).

there is some evidence that increase in the home market liquidity also increases the ADR (ordinaries) premium.

The effect of liquidity on the premium remains significant when we control for information asymmetry and limits to arbitrage. The signs of these controls are as expected. Increase in analyst coverage and institutional holdings (asymmetric information) decrease the ADR premium whereas an increase in the idiosyncratic volatility (our proxy for limits to arbitrage) increases the ADR premium. The foreign exchange premium and the stock market development of the home country, on the other hand, have a negative effect on the premium.

We extend the analysis of Chan et al (2008) to address the endogeneity between stock liquidity and ADR (ordinaries) premium by using the introduction of decimal trading in 2001 as an exogenous shock to liquidity in the US market[14]. The conversion to decimalization was completed by January 29, 2001 for NYSE and AMEX and by April 9, 2001 for NASDAQ. Previous studies have documented an increase in trading volume and reduction of bid-ask spreads after the reduction in minimum tick size (see Bacidore, Battalio and Jennings, 2002)[15]. To address the endogeneity between stock liquidity and ADR premium, we use the difference-in-difference approach to determine the effect of a change in US market liquidity on ADR premium.

The difference-in-difference approach has the advantage that it excludes omitted trends that are correlated with stock liquidity and ADR premium in both the treatment and the control groups. Also the DiD approach helps establish identification as tests are conducted around periods of policy changes that cause exogenous variation in the change in liquidity (the main independent variable). Finally, with the inclusion of firm fixed effects we can control for unobserved differences between the treatment and the control groups. For example, management quality or governance provisions could be correlated with both

[14] Chan et al (2008) use pooled OLS regression without controlling for unobservable firm-specific effects or endogeneity issues.

[15] Prior empirical work has also used decimalization as a shock to liquidity to study corporate governance (see Gerken, 2009, Bharath 2013, Fang 2009 etc.) and firm innovation (see Fang et al. 2014).

stock liquidity and the ADR premium and may drive the negative relationship between them.

To construct a treatment group and a control group, we calculate the change in ADR liquidity from the pre-decimalization year after the decimalization.[16] We sort the cross-listed firms into terciles based on the change in liquidity. The top 103 firm - tercile is the treatment group, representing the firms that are affected by the decimalization the most and have experienced the largest increase in liquidity. The bottom 103 firm - tercile is the control group, consisting of the firms that are affected by the decimalization the least and have the smallest increase in liquidity[17]. Finally, we employ a propensity score matching algorithm to identify matches between firms in the top tercile and firms in the bottom tercile. We first estimate a probit model based on the 206 sample firms in the top and bottom terciles. The dependent variable is equal to one if the firm-month belongs to the treatment group (top tercile) and zero otherwise. The probit model includes firm and country-level control variables from equation (1). These variables are included to help satisfy the parallel trends assumption as the DiD estimator should not be driven by differences in firm or country specific characteristic. Tests of the balancing property of the propensity score matching shows that the assumption is satisfied.

We estimate the following regression:

$$\begin{aligned} Premium_{it} = {} & a + \theta_1 Treatment_i + \theta_2 Decimalization_t \\ & + \theta_3 Treatment \times Decimalization_{it} + \gamma_1 Liquidity_{it}^{Home} + \gamma_2 FX\ premium_{it} \\ & + \gamma_3 \Delta Equity\ return_{it}^{Home} + \gamma_4 Firm\ factors_{it} + \gamma_5 Country\ factors_{it} + \varepsilon_{it} \end{aligned} \quad (2)$$

where $Treatment_i$ is one is a firm is in the treatment group, and $Decimalization_t$ is one for post-decimalization period. The other variables are the same as in equation (1).

Table 3 reports the estimation results from equation (2), with three model specifications. The results show that, compared to control firms, treatment firms have

[16] We design the DID test in the spirit of Fang et al. (2014).

[17] We have only 103 firms in each tercile because not all firms in the sample have observations both before and after the 2001 change to decimalization.

smaller ADR premium after a positive shock to stock liquidity. Specifically, column (II) of Table 3 shows that firms with an increase in liquidity in the top tercile of the sample due to decimalization experience 12.69% lower ADR premium following decimalization than matched firms of similar characteristics but with an increase in liquidity in the bottom tercile. This causal effect of liquidity on the ADR premium remains significant when we control for information asymmetry and limits to arbitrage. The signs of these controls are the same as our baseline results in Table 2. Increase in analyst coverage and institutional holdings (asymmetric information) decrease the ADR premium whereas an increase in the idiosyncratic volatility (our proxy for limits to arbitrage) increases the ADR premium. The foreign exchange premium and the stock market development of the home country, on the other hand, have a negative effect on the premium. The next section investigates the effect of home and US market liquidity on the process of price discovery.

4. Price discovery and liquidity

In the second part of the study, we examine the price discovery process of a cross-listed stock's home-U.S. price pair. We test for (long-run) conversion of the pair of stock prices by estimating an error correction model to assess the impact of liquidity on the speed of conversion to the long-term co-integration relation. The estimates of the error correction coefficients show how the home market and the U.S. market contribute to price discovery. Our hypothesis is that liquidity has an important effect on price convergence that explains the cross sectional variation in the speed with which the cross-listed stock's home-market price and U.S.-market price adjust toward the long run parity.

We begin with preliminary analysis of whether or not the home and U.S. price series are cointegrated. The home-U.S. price pair has to be cointegrated since a pair of cross-listings represents the prices of the same underlying stock and even though the price-pair may temporarily deviate from parity, such deviations should be quickly corrected as market participants take advantage of the arbitrage opportunities. The results from Augmented Dickey-Fuller unit root tests for the order of integration of the ADR price, home market underlying stock price, US equity index, and home market equity index series, show that for most price series and stock market indices, the null hypothesis of a unit root cannot be rejected at conventional significance levels[18].

Panel A of Table 4 displays the mean and median values for the number of cointegration vector at 95% and 99% confidence level from Johansen's cointegration tests. As the table shows, the majority of the cross-listed stocks in the sample have one cointegration vector. In addition, when we sort stocks in portfolios based on their liquidity, the rank test results are the same for each portfolio sorted by each of the liquidity proxies. The median value is one for all portfolios and the means are not significantly different at conventional levels. Our result suggests that liquidity is not driving the results from our cointegration tests.

The next step is to examine the speed of price convergence using an error correction model. We estimate the following model for each firm i.[19]

$$\Delta p_{i,t}^{H} = \alpha_i^{H}\left(\beta_i^{H} p_{i,t-1}^{H} + \beta_i^{US} p_{i,t-1}^{US} + \beta_i^{Hindex} p_{i,t-1}^{Hindex} + \beta_i^{USindex} p_{i,t-1}^{USindex}\right) + \gamma_i \Delta p_{i,t-1}^{H} + \delta_i \Delta p_{i,t-1}^{US} + \theta_i \Delta p_{i,t-1}^{Hindex} + \vartheta_i \Delta p_{i,t-1}^{USindex} + a_i^{H} \quad (3)$$

$$\Delta p_{i,t}^{US} = \alpha_i^{US}\left(\beta_i^{H} p_{i,t-1}^{H} + \beta_i^{US} p_{i,t-1}^{US} + \beta_i^{Hindex} p_{i,t-1}^{Hindex} + \beta_i^{USindex} p_{i,t-1}^{USindex}\right) + \gamma_i \Delta p_{i,t-1}^{H} + \delta_i \Delta p_{i,t-1}^{US} + \theta_i \Delta p_{i,t-1}^{Hindex} + \vartheta_i \Delta p_{i,t-1}^{USindex} + a_i^{US} \quad (4)$$

$$\Delta p_{i,t}^{Hindex} = \alpha_i^{Hindex}\left(\beta_i^{H} p_{i,t-1}^{H} + \beta_i^{US} p_{i,t-1}^{US} + \beta_i^{Hindex} p_{i,t-1}^{Hindex} + \beta_i^{USindex} p_{i,t-1}^{USindex}\right) + \gamma_i \Delta p_{i,t-1}^{H} + \delta_i \Delta p_{i,t-1}^{US} + \theta_i \Delta p_{i,t-1}^{Hindex} + \vartheta_i \Delta p_{i,t-1}^{USindex} + a_i^{Hindex} \quad (5)$$

$$\Delta p_{i,t}^{USindex} = \alpha_i^{USindex}\left(\beta_i^{H} p_{i,t-1}^{H} + \beta_i^{US} p_{i,t-1}^{US} + \beta_i^{Hindex} p_{i,t-1}^{Hindex} + \beta_i^{USindex} p_{i,t-1}^{USindex}\right) + \gamma_i \Delta p_{i,t-1}^{H} + \delta_i \Delta p_{i,t-1}^{US} + \theta_i \Delta p_{i,t-1}^{Hindex} + \vartheta_i \Delta p_{i,t-1}^{USindex} + a_i^{USindex} \quad (6)$$

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[18] Results from the unit root tests are available upon request.

[19] We use Bayesian information criteria to choose the optimal lag order. For most of the firms, a lag order of one is optimal so we estimate the model with one lag.

We expect that the home price and the U.S. price of a cross-listed stock to be very close to one another, i.e. long-run conversion. With β_i^H normalized to 1, we expect β_i^{US} to be insignificantly different from -1, β_i^{Hindex} and $\beta_i^{USindex}$ insignificantly different from 0.

Panel B of Table 4 reports the estimated coefficients for the cointegration vector. The mean of β_i^{US} is -0.9689 and median is -0.9994. The t-test shows that the sample mean is not significantly different from -1. The estimates for the other two coefficients, β_i^{Hindex} and $\beta_i^{USindex}$, are not significantly different from zero. Overall, the results are as expected; the median of normalized cointegration vector estimates is (1, -1, 0, 0), i.e. there is long-run convergence of the home-market price and the U.S.-market price for our sample of the cross-listed stocks.

The main parameters of interest are the short-run coefficients, α_i^H and α_i^{US}. These coefficients show how each price responds to a divergence of the home-market price and the U.S.-market price. α_i^H indicates how the home-market price adjusts to a previous divergence between the price pair; α_i^{US} indicates how the U.S.-market price adjusts to a previous divergence between the price pair. We expect the sign of α_i^H to be negative and the sign of α_i^{US} to be positive, given our specification of the cointegration vector $\beta_i = (\beta_i^H, \beta_i^{US}, \beta_i^{Hindex}, \beta_i^{USindex})$.[20]

Panel C of Table 4 presents the results for the coefficients of the error correction model. For our sample overall, the signs of α_i^H and α_i^{US} estimates are as expected: α_i^H is negative; and α_i^{US} is positive. The mean firm in our sample has a short-term correction coefficient α_i^H of -0.4840, and α_i^{US} of 0.3595. This means that when home market price is higher than U.S. market price by one dollar, home market price subsequently decreases by 48 cents and U.S. market price increases by 36 cents. α_i^H measures the U.S. market contribution to the price discovery, because it is the extent to which home market price responds to information (a deviation from home market price) provided by the U.S. market

[20] This is because we expect larger price correction when the magnitude of divergence between a home-U.S. price pair is larger. Consider the case where $P_{i,t-1}^H > P_{i,t-1}^{US}$, and $\left(\beta_i^H p_{i,t-1}^H + \beta_i^{US} p_{i,t-1}^{US} + \beta_i^{Hindex} p_{i,t-1}^{Hindex} + \beta_i^{USindex} p_{i,t-1}^{USindex}\right) > 0$. We expect that (1) $P_{i,t}^H$ goes down, $\Delta p_{i,t}^H < 0$, thus $\alpha_i^H < 0$; or (2) $P_{i,t}^{US}$ goes up, $\Delta p_{i,t}^{US} > 0$, thus $\alpha_i^{US} > 0$. Similar results can be obtained by considering the case where $P_{i,t-1}^H < P_{i,t-1}^{US}$. For more details see Eun and Sabherwal (2003).

price; in turn, α_i^{US} measures home market contribution to the price discovery. Our results show that both the U.S. and the home markets react to deviations from parity, and that both markets contribute to price discovery. The magnitudes of α_i^{H} and α_i^{US} are different implying that the extent of the U.S. and the home market contribution to the price discovery process is different. Even though the U.S. market contributes more to the price discovery than the home markets for both the mean and the median firms, there is substantial variation. This finding helps to explain the mixed results of previous studies with respect to the relative importance of the US market in the price discovery process.

In order to analyse the effect of liquidity on the speed of convergence, we examine the cross-sectional variations in the magnitudes of α_i^{H} and α_i^{US}. We use seemingly unrelated regressions to jointly estimate the following two equations:

$$\left|\alpha_i^{H}\right| = a_0 + a_1 Liquidity^{US} + a_2 Firm\, factors + a_3 Country\, factors + \epsilon_1 \quad (7)$$

$$\left|\alpha_i^{US}\right| = b_0 + b_1 Liquidity^{H} + b_2 Firm\, factors + b_3 Country\, factors + \epsilon_2 \quad (8)$$

The firm and country factors in (7) and (8) are the same as the control variables discussed in section 3. Our hypothesis is that liquidity has a positive effect on the speed of correction to long-run parity.

Table 5 reports error correction coefficients for portfolios sorted by liquidity measures. P1 is the least liquid portfolio; P4 is the most liquid one. In panel A, firms in the sample are sorted by home market liquidity, because α_i^{US} measures home-market contribution to price discovery and is likely to be affected by the home-market liquidity. The relationship between α_i^{US} and home-market liquidity appears less consistent, although t-tests show that the magnitudes of the error correction coefficients differ between portfolios. In panel B, firms are sorted by our measures of U.S. market liquidity. There is a monotonic relationship between α_i^{H} and the U.S. market liquidity. The most liquid portfolio, as measured by all four proxies, has the largest error correction coefficient in absolute value. The U.S. market contributes more to the price discovery for firms with higher stock liquidity in the U.S. market.

Next, we analyze the impact of stock liquidity on the convergence to price parity in cross-sectional regressions, i.e. equations (7) and (8). Table 6 presents the estimates from the model. The results suggest that liquidity have an important effect on the price convergence that explains the cross sectional variation in the speed with which the cross-listed stock's home-market price and U.S.-market price adjust toward the long-run parity. The signs of the estimation coefficients are as expected. The more liquid the ADR (underlying stock) is, the faster the convergence to price parity.[21] For example, with one standard deviation increase in turnover, α_i^H increases by approximately 0.24 and α_i^{US} by approximately 0.14. The effect is even larger for the other measures. For example, one standard deviation decrease in the Amihud illiquidity measure, increases α_i^H by approximately 0.41 and α_i^{US} by approximately 0.20.

The rest of our control variables also have the expected signs. Profitability and leverage have a significant negative effect on price convergence whereas size has a significant positive effect. Foreign exchange rate volatility and equity market volatility have a negative effect, whereas the shareholder rights index, the stock market development index and the legal origin of the home country do not have a significant impact. The next section provides duration analysis of the speed of price convergence.

5. Duration analysis

In the last part of the study, we carry out a duration analysis on the conditional probability that the price – pairs converge. We examine the relationship the price changes of cross-listed stocks on home and the U.S. market liquidity measures and control variables. In particular, we analyze how liquidity affects the time spell, during which a price pair deviates from parity before the two prices converge. We use a standard Cox regression framework to estimate the coefficients in a proportional hazard function.

[21] Smaller values of percentage spread, Amihud illiquidity and zero-return day and larger value of turnover represent higher level of stock liquidity. So we expect that the coefficients of spread, Amihud and zeros have negative sign, and the coefficient for turnover has positive sign.

The first step is to convert the sample into time-to-event data. The "failure event" here is the convergence of a cross-listed firm's pair of prices. We calculate the percentage price differential as

$$price\ diff_{i,t} = \frac{abs(p_{i,t}^{H} - p_{i,t}^{US})}{(p_{i,t}^{H} + p_{i,t}^{US})/2} \qquad (9)$$

When the price differential is small and/or trading costs are large, it may not be worthwhile for investors to trade to take advantage of the deviation from parity. For investors using long-short strategy, there are two times round trip transaction costs, position open and close on both long and short side. For investors taking either long or short position, there are at least one round trip transaction costs, position open and close. In order for investors to trade on the price disparities, the benefits from the trades need to exceed at least one round trip transaction costs. We consider a price pair diverges when the price differential is larger than estimated round trip trading costs. Grundy and Martin (2001) calculate the raw and risk-adjusted returns of a zero investment momentum trading strategy and estimate that a 1.5% round trip costs would make the profits insignificant. Mitchell and Pulvino (2002) assess the effect of transaction costs on risk arbitrage portfolio returns. By comparing the return series of Value Weighted Average Return portfolio and Risk Arbitrage Index Manager portfolio, they approximate a 1.5 percent reduction in annual return by direct transaction costs (commission, surcharges, taxes) and another 1.5 percent reduction by indirect transaction costs (price impact). Kaul and Mehrotra (2007) estimate trading costs of a sample of cross-listed firms using effective spreads. They estimate a median spread of 1.2 percent on NYSE and Nasdaq, and 0.8 to 1.5 percent on TSX. Given the results of these studies, we assume a 1.5 percent roundtrip trading costs. We assign a value of 1 to the "event" dummy variable when price diff in equation (9) is smaller than 1.5 percent, and a value of 0 otherwise. Domowitz et al (2001) and Chakravarty et al (2011) estimate equity market trading costs for different countries. We use country-specific trading costs to define the "event" dummy. The results remain the same[22].

[22] The results are available on request.

Then we estimate a Cox proportional hazard model following the specification

$$h(t) = h_0(t)e^{(A_{it})} \quad (10)$$

where $h(t)$ is hazard ratio, $h_0(t)$ is baseline hazard and the explanatory and control variables are in A_{it}, which is specified as follows:

$$A_{it} = a_i + \gamma_1 Liquidity_{it} + \gamma_2 Firm\,factors_{it} + \gamma_3 Country\,factors_{it} + \varepsilon_{it} \quad (11)$$

where the firm and country specific control variables are the same as in equation (1).

Table 7 presents the estimation results from our duration analysis. We document evidence that the duration of the deviations from price parity is shorter for more liquid stocks. The coefficients are as expected, i.e. negative and significant for the spread and the Amihud illiquidity measure, and positive and significant for turnover. The effect is also economically significant with one standard deviation increase in U.S.-market turnover associated with approximately 4.3% increase in the conditional probability of price convergence, and one standard deviation increase in home-market turnover associated with approximately 4.7% increase in the conditional probability of convergence. We obtain similar results when we use the Amihud illiquidity measure as a proxy for stock liquidity. The number being 4.5% for the U.S. market and 5.3% for the home market.

The results for our control variables are consistent with the estimation results of equation (1) and equations (7) and (8). Profitability and size have a positive effect on the hazard ratio, whereas idiosyncratic volatility has a negative effect. Home-market (U.S.-market) idiosyncratic volatility is the standard deviation of the residuals of the home-market (U.S.-market) return regressed on the home-market (U.S.-market) index return. Interestingly, only the home-market idiosyncratic risk significantly affects the hazard ratio. The coefficients for U.S.-market idiosyncratic risk do not display a significant impact. The relative importance of the home- and the U.S.-markets is reversed when looking at the overall market volatility. The U.S. equity market volatility has a significantly negative effect on the hazard ratio, whereas the home equity market volatility does not have a significant effect. Consistent with previous results, foreign currency volatility has a negative effect on the conditional probability of price convergence.

Finally, we explore the mechanisms through which liquidity may affect the cross-listed pair price convergence. Table 8 reports the results of our duration model augmented with the interaction terms between stock liquidity and (i) institutional ownership; (ii) idiosyncratic volatility (our proxy for holding costs). We conjecture that for stocks with high institutional ownership, the liquidity effect on the price convergence will be weaker than for stocks with low institutional ownership. Institutional investors' trades are a major source of liquidity. Often institutional investors act as the classical 'noise' traders who trade for portfolio rebalancing and risk-sharing reasons but not for arbitrage motives. These "noise" trades provide liquidity, but may not help restore price parity of the cross-listed shares. So with high institutional ownership, the effect of liquidity on price convergence is weaker; with low institutional ownership, the effect of liquidity is stronger. In contrast, for stocks with high holding costs, the effect of liquidity will be stronger than for stocks with lower holding costs. Both holding costs and stock illiquidity contribute to the total costs of arbitrage. An investor would only arbitrage when such costs do not exceed potential profits. If holding costs are higher, the arbitrage trades are feasible only when there is sufficient stock liquidity; if holding costs are lower, stock liquidity or illiquidity may be less of a concern for arbitrageurs. So with high holding costs, the effect of stock liquidity on price convergence is stronger; with low holding costs, the effect of liquidity is weaker. Table 8 shows that the interaction variable for institutional ownership[23] has the opposite sign from the liquidity measure whereas the interaction variable for idiosyncratic volatility has the same sign. Overall our results are consistent with the notion that institutional trading lessens deviations from parity whereas holding costs impede arbitrage.

6. Summary and Conclusions

Our paper makes a contribution to the literature that examines the relationship between cross-listing and market liquidity and the literature on limits to arbitrage in international equity markets. We examine the determinants of the cross-sectional variation

[23] As a robustness check, we also use short interest and change in short interest as proxies for institutional investor trading activities. The results are similar to those presented in Table 2, 3, 7 and 8.

in the ADR (ordinaries) premium and show that a higher premium is associated with higher home share and lower ADR (ordinaries) liquidity. The effect remains significant even after we control for greater risk of information asymmetry, limits to arbitrage and other firm and country-level characteristics. We use the introduction of decimal trading in 2001 as an exogenous shock to liquidity in the US market to control for potential endogeneity between liquidity and ADR (ordinaries) premium. Our results remain the same. The effect of liquidity on the ADR premium is large and statistically and economically significant.

We also examine the extent to which the U.S. stock market contributes to the price discovery of cross-listed non-U.S. shares. We estimate an error-correction model for the stock-pair prices and analyze the factors that affect the extent of the U.S. stock market's contribution to price discovery. We use the short-term converge coefficients in a cross-sectional regression analysis to show that there is a positive effect of liquidity on price discovery, where the liquidity effect is much stronger for the U.S. market than the home market. The foreign currency volatility, home country stock market development and shareholder rights play an important role in explaining the cross sectional variations in the contribution to price discovery.

Finally, our duration analysis provides evidence that the deviations from price parity are shorter for more liquid stocks. We explore whether the liquidity effect is different for stocks with higher institutional ownership and larger holding costs. We document evidence to support the notion that institutional trading lessens deviations from parity whereas holding costs impede arbitrage. Overall our results show that liquidity is an important determinant of the ADR premium, price discovery and the way differences in the cross-listed pair-prices are arbitraged away.

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Table 1: Descriptive Statistics

This table presents descriptive statistics for the sample of cross-listed firms. The sample period is 2 January 1997 to 29 December 2012. The sample consists of 650 cross-listed firms from 18 countries. When the US and home markets do not have any overlap in trading, we use the U.S. intraday price closest to and within 30 minutes after the U.S. market opens. Panel A presents statistics for the security characteristics; Panel B presents descriptives for our liquidity measures; Panel C presents firm-level characteristics. T test is the p value from a standard test for differences in means.

Panel A: Cross-listed share characteristics					
	Mean	Median	Std Dev	5%	95%
Premium/Discount (%)	2.36%	0.09%	0.1716	-4.00%	13.81%
SO(ADR)/SO(HOME)	0.1755	0.0373	0.3945	0.0017	0.9941
Volume(ADR)/Volume(HOME)	11.4691	1.0846	44.1735	0.0110	47.6326
NYSE	0.5184	1.0000	0.5000	0.0000	1.0000
AMEX	0.1718	0.0000	0.3775	0.0000	1.0000
NASDAQ	0.3098	0.0000	0.4628	0.0000	1.0000
Panel B: Liquidity measures					
	US market		Home market		
	Mean	Std Dev	Mean	Std Dev	T test
Spread	-4.9423	1.3200	-5.0187	1.2343	(0.000)***
Turnover	-6.4421	1.6255	-6.7788	1.4744	(0.000)***
Amihud	-17.2618	2.6917	-18.2194	3.1455	(0.000)***
Zeros	0.1570	0.1509	0.0959	0.1373	(0.000)***
Panel C: Firm characteristics					
	Mean	Median	Std Dev	5%	95%
Asset ($millions)	9,490	911	27,545	29	48,954
Sales ($millions)	4,857	623	11,815	3.5303	25,080
Debt to Asset	0.1697	0.1383	0.1437	0.0032	0.4567
Profitability	-0.0359	0.0110	0.1428	-0.3345	0.1047

Table 2: ADR Premium and Liquidity Effects

This table summarizes the OLS regressions of the ADR (ordinaries) premium on the US and home market liquidity measures and controls. The sample includes 650 pairs of ADR (ordinaries) and the corresponding underlying share in the home market from 18 countries, from 2 January 1997 to 29 December 2012. The liquidity measures and the control variables are as defined in Table A2. The reported coefficient are the estimates from panel OLS regressions. p-values based on robust standard errors are reported in parenthesis. *, **, and *** indicate 10%, 5% and 1% significance, respectively.

		(I)				(II)			
Liquidity measures									
Spread	Home	0.0034 (0.093)*				0.0067 (0.000)***			
	US	0.0296 (0.000)***				0.0058 (0.000)***			
Turnover	Home		0.0023 (0.006)***				0.0030 (0.000)***		
	US		-0.0105 (0.000)***				-0.0031 (0.000)***		
Amihud	Home			0.0092 (0.000)***				0.0013 (0.002)***	
	US			0.0030 (0.000)***				0.0023 (0.000)***	
Zeros	Home				-0.0565 (0.000)***				0.0192 (0.000)**
	US				0.2023 (0.000)***				0.0059 (0.254)
Firm-level controls									
Profitability						0.0135***	0.0042	0.0058**	0.0050*
						(0.004)	(0.161)	(0.049)	(0.096)
Debt to Asset						-0.0185**	-0.0142***	-0.0155***	-0.0156***
						(0.013)	(0.004)	(0.002)	(0.002)
Log ADR size						0.0108***	0.0037***	0.0068***	0.0022***
						(0.000)	(0.000)	(0.000)	(0.000)
Idiosyncratic volatility	Home					0.0017	0.0184	0.0149	0.0117
						(0.909)	(0.121)	(0.209)	(0.327)
	US					-0.0110	-0.0017	-0.0081	-0.002
						(0.366)	(0.862)	(0.401)	(0.842)
Analyst coverage						0.0013***	-0.0002*	-0.0002	-0.0003*
						(0.000)	(0.080)	(0.205)	(0.065)
Institutional holdings						-0.0040**	-0.0045***	-0.0038***	-0.0039***
						(0.011)	(0.001)	(0.005)	(0.005)
Country-level controls									
FX premium						-1.5418***	-0.5654***	-0.5501***	-0.5800***
						(0.000)	(0.000)	(0.000)	(0.001)
ΔEquity market return						0.0007	-0.0000	-0.0007	0.0010
						(0.875)	(0.991)	(0.852)	(0.785)
Stock market turnover						-0.0047***	-0.0072***	-0.0067***	-0.0065***
						(0.010)	(0.000)	(0.000)	(0.000)
Financial crisis		-0.0044	-0.0075***	-0.0019	-0.0059*	0.0025*	0.0031**	0.0031**	0.0033***
		(0.170)	(0.008)	(0.501)	(0.055)	(0.082)	(0.011)	(0.012)	(0.008)
Model				FE				FE	
Number of observations		35,709	58,016	57,382	58,401	18,402	26,386	26,298	26,389

Table 3: ADR Premium and Liquidity Effects: Difference-in-Difference Estimation

This table summarizes the difference-in-difference estimates in a regression framework. Cross-listed firms are sorted into terciles based on the change in liquidity after the decimalization. The top tercile is the treatment group; the bottom tercile is the control group. We use four common liquidity measures. The values in parenthesis are the corresponding p-values for the coefficient estimates using robust standard errors. *, **, and *** indicate 10%, 5% and 1% significance, respectively.

		(I)				(II)			
Treatment*Decimalization									
Spread		-0.0045				-0.1269***			
		(0.876)				(0.000)			
Turnover			0.0327***				0.0261***		
			(0.000)				(0.000)		
Amihud				0.0755***				-0.0123**	
				(0.000)				(0.046)	
Zeros					-0.0357***				-0.0191***
					(0.000)				(0.001)
Treatment		0.0732***	-0.0240***	-0.0966***	0.0490***				
		(0.008)	(0.005)	(0.000)	(0.000)				
Decimalization		-0.0564***	-0.0273***	-0.0899***	-0.0053	0.1588***	-0.0285***	0.0045	0.0144***
		(0.003)	(0.000)	(0.000)	(0.366)	(0.000)	(0.000)	(0.418)	(0.001)
Home liquidity		0.0070***	0.0248***	-0.0082***	-0.0230*	0.0172***	0.0036***	0.0042***	0.0522***
		(0.009)	(0.000)	(0.000)	(0.078)	(0.000)	(0.000)	(0.000)	(0.000)
Firm-level controls									
Profitability						0.0145	-0.0079	0.0007	-0.0042
						(0.162)	(0.155)	(0.917)	(0.495)
Debt to Asset						-0.0419***	-0.0467***	-0.0635***	-0.0415***
						(0.003)	(0.000)	(0.000)	(0.000)
Log ADR size						0.0449***	0.0133***	0.0115***	0.0076***
						(0.000)	(0.000)	(0.000)	(0.000)
Idiosyncratic volatility	Home					0.1929***	0.0027	0.0185	0.0829***
						(0.000)	(0.890)	(0.408)	(0.000)
	US					-0.0286	-0.0307**	-0.0283	-0.0302*
						(0.204)	(0.049)	(0.110)	(0.077)
Analyst coverage						-0.0002	-0.0017***	-0.0007***	0.0000
						(0.652)	(0.000)	(0.004)	(0.939)
Institutional holdings						-0.0029	-0.0559***	-0.0308***	-0.0028
						(0.158)	(0.000)	(0.000)	(0.138)
Country-level controls									
FX premium						-1.8211***	-0.4115***	-0.4878***	-0.8209***
						(0.000)	(0.000)	(0.000)	(0.000)
ΔEquity market return						-0.0003	0.0008	-0.0011	0.0012
						(0.978)	(0.901)	(0.865)	(0.868)
Stock market turnover						-0.0338**	-0.0157***	-0.0142***	-0.0119***
						(0.000)	(0.000)	(0.000)	(0.000)
Financial crisis						0.0071**	0.0037*	0.0049**	0.0047*
						(0.013)	(0.082)	(0.028)	(0.055)
Model			OLS				FE		
Number of observations		12,431	25,392	24,883	24,882	6,111	11,130	11,497	10,365

Table 4: Cointegration and VECM

The table reports the results from the estimation of our vector error correction model. The sample includes 650 cross listed firms from 18 countries for the period 2 January 1997 to 29 December 2012. Panel A reports the mean and median for the number of cointegration vectors. Panel B presents the estimated coefficients for the cointegration vector, (β^{H},β^{US},β^{Hindex},$\beta^{USindex}$), see equations (2) and (3). Panel C presents the estimated coefficients for the error correction coefficients, (α^{H},α^{US},α^{Hindex},$\alpha^{USindex}$), see equations (4) and (5). The p-values from T-tests for differences in sample means are reported in parenthesis.

Panel A: Cointegration rank test		
	Mean	Median
Rank, 95% significance	0.9905	1
Rank, 95% - ADR	0.9483	1
Rank, 95% - Equity	1.0221	1
Rank, 99% significance	0.8932	1
Rank, 99% - ADR	0.8218	1
Rank, 99% - Equity	0.9475	1

Panel B: Cointegration vector			
	Mean	Median	T test
US price, β^{US}	-0.9689	-0.9994	(0.478)
Home price, β^{H}	Normalize to 1		
US index, $\beta^{USindex}$	-0.0269	-0.0000	(0.305)
Home index, β^{Hindex}	3.3156	-0.0000	(0.317)

Panel C: Error correction coefficients			
	Mean	Median	T test
US price, α^{US}	0.3595	0.2085	(0.000)
Home price, α^{H}	-0.4840	-0.4086	(0.000)
US index, $\alpha^{USindex}$	25.0213	3.5726	(0.000)
Home index, α^{Hindex}	-21.5030	-3.1372	(0.523)

Table 5: Price Convergence and liquidity

The table reports the means of the error correction coefficients (alphas) for portfolios sorted by the four liquidity measures. The sample consists of 650 cross-listed firms from 18 countries 2 January 1997 to 29 December 2012. We use four liquidity measures as defined in Table A2 to sort ADR (ordinaries) into four portfolios. Panel A reports α^{US} for firms sorted by home-market liquidity; panel B reports α^{H} for firms sorted by U.S.-market liquidity.T test is the p value from a standard test for differences in means between the least and most liquid portfolios.

Panel A: Alphas (US) for sorted portfolios with T tests					
	Least liquid			Most liquid	T test
	P1	P2	P3	P4	P4 = P1
Spread	0.5827	0.3267	0.2535	0.1280	(0.020)
Turnover	0.3644	0.3468	0.5027	0.2229	(0.155)
Amihud	0.4079	0.3811	0.4448	0.2051	(0.033)
Zeros	0.4795	0.3593	0.4944	0.1959	(0.082)

Panel B: Alphas (Home) for sorted portfolios with T tests					
	Least liquid			Most liquid	T test
	P1	P2	P3	P4	P4 = P1
Spread	-0.1851	-0.4131	-0.6083	-0.7452	(0.000)
Turnover	-0.2795	-0.5442	-0.4925	-0.6230	(0.000)
Amihud	-0.1999	-0.3636	-0.6273	-0.7440	(0.000)
Zeros	-0.2053	-0.3578	-0.6738	-0.6983	(0.000)

Table 6: Cross-sectional Variation in Price Discovery

The table reports cross sectional regressions of the error correction coefficients on liquidity and other control variables for our sample of cross-listed firms. Seemingly unrelated regressions are performed to jointly estimate the relationships between the error correction coefficients and liquidity, along with firm- and country-level control variables. Numbers in parenthesis are the corresponding p-values for the coefficient estimates. Panel A are models using liquidity measures and country dummies as independent variables. Models in Panel B include firm- and country-level control variables. *, **, and *** indicate 10%, 5% and 1% significance, respectively.

Panel A: Price discovery and liquidity	(I)		(II)		(III)		(IV)	
	α^H	α^{US}	α^H	α^{US}	α^H	α^{US}	α^H	α^{US}
Liquidity measures								
Spread	-0.0899***	0.0573						
	(0.001)	(0.208)						
Turnover			0.0908***	0.0132				
			(0.000)	(0.688)				
Amihud					-0.0610***	0.0056		
					(0.000)	(0.734)		
Zeros							-1.2516***	-0.1809
							(0.000)	(0.629)
Country dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	454	454	573	573	574	574	574	574
R^2, %	15.85	6.02	14.15	6.41	14.81	6.40	16.36	6.44

Panel B: Price discovery and liquidity with firm and country-level controls								
Liquidity measures								
Spread	-0.2818***	-0.0278						
	(0.000)	(0.614)						
Turnover			0.1459***	0.0941***				
			(0.000)	(0.006)				
Amihud					-0.1540***	-0.0648**		
					(0.000)	(0.017)		
Zeros							-1.5928***	-1.2410**
							(0.000)	(0.016)
Firm-level controls								
Profitability	-0.6925***	-0.8585***	-0.9796***	-1.0360***	-0.9862***	-1.0316***	-0.8922***	-1.0818***
	(0.010)	(0.002)	(0.001)	(0.000)	(0.001)	(0.000)	(0.002)	(0.000)
Debt to Asset	-0.5549	-0.0632	-0.5932	-0.1942	-0.5433	-0.2315	-0.6390	-0.1767
	(0.157)	(0.867)	(0.135)	(0.605)	(0.172)	(0.541)	(0.107)	(0.640)
Log ADR size	-0.0062	0.0062	0.1023***	0.0649*	-0.0511	0.0167	0.0590	0.0347
	(0.879)	(0.863)	(0.005)	(0.067)	(0.278)	(0.675)	(0.128)	(0.346)
Idiosyncratic volatility	1.9454	1.5487	-0.0823	2.9221*	0.8833	3.9644**	-0.7762	1.4805
	(0.139)	(0.372)	(0.950)	(0.058)	(0.490)	(0.022)	(0.572)	(0.333)
Analyst coverage	-0.0200*	0.0061	-0.0194	-0.0022	-0.0193	0.0008	-0.0179	0.0033
	(0.084)	(0.587)	(0.106)	(0.850)	(0.108)	(0.943)	(0.134)	(0.772)
Institutional holdings	0.3211*	0.2533	0.2579	0.0143	0.2410	0.1687	0.2723	0.1329
	(0.059)	(0.121)	(0.151)	(0.935)	(0.180)	(0.331)	(0.129)	(0.441)
Country-level controls								
FX Volatility	-84.4946**	-27.8996	-86.1916***	-52.7180	-90.6102***	-51.0675	-77.6345**	-46.9133
	(0.012)	(0.412)	(0.007)	(0.111)	(0.005)	(0.126)	(0.015)	(0.155)
Equity market volatility	-28.7614	-35.2053	-5.5817	-40.9530*	-1.7891	-39.9357*	-3.1764	-39.4092*
	(0.392)	(0.152)	(0.859)	(0.082)	(0.954)	(0.093)	(0.920)	(0.099)
Stock market turnover	-0.0106***	-0.0033	-0.0129***	-0.0061**	-0.0127***	-0.0074*	-0.0102***	-0.0041
	(0.001)	(0.307)	(0.000)	(0.085)	(0.000)	(0.052)	(0.002)	(0.231)
SH right	0.0033	0.0482	0.0324	0.0946	0.0373	0.0783	0.0261	0.0956
	(0.955)	(0.401)	(0.590)	(0.106)	(0.534)	(0.180)	(0.664)	(0.105)
SMI	0.6920	0.1366	0.8932	-0.1806	0.8297	-0.0602	0.8265	-0.0393
	(0.170)	(0.807)	(0.101)	(0.757)	(0.127)	(0.918)	(0.129)	(0.947)
Legal origin dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	310	310	345	345	345	345	345	345
R^2, %	28.55	23.43	25.69	24.34	25.75	23.32	25.98	23.47

Table 7: Price convergence: duration analysis

The table presents the results from the estimation of the duration model for price convergence using Cox proportional hazard model. The dependent variable is the hazard ratio, i.e. the conditional probability of the stock pair price convergence. The sample includes 650 pairs of ADR (ordinaries) and the corresponding underlying share in the home market from 18 countries, from 2 January 1997 to 29 December 2012. The liquidity measures and the control variables are as defined in Table A2. The the corresponding p-values for the coefficient estimates using robust standard errors clustered by firm are reported in parenthesis. *, **, and *** indicate 10%, 5% and 1% significance, respectively.

		(I)				(II)			
Liquidity									
Spread	Home	-0.0047				-0.0377***			
		(0.666)				(0.000)			
	US	-0.0757***				-0.0769***			
		(0.000)				(0.000)			
Turnover	Home		0.0252***				0.0310***		
			(0.005)				(0.000)		
	US		0.0187**				0.0259***		
			(0.029)				(0.001)		
Amihud	Home			0.0013				-0.0165**	
				(0.874)				(0.046)	
	US			-0.0136**				-0.0164***	
				(0.011)				(0.001)	
Zeros	Home				0.0055				0.0062
					(0.909)				(0.857)
	US				-0.0290				-0.0410
					(0.342)				(0.181)
Firm-level controls									
Profitability		0.3010*	0.2120*	0.1973*	0.2457**	0.2882**	0.2260**	0.1889**	0.2615***
		(0.067)	(0.074)	(0.092)	(0.040)	(0.016)	(0.016)	(0.023)	(0.008)
Debt to Asset		-0.2338*	-0.0925	-0.0616	-0.1008	-0.2265*	-0.1082	-0.1006	-0.1233
		(0.071)	(0.335)	(0.464)	(0.297)	(0.063)	(0.239)	(0.191)	(0.207)
Log ADR size		0.0018	0.0438***	0.0233	0.0459***	0.0022	0.0496***	0.0131	0.0509***
		(0.927)	(0.002)	(0.185)	(0.001)	(0.882)	(0.000)	(0.345)	(0.000)
Idiosyncratic volatility	Home	-0.5393**	-0.4274*	-0.3346	-0.4283*	-0.6966***	-0.7750***	-0.6152***	-0.6891***
		(0.045)	(0.094)	(0.125)	(0.098)	(0.008)	(0.002)	(0.001)	(0.005)
	US	0.2828	0.0463	-0.1560	0.0720	0.2656	0.0321	-0.1575	0.0676
		(0.124)	(0.831)	(0.319)	(0.743)	(0.136)	(0.881)	(0.249)	(0.751)
Analyst coverage		0.0076**	0.0079***	0.0095***	0.0087***	-0.0053	-0.0014	-0.0020	0.0011
		(0.048)	(0.005)	(0.001)	(0.002)	(0.120)	(0.530)	(0.429)	(0.622)
Institutional holdings		0.0455**	0.0167	0.0323	0.0313*	0.0229	-0.0189	0.0005	0.0121
		(0.026)	(0.406)	(0.113)	(0.088)	(0.209)	(0.489)	(0.983)	(0.556)
Industry dummy		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
country-level controls									
FX Volatility		-14.4410	-11.7206	-14.5654*	-10.2818	-14.9812	-13.6619*	-18.7599***	-13.7658*
		(0.123)	(0.119)	(0.059)	(0.181)	(0.119)	(0.053)	(0.009)	(0.055)
Equity market volatility	Home	3.7788	-0.5973	1.1709	-0.3819	5.5085**	1.5868	4.7764**	2.1767
		(0.178)	(0.821)	(0.652)	(0.887)	(0.020)	(0.419)	(0.015)	(0.267)
	US	-7.2111**	-6.0085**	-6.9007**	-6.5104**	-8.0783**	-7.1271***	-8.1803***	-7.5067***
		(0.039)	(0.028)	(0.021)	(0.025)	(0.018)	(0.004)	(0.003)	(0.004)
Stock market turnover		0.0222	-0.0057	0.0021	0.0246	0.0336	0.0296	0.0300	0.0362
		(0.557)	(0.889)	(0.955)	(0.542)	(0.383)	(0.467)	(0.457)	(0.375)
SH right		0.0240	0.0387	0.0471*	0.0382				
		(0.337)	(0.129)	(0.058)	(0.149)				
SMI		0.3102	0.4190*	0.4412*	0.4567*				
		(0.176)	(0.076)	(0.071)	(0.068)				
Legal origin dummy		Yes	Yes	Yes	Yes				
Country dummy						Yes	Yes	Yes	Yes
Financial crisis		0.0334	-0.0036	-0.0052	-0.0063	0.0332	-0.0041	-0.0020	0.0007
		(0.517)	(0.947)	(0.931)	(0.904)	(0.416)	(0.922)	(0.964)	(0.986)
Number of observations		273,798	405,649	369,976	405,906	273,798	405,649	369,976	405,906

Table 8: Price convergence: mechanisms of the liquidity effect

The table presents the results from the estimation of the duration model for price convergence using Cox proportional hazard model. The dependent variable is the hazard ratio, i.e. the conditional probability of the stock pair price convergence. The sample includes 650 pairs of ADR (ordinaries) and the corresponding underlying share in the home market from 18 countries, from 2 January 1997 to 29 December 2012. The liquidity measures and the control variables are as defined in Table A2. The the corresponding p-values for the coefficient estimates using robust standard errors clustered by firm are reported in parenthesis. *, **, and *** indicate 10%, 5% and 1% significance, respectively.

		(I)				(II)			
Liquidity									
Spread	Home	0.0188 (0.395)				-0.0214 (0.194)			
	US	-0.1522 (0.000)***				-0.0819 (0.000)***			
Turnover	Home		0.0602 (0.000)***				0.0170 (0.175)		
	US		-0.0113 (0.346)				0.0484 (0.001)***		
Amihud	Home			0.0089 (0.296)				-0.0023 (0.870)	
	US			-0.0421 (0.000)***				-0.0137 (0.111)	
Zeros	Home				-0.1291 (0.267)				0.0649 (0.306)
	US				-0.0913 (0.207)				0.0593 (0.120)
Liquidity*Idiosyncratic	Home	-0.3901	0.0198	-0.0752	-0.8295	-0.3935***	0.1723**	-0.1345**	-0.7195
volatility		(0.161)	(0.873)	(0.246)	(0.182)	(0.009)	(0.047)	(0.034)	(0.162)
	US	-0.0713	0.1538**	-0.1853***	-0.4706	-0.1050	-0.0141	-0.1688***	-0.8994***
		(0.631)	(0.027)	(0.000)	(0.239)	(0.203)	(0.851)	(0.000)	(0.010)
Liquidity*Institutional	Home	0.0036	-0.0052**	-0.0005	0.0014***	0.0523**	-0.0065	-0.0137	0.0590
holdings		(0.840)	(0.018)	(0.270)	(0.002)	(0.045)	(0.615)	(0.218)	(0.197)
	US	0.0673***	-0.0099	0.0011	-0.0008	0.0637**	-0.0904***	0.0558***	0.0165
		(0.003)	(0.484)	(0.286)	(0.428)	(0.035)	(0.001)	(0.004)	(0.842)
Firm-level controls									
Profitability						0.2596**	0.2212**	0.1592**	0.2606***
						(0.022)	(0.016)	(0.038)	(0.009)
Debt to Asset						-0.2205*	-0.1157	-0.0989	-0.1232
						(0.064)	(0.209)	(0.195)	(0.206)
Log ADR size						-0.0003	0.0500***	0.0124	0.0509***
						(0.982)	(0.000)	(0.371)	(0.000)
Idiosyncratic volatility	Home	-2.2111	-0.5766	-1.5480	-0.7189*	-2.4488***	0.3774	-2.8310**	-0.6692***
		(0.170)	(0.553)	(0.186)	(0.072)	(0.001)	(0.525)	(0.012)	(0.006)
	US	-0.2405	0.2771	-3.9887***	-0.6696**	-0.3487	-0.0439	-3.3703***	0.0874
		(0.792)	(0.486)	(0.000)	(0.024)	(0.502)	(0.889)	(0.000)	(0.676)
Analyst coverage						-0.0032	-0.0012	-0.0006	0.0012
						(0.357)	(0.599)	(0.810)	(0.613)
Institutional holdings		0.4885***	-0.0738	0.0115	0.0031*	0.7267***	-0.5602***	0.7865**	0.0111
		(0.005)	(0.358)	(0.386)	(0.073)	(0.004)	(0.002)	(0.049)	(0.595)
Country-level controls									
FX Volatility						-14.1636	-13.9774**	-17.9780***	-13.8723*
						(0.107)	(0.049)	(0.010)	(0.053)
Equity market volatility	Home					5.5601**	1.1178	4.7934***	2.1741
						(0.018)	(0.567)	(0.010)	(0.268)
	US					-8.7474***	-6.5352***	-8.9607***	-7.5162***
						(0.008)	(0.008)	(0.001)	(0.004)
Stock market turnover						0.0317	0.0330	0.0403	0.0366
						(0.407)	(0.413)	(0.297)	(0.370)
Country and industry dummies						Yes	Yes	Yes	Yes
Financial crisis						0.0258	-0.0050	-0.0075	0.0005
						(0.528)	(0.904)	(0.865)	(0.990)
Number of observations		342,366	541,312	488,169	542,352	273,798	405,649	369,976	405,906

Table A1: Cross-listed Firms and Country-level Characteristics

This table presents the distribution of sample firms by country and country-level characteristics. Legal origins and shareholder (SH) rights is from La Porta et al (1998). Stock market development index is from Mclean et al (2014). Foreign exchange (FX) volatility is the annualized volatility of daily exchange rates. Stock market turnover is a turnover index published by the World Bank in World Development Index 2012.

Country	# crosslisted firms	Legal origin	SH right	Stock market development index	FX Volatility	Stock market turnover
Argentina	14	French	4	0.064	0.1709	3.76
Australia	20	English	4	0.744	0.1333	84.65
Brazil	14	French	3	0.235	0.1624	67.88
Canada	334	English	5	0.778	0.0896	61.58
Chile	18	French	5	0.308	0.0950	16.01
France	14	French	3	0.581	0.1042	66.43
Germany	8	German	1	0.474	0.1027	91.77
Hong Kong	7	English	5	0.788	0.0047	123.08
Israel	37	English	3	0.632	0.0769	45.90
Japan	23	German	4	0.509	0.1124	99.85
Mexico	28	French	1	0.150	0.1040	25.31
Netherlands	13	French	2	0.769	0.1045	70.85
Norway	10	Scandinavian	4	0.598	0.1228	56.28
South Africa	14	English	5	0.598	0.1749	54.93
Spain	8	French	4	0.607	0.1041	106.32
Sweden	9	Scandinavian	3	0.692	0.1243	73.00
Switzerland	8	German	2	0.821	0.1143	63.74
United Kingdom	71	English	5	0.829	0.0891	84.04

Table A2: Variables Description

Variable	Definition
Panel A: Security characteristics	
ADR (ordinaries) premium	the US-market (intraday) price over the home-market price adjusted by the ADR ratio minus one, i.e a number greater(less) than zero represents ADR premium(discount)
Shares outstanding (U.S.)/ Shares outstanding (Home market)	Ratio of ADR (ordinaries) outstanding to shares outstanding of the underlying stock in the home market.
NYSE	Dummy variable equals one if ADR (ordinary) is traded on NYSE
AMEX	Dummy variable equals one if ADR (ordinary) is traded on AMEX
NASDAQ	Dummy variable equals one if ADR (ordinary) is traded on NASDAQ
Idiosyncratic volatility	Standard deviation of the residuals of the stock returns regressed on market index returns from the previous quarter
Analyst coverage	Number of price estimates
Institutional holdings	Shares held by institutional investors over shares outstanding
Short interest	Short interest over shares outstanding
Panel B: Liquidity measures	
Spread	Natural logarithm of the Bid-ask spread over the mid point of bid-ask spread
Turnover	Natural logarithm of daily volume over shares outstanding
Amihud	Natural logarithm of absolute daily return over dollar volume
Zeros	Number of zero-return days in a month over the number of trading days in that month
Panel C: Firm-level variables	
Assets	Natural logarithm of total assets
Sales	Net sales
Debt to Asset	Book value of long term debt over book value of total assets
Profitability	Net income over book value of total assets
Panel D: Country-level variables	
English	Dummy variable equals one if the country has English legal origin
French	Dummy variable equals one if the country has French legal origin
German	Dummy variable equals one if the country has German legal origin
Emerging	Dummy variable equals one if the country is an emerging market
Shareholder rights	An index constructed to capture the rights of minority shareholders
Stock market turnover	Stock market turnover index
SMI	Stock market development index
Equity market index	Broad-based equity market index by country
FX premium	1-month forward exchange rate over spot exchange rate minus one
FX volatility	Annualized volatility of daily exchange rates
Panel E: Time events	
Financial crisis	Dummy variable equals one for time period between September 1, 2007 and September 30, 2008
Decimalization	Dummy variable equals one for time period after the decimalization. For cross-listed firms on NYSE and Amex, the dummy is one from January 29, 2001 until end of sample; for firms on Nasdaq, the dummy is one from April 9, 2001 until end of sample