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Abstract

We analyze the effects of a recent financial reform that enables cross-market investment between Hong Kong and Shanghai stock exchanges. Using a vector error-correction model, we find that the reform announcement considerably narrows the equilibrium level of price disparity and strengthens the price comovement of shares that are cross-listed in both markets. First, there is a substantial increase in the number of cross-listed firms with cointegrated share prices, and the estimated equilibrium relationship is in support of the relative law of one price. Second, our model predicts that the price disparity narrows by as much as 40 percent in equilibrium. Third, we find that both markets adjust in response to a disequilibrium in price disparity, leading to a sizable error-correction activity. The Shanghai market contributes to approximately two-thirds of the price discovery process. Competition and informativeness of trading affect the relative role of price discovery in each market.

JEL CLASSIFICATION: F36, G18, C32

Keywords: Capital account liberalization, co-integration, vector error-correction model, cross-listing, Chinese A-H shares

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1 Introduction

Capital account liberalization has played an integral role in China's reform agenda in recent years. Although China's capital account remains relatively closed – it accounts for less than 3 percent of global holdings of cross-border assets and liabilities – ambitious attempts have recently been launched to liberalize its financial and foreign exchange systems. However, it remains a highly controversial issue as to how financial markets will be affected by such liberalizations.

This study presents new evidence on the topic by examining a unique natural experiment from a recent financial reform in China. The financial reform, known as *Shanghai-Hong Kong Stock Connect*, enables cross-market investment between two of the largest ten stock exchanges in the world – Shanghai and Hong Kong. Hong Kong investors are allowed to invest in selected stocks in the Shanghai market, and vice versa, subject to a daily quota. An interesting feature of the reform is that while it restricts cross-market investment to designated stocks, it includes shares of all firms that are concurrently listed in both markets. Since these shares have the same dividend and voting rights, the presence of price disparity, which can be substantial, has been one of the most interesting puzzles in the Chinese financial market. By exploiting the uniqueness of the reform and the prevalence of cross-listed firms between Shanghai and Hong Kong, we formally assess the implications of capital account liberalization for the dynamics of price discovery and financial market integration in China.

At a general level, our study integrates two important strands of literatures. The first literature is related to the effects of capital account liberalization, especially in emerging markets. In recent years, the policy-experiment approach has been advocated as a clean source of identification of policy effects (Henry (2007)).[1] While few studies have pursued this approach, an exception is Chari and Henry (2004), who disentangle the effects on stock prices using firms that are eligible and ineligible for purchase by foreigners in liberalizations. However, their model does not incorporate pricing dynamics. The second literature is related to the mechanism of price discovery among cross-listed firms. For instance, our model is similar to Eun and Sabherwal (2003), who analyze Canadian stocks that are listed on both the

[1] A prevailing empirical approach is to analyze cross-country time-series data using various measures of liberalization as the principal source of policy variation (e.g., Henry (2000), Harrison et al. (2004), Gallindo et al. (2007)). The findings are often sensitive to country coverage, sample periods, and indicators of liberalization (Eichengreen (2001)).

Toronto and U.S. stock exchanges.[2] They find that the home market's share of price discovery is around 60 percent. However, as in most studies in the literature, they focus on preexisting patterns of pricing dynamics. There remains a large knowledge gap on the relationship between the pricing dynamics of cross-listed firms and financial market globalization.

Our study also extends the literature on cross-listings in Hong Kong (H-shares) and Mainland (A-shares) markets. In 2014, there are more than 60 firms that are concurrently listed in the Hong Kong and Shanghai stock exchanges, and these firms constitute a sizable proportion of the total market capitalization in both markets. A large body of the literature, which is predominantly based on static models, has focused on the level of price disparity between H-shares and A-shares.[3] By contrast, there are fewer studies that analyze the price co-movement between H-shares and A-shares. Su et al. (2007) find that there were more firms with cointegrated H-share and A-share prices in 2004 when earlier episodes of liberalization were launched (QFII and CEPA). Choi et al. (2013) document a stronger cointegration between H-share and A-share prices in the post global financial crisis period from 2009 to 2011. Both papers do not formally model the dynamics of price disparity, however. Using an error-correction model for H-shares, Cai et al. (2011) find that the error correction activity was generally very low, but the relationship between A-shares and H-shares strengthened during the 2000s, both in terms of price disparity and pricing dynamics. They also find that policy and corporate governance contributed to the change. While their univariate model allows the return of H-shares to be affected by the return of A-shares and the level of price disparity, the return of A-shares is assumed to be exogenous (as a martingale difference sequence). As we will show in the model section, this may lead to a biased estimate of the error correction process if *both* H-share and A-share prices adjust in response to a disequilibrium in price disparity. Their model also restricts the cointegrating coefficient to unity, which precludes tests on the validity of the relative law of one price.[4]

To analyze the dynamic effects of the financial reform, we adopt a more integrated ap-

[2] For an earlier study that apply a similar model to one firm (IBM), see Harris et al. (1995).

[3] Examples of recent studies include Arquette et al. (2008), Chang et al. (2013) and Chung et al. (2013). Chan (2014) considers the same financial reform as in this paper, but he only looks at the price disparity on the day of policy announcement and up to two days prior to the announcement.

[4] As an illustration, the cointegrating relationship can be written as $log(P_t^H) + \beta log(P_t^A) + c = 0$, where P_t^H is the H-share price, P_t^A is the A-share price, β is the cointegrating coefficient, and c is a constant. The relative law of one price implies that $\beta = -1$.

proach by estimating a vector error-correction model (Engle and Granger (1987)) for firms that are concurrently listed in the Hong Kong and Shanghai markets. Since the model captures the *joint* price movements of the firm's H-shares and A-shares, we are able to derive estimates of the equilibrium price disparity, as well as the magnitude and share of the disequilibrium price adjustment process in each market. For each firm, we also use cointegration tests to formally test for the existence of equilibrium relationship between the prices of H-shares and A-shares. The empirical analysis is performed separately using data from before the policy announcement and data from the post-announcement period. In addition, we exploit the fact that the firms in the data have widely different preexisting levels of price disparity, in particular, one-third have a premium and two-thirds have a discount in the H-share market. This allows us to robustly test hypotheses regarding how the reform affects the price convergence process.

Our results strongly indicate that the reform strengthens the degree of financial integration between the Hong Kong and Shanghai markets. There are three major findings. First, the cointegration tests show that substantially more firms have cointegrated A-share and H-share prices during the post-announcement period. Among these firms, which constitute 40 percent of the baseline sample, the estimated cointegrating coefficients are close to unity. Therefore, the equilibrium relationship formed after the policy announcement is consistent with the relative law of one price. Second, the estimated post-announcement equilibrium level of price disparity is considerably narrower than the price disparity just before the announcement. In particular, among firms whose H-shares were traded at a premium to A-shares, our model predicts that the price disparity will narrow by an average of 40 percent in equilibrium. Third, *both* markets adjust in response to a disequilibrium in price disparity, leading to a sizable error correction process. On average, a 1-percent deviation from equilibrium will generate a next-day price response of 0.27 percent in H-shares and 0.14 percent in A-shares. Therefore, the Shanghai market contributes to approximately two-thirds of the price discovery process. Regression analysis indicates that competition and informativeness of trading affect the relative role of price discovery in both markets, a finding that is consistent with Eun and Sabherwal (2003).

The paper proceeds as follows. Section 2 provides a policy background for the empirical analysis. Section 3 describes the vector error-correction model and its relationship with the literature. Section 4 discusses the data. Section 5 reports the estimation results of the vector error-correction model, regression analysis, and sensitivity analysis. Section 6 concludes.

2 Policy Background

The Hong Kong and Shanghai markets are ranked among the largest 10 stock exchanges in the world. However, there is a strong asymmetry in institutional characteristics and the degree of openness between both markets. A interesting feature of both markets is the prevalence of firms that are concurrently listed – in 2014, there were more than 60 firms that are concurrently listed in both markets, and their shares constitute approximately 50 and 18 percent of the total market capitalization of the Shanghai and Hong Kong markets, respectively.

For each cross-listed firm, its A-shares (in Shanghai market) and H-shares (in Hong Kong market) are non-fungible and can be traded in their respective stock exchanges only. Although A-shares and H-shares have the same dividend and voting rights, their price disparity is highly heterogeneous across firms – for instance, in March 2014, one-third of the firms had A-shares that were at least 50 percent more expensive than H-shares. The price disparity between A-shares and H-shares is one of the most interesting puzzles in the study of Chinese financial markets.

The recent announcement of a pilot program, called *Shanghai-Hong Kong Stock Connect*, fundamentally changed the prospect of market segmentation between Shanghai and Hong Kong markets. The policy announcement, which was made on April 10, 2014, described in detail how the pilot program will enable cross-market investment between Hong Kong and Shanghai's stock markets. In particular, Hong Kong investors can invest in the Shanghai market, and vice versa, subject to an overall quota of 250 billion yuan (40 billion USD) and 300 billion yuan (48 billion USD), respectively.[5] The quotas constitute 2 and 1.6 percent of the market capitalization in the Shanghai and Hong Kong stock exchanges, respectively. The program also restricts cross-market investment to designated stocks in both markets. These include constituents of major indices, and shares of firms that are concurrently listed in the

[5]The daily quotas in the Shanghai and Hong Kong markets are 10.5 and 13 billion yuan, respectively. Investors in Mainland China who are allowed to invest in the Hong Kong market must have at least 500,000 yuan (80,645 USD) in securities or cash.

Shanghai and Hong Kong stock exchanges.[6] The pilot program was scheduled to launch six months after the policy announcement.

The pilot program represents a significant step towards China's capital control liberalization. Prior to the program, cross-border investment in stock markets between Mainland China and the rest of the world was dominated by the Qualified Foreign Institutional Investor (QFII) and Qualified Domestic Institutional Investor (QDII) programs. The QFII program started in 2002 and allows foreign institutional investors to invest in Mainland China's securities markets. The QDII program started in 2006 and allows institutional investors in Mainland China to invest in financial markets abroad. Quotas were allocated to both programs for institutional investors only, and the quotas were gradually increased over the past decade. As of 2014, the total quotas for QFII and QDII are 53.5 and 86.5 billion US dollars, respectively. Therefore, the combined sizes of QFII and QDII programs are similar to the pilot program.

3 Vector Error-Correction Model

We consider the joint pricing dynamics of H-shares and A-shares for a firm that is concurrently listed on both the Hong Kong and Shanghai stock exchanges. Let the price of the firm's H-shares and A-shares at time t be P_t^H and P_t^A, respectively. Both prices are exchange-rate-adjusted to Hong Kong dollars. The log-prices are denoted by $h_t = log(P_t^H)$ and $a_t = log(P_t^A)$, respectively, so that $\triangle h_t = h_t - h_{t-1}$ and $\triangle a_t = a_t - a_{t-1}$ are the relative returns. We are interested in modelling the evolution of the bivariate log-price process over the period $t = 0, ..., T$. The vector error-correction model of order p is given as follows (VECM, Engle and Granger (1987)):

$$\triangle h_t = c^h + \alpha^h w_{t-1} + \sum_{j=1}^{p} \pi_j^{hh} \triangle h_{t-j} + \sum_{j=1}^{p} \pi_j^{ha} \triangle a_{t-j} + u_t^h, \quad (1)$$

$$\triangle a_t = c^a + \alpha^a w_{t-1} + \sum_{j=1}^{p} \pi_j^{ah} \triangle h_{t-j} + \sum_{j=1}^{p} \pi_j^{aa} \triangle a_{t-j} + u_t^a, \quad (2)$$

[6] The Mainland market has two stock exchanges (Shanghai and Shenzhen). Firms can only list in either the Shanghai or the Shenzhen market. Firms that are concurrently listed in the Shenzhen and Hong Kong stock exchanges are unaffected by the program, and can form a natural control group for analysis. We will discuss this point in further detail in the results section.

where the cointegrating equation, which represents the equilibrium relationship between the log-prices h_t and a_t, is given by

$$w_{t-1} = h_{t-1} + \beta a_{t-1} + \mu + \gamma t. \tag{3}$$

If $w_t = 0$, the pair of log-prices is in equilibrium. Otherwise, a deviation from equilibrium occurs, which will lead to a subsequent adjustment of both log-prices according to equations (1) and (2). In particular, the rates of price adjustments from disequilibrium will depend on the error-correction adjustment coefficients α^h and α^a. We expect that $\alpha^h < \alpha^a$ or, more specifically, $\alpha^h < 0$ and $\alpha^a > 0$, so that prices will converge to the equilibrium relationship in the long-run should a deviation from equilibrium occurs.

The cointegrating equation allows for an unrestricted value of the cointegrating coefficient β. The equation also contains a constant μ, as well as a linear time trend γt (Johansen (1991, 1995)). A special case of interest is $\beta = -1$, which implies the *relative law of one price*. The component $\mu + \gamma t$ can then be interpreted as the equilibrium level of discount of H-shares relative to A-shares, a point which we will discuss in detail in the results section.

When the log-prices are cointegrated, $\{w_t\}_{t=0}^{T}$ will be a trend stationary process. The cointegration tests, as well as unit root tests for h_t and a_t, will be discussed in the results section. In addition to the adjustments due to departure from the long-run equilibrium, the VECM representation in equations (1) and (2) captures a rich array of short-run price dynamics in terms of a vector autoregressive process. The innovation vector $\boldsymbol{u}_t = [u_t^h \quad u_t^a]'$ is independent and identically distributed with mean 0 and has an unrestricted covariance matrix Σ_u. Therefore, the short-run dynamics allow for both contemporaneous change and two-way temporal feedback between H-share and A-share prices. The former is achieved by the potential correlation in innovations u_t^h and u_t^a, while the latter is captured by the lagged returns (up to lag p) of both types of shares.

3.1 Relationship with Cai et al. (2011)

Our model can be written as a general version of the univariate error correction model of Cai et al. (2011). Their model is given by

$$\triangle h_t = \lambda + \delta \triangle a_t + \kappa(h_t - a_t) + v_t, \tag{4}$$

where v_t is iid$(0, \sigma_v^2)$. To see how this model is related to ours, we first restrict the parameters on short-run dynamics in our model to zero: $\pi_j^{hh} = \pi_j^{ha} = \pi_j^{ah} = \pi_j^{aa} = 0$ for all j. Then, we express the innovation in H-shares (i.e., u_t^h in equation (1)) as a function of the innovation in A-shares (i.e., u_t^a in equation (2)):

$$u_t^h = bu_t^a + v_t, \tag{5}$$

where b is the correlation between u_t^h and u_t^a due to covariance matrix Σ_u, and v_t is an iid shock. Substituting the above expression and equation (2) into equation (1) yields

$$\triangle h_t = c^h - bc^a + (\alpha^h - b\alpha^a)(\mu + \gamma t) + b \triangle a_t + (\alpha^h - b\alpha^a)(h_t + \beta a_t) + v_t. \tag{6}$$

Under the restriction of $\beta = -1$, the parameters of both models will be related through the following equations:

$$\lambda = c^h - bc^a + (\alpha^h - b\alpha^a)(\mu + \gamma t), \tag{7}$$

$$\delta = b, \tag{8}$$

$$\kappa = \alpha^h - b\alpha^a, \tag{9}$$

where the parameters of Cai et al.'s model are given on the left hand side.

There are a few important observations. First, Cai et al.'s model assumes that the relative law of one price holds, and they do not allow for trends in the cointegrating relationship. By contrast, we allow for the cointegrating coefficient β to take any value, thus allowing for statistical tests of the law. Second, our model also allows for contemporaneous changes in $\triangle h_t$ and $\triangle a_t$, via the correlation between innovations u_t^h and u_t^a. Third, and more importantly, the error correction coefficient κ in Cai et al.'s model is a linear combination of the adjustment coefficients in *both* markets. In particular, if the innovations are positively correlated ($b > 0$) and the A-share price adjusts in response to disequilibrium ($\alpha^a > 0$), the error correction coefficient κ will tend to overrepresent the magnitude of the true price adjustment process.[7]

4 Data

Our analysis sample consists of daily close prices of stocks that are cross-listed on both Hong Kong and Shanghai stock exchanges. We exclude the following stocks from the raw sample: (i) stocks with extended non-trading periods in at least one of the markets over the post-announcement period, and (ii) stocks of firms that are heavily involved in brokerage activities. In the end, there are 61 firms in the analysis sample, which contains 122 stock price series.[8] The cointegration tests are carried out separately using data from the pre- and post-announcement periods. The pre-announcement period lies between January 2, 2014 and April 9, 2014, while the post-announcement period lies between April 10, 2014 and July 29, 2014.[9] Estimation of the vector error-correction model is carried out using the post-announcement period, which spans over 77 days of trading. In the baseline model, the maximum lag order in equations (1) and (2) is chosen to be $p = 2$, and sensitivity analysis on lag length will be discussed in the results section. The model is estimated by the method of maximum likelihood with Gaussian innovations (e.g., Johansen (1988, 1991)).

Table I reports summary statistics of the market variables related to the H- and A-shares of the 61 firms during the post-announcement period. After adjusting for the exchange rate, A-shares have a slightly higher average price than H-shares and they have a similar average dollar amount of trading volume. We follow Eun and Sabherwal (2003) and construct measures of volume shares and bid-ask spread as potential determinants of the price discovery process. The Hong Kong market takes up an average of 38.9 percent of the combined trading volumes in both markets ($HvolShare = \frac{HVol}{HVol+AVol}$). While the mean percentage bid-ask spread of H-shares ($HBas$) is slightly higher than that of A-shares ($ABas$), the average spread ratio is

[7] For instance, consider a special case where $\alpha^h = 0$. Then, according to equation (1), a deviation from equilibrium last period (i.e., $w_{t-1} \neq 0$) should not affect the return of H-shares this period at all. However, the estimate for κ is $0 - b\alpha^a < 0$, which indicates the presence of error-correction activity.

[8] The complete list of stocks is available upon request. See Chan (2014) for further description of the cross-listed firms.

[9] An observation is still included if the stock is traded only in one of the markets (e.g., public holiday). The missing price in the other market is filled in by interpolation.

1.54 ($SpreadRatio = \frac{HBas}{ABas}$). Following Cai et al. (2011), we construct measures of differential market sentiment and information asymmetry, respectively:

$$VolRelative = \frac{|HVol - AVol|}{HVol + AVol},$$
$$BasRelative = \frac{|HBas - ABas|}{HBas + ABas}.$$

If there is any difference in the trading volume or bid-ask spread between both markets in either direction, the measures above will be strictly positive. The sample averages of $VolRelative$ and $BasRelative$ are 0.40 and 0.21, respectively. The table also reports the firms' market capitalization on April 9. The average market capitalization is rather sizable at 65.79 billion HKD, with a standard deviation of 184.69 billion HKD.

A key summary measure of interest, called the *HA premium*, is defined as follows:

$$HApremium_t = \frac{P_t^H}{P_t^A} - 1. \tag{10}$$

The measure compares the exchange-rate-adjusted prices of H-shares (P_t^H) and A-shares (P_t^A) of the firm. If the firm's H-shares are traded at a relative discount to A-shares, the HA premium is negative. If the H-shares are more expensive than A-shares, the HA premium is positive. If both are traded at price parity, the HA premium is zero.

The average HA premium on April 9 is -0.13, which implies that H-share prices are on average 13 percent less expensive than A-share prices. The standard deviation is 0.29, which indicates a wide spread of price disparity (either in terms of premium or discount). On April 10, the average HA premium only changed slightly to -0.12. However, the standard deviation decreased substantially by 5 percentage points to 0.24, which suggests that the price disparity became closer to zero upon the policy announcement. In addition, firms that have a larger initial price disparity tend to experience a larger change in the HA premium, a result that is consistent with Chan (2014).

Table II reports summary statistics related to the daily returns of A-shares and H-shares during the week surrounding the policy announcement on April 10. The results are reported by three separate subgroups as defined by the firm's HA premium on April 9: (1) lower than -10 percent; (2) between -10 and +10 percent; (3) larger than +10 percent. There are 32, 14, and 15 firms in the above groups, respectively. The daily stock returns in both markets did not exhibit any anomaly on April 8 and 9. However, on April 10, the Hong Kong market experienced a 9.46 percent price increase among firms whose H-shares were at a relative discount, and the Shanghai market experienced a 4.87 percent price increase among firms whose A-shares were at a relative discount. On April 11, the price disparity narrowed further, as the Hong Kong market experienced a 3.24 percent price *reduction* among firms whose H-shares were at a relative premium, and the Shanghai market experienced a mild 1.13 percent price *reduction* among firms whose A-shares were at a relative premium.

5 Empirical Results

5.1 Cointegration Tests

Table III summarizes the results of cointegration tests that are conducted on all 61 firms in the analysis sample. For each firm, the test is run separately using data from the pre-announcement period from January 2, 2014 to April 9, 2014, and data from the post-announcement period from April 10, 2014 to July 29, 2014. We report results from two test methods: (1) Schwarz Bayesian information criterion (SBIC) (Gonzalo and Pitarakis (1998), Aznar and Salvador (2002)); (2) Trace statistic method (Johansen (1991, 1995)) at the 1 percent significance level.[10] The results are classified by three firm subgroups as defined by the firm's HA premium on the day prior to policy announcement.

The test results show that there are substantially more firms with cointegrated share prices after the policy announcement. During the pre-announcement period, the SBIC and trace statistic methods detect cointegration between the prices of H-shares and A-shares in 8 firms and 1 firm, respectively. By contrast, during the post-announcement period, the number of firms with cointegrated share prices increases to 26 and 16, respectively. Therefore, as a whole, there is stronger evidence for an equilibrium relationship between the prices of H-shares and A-shares after the policy announcement. In addition, all three firm subgroups experience an increase in the number of firms with cointegrated share prices. The effect is particularly notable among firms with a large positive HA premium just prior to the policy

[10] We also test for cointegration using the trace statistic method at the five percent significance level. The results are similar and are available upon request.

announcement.

5.2 Key Model Estimates

Table IV summarizes the estimation results of 26 vector error-correction models that use data from firms with cointegrated share prices as determined by SBIC. The firms are classified into three subgroups according to their level of HA premium on the day prior to policy announcement: (1) lower than -10 percent; (2) between -10 and +10 percent; (3) larger than +10 percent. For each of the above subgroup and as a whole, the table reports the mean of parameter estimates, the standard deviation (in parentheses), and the number of firms with a parameter estimate that is different from zero at the five percent significance level (in squared brackets).

The top panel of the table reports summary statistics of parameter estimates from the cointegrating equation, which represents the long-run equilibrium relationship between the price of H-shares and A-shares. The average cointegrating coefficient (β) for all 26 firms is -1.237, and the standard deviation is 0.611. Therefore, as a whole, the result is consistent with the theoretical prediction that the cointegrating coefficient is -1 or, in other words, the relative law of one price. While firms with a negative initial HA premium (subgroup 1) tend to have a more negative cointegrating coefficient, the other subgroups are strongly consistent with this theoretical prediction.

In the cointegrating equation, the intercept coefficient tends to be smaller among firms with a higher initial HA premium. This is broadly consistent with theoretical predictions on the level of equilibrium, a point which we will return to when the restricted model is discussed. The average time trend coefficient is negative at -0.0012, which implies that H-shares tend to become relatively more expensive than A-shares over time. While 17 firms have a statistically significant estimate, the estimates are quite heterogeneous as indicated by a relatively large standard deviation. We will revisit the time trend coefficients when the restricted model is discussed.

The next two panels of the table report summary statistics of parameter estimates from the vector autoregressive equations, which represent short-run dynamics. The key results are the adjustment coefficients in the H-share and A-share equations, which have an average value of -0.273 (α^h) and 0.134 (α^a), respectively. Therefore, as a whole, the price of H-shares tends to adjust twice as fast as the price of A-shares toward the equilibrium, and the *overall* magnitude of the error-correction process is quite sizable (i.e., 0.273+0.134 = 0.407). Moreover, there is stronger evidence that the H-share market is subject to such an adjustment – 21 firms have a statistically significant estimate in the H-share equation, but there are only 14 such firms in the A-share equation. Turning to the subgroups, firms with a negative initial HA premium tend to have a strong price adjustment in H-shares but minimal price adjustments in A-shares; by contrast, firms with a positive initial HA premium tend to have symmetric price adjustments in both markets.

The remaining coefficients in the vector autoregressive equations suggest that the relationship of prices in both markets are largely determined by the cointegrating equation rather than short-run dynamics. For most firms, the stock return in one market has an insignificant effect on the stock return in the other market the following day (π_1^{ha} and π_1^{ah}). The equations also suggest that the current stock return generally has an insignificant effect on the stock return in the same market the following day (π_1^{hh} and π_1^{aa}). Similarly, the second order lagged terms (π_j for $j = 2$) are statistically insignificant in almost all the cases (results not shown). Both markets do not have a significant trend in price levels according to the short-run equations (c^h and c^a).

Figures 1 to 3 focus on the 26 firms with cointegrated share prices, and plot each firm's key model estimates against its level of HA premium on the day prior to policy announcement. Figure 1 reports the point estimates and 95 percent confidence intervals of the cointegrating coefficient β. Almost all the firms have a point estimate between 0 and -2; in addition, the majority of the firms have a cointegrating coefficient is not different from -1 at the 5 percent significance level. Interestingly, firms with a highly negative initial HA premium tend to have a more negative cointegrating coefficient.

Figures 2 and 3 report the point estimates and 95 percent confidence intervals of the price adjustment coefficient in the H-share market (α^h) and the A-share market (α^a), respectively. The point estimates for α^h typically range from -0.2 and -0.5, and the point estimates for α^a are typically smaller in magnitude (between +0.1 and +0.4). While the adjustment coefficients are relatively homogeneous across firms, there is a slight tendency for firms with a highly negative initial HA premium to experience a more sensitive price adjustment in the H-share market than the A-share market.

5.3 Determinants of Error Correction Dynamics

The results above indicate that both the Hong Kong and Shanghai markets contribute to the price discovery process. In this section, we present further evidence of the mechanism of price adjustment dynamics. Figure 4 plots the price adjustment coefficients in the A-share market (α^a) versus the negative value of the price adjustment coefficients in the H-share market ($-\alpha^h$) for 26 firms with cointegrated share prices. In 21 firms, the price of H-shares adjusts by a larger degree than the price of A-shares whenever the price levels are in disequilibrium. Thus, for the majority of the firms, the Hong Kong market plays a *smaller* role in price discovery than the Shanghai market. This is consistent with the fact that the Mainland market is often considered as the "home market" of these firms where substantial information is produced.

We further analyze how various factors contribute to the role of price discovery in both markets. Following Eun and Sabherwal (2003), we construct a measure for the Shanghai share of total adjustment in prices:

$$ShAdj = \frac{\alpha^a}{\alpha^a - \alpha^h}. \tag{11}$$

A special case is no price adjustment in the Shanghai market (i.e., α^a=0). Then, *ShAdj* will be zero, and the Hong Kong market is a "pure satellite" of the Shanghai market (e.g., Garbade and Silber (1982)). In our subsample of 26 firms, the mean of *ShAdj* is 31.2 percent (the median is 32.2 percent), and the standard deviation is 36.1 percent. Therefore, on average, the Shanghai market contributes to approximately two-thirds of the price discovery process. The estimate is strikingly similar to Eun and Sabherwal (2003), who find that the Canadian (home) market contributes to 61.9 percent of price discovery among Canadian stocks that are cross-listed in the U.S. market.

We focus on the following measures as potential determinants of the price adjustment mechanism. In a similar spirit to Eun and Sabherwal (2003), we construct variables on the Hong Kong share of trading volume ($HVolshare$) and the bid-ask spread ratio between both markets (Hong Kong divided by Shanghai, denoted by *SpreadRatio*). A larger Hong Kong share of trading volume implies more intense competition from Hong Kong as well as greater informativeness of the Hong Kong trading, which should drive *ShAdj* higher. By contrast, a higher spread ratio suggests that the Hong Kong stock exchange poses a smaller competitive threat and carries less informative trading, which should drive $ShAdj$ lower. As in Cai et al. (2011), we also include two variables that capture differential market sentiment effects ($VolRelative$) and information asymmetries ($BASRelative$) between both markets, respectively. A larger value of either variable may reduce the magnitude of the price adjustment process. We include the log of market capitalization ($LMktCap$) to control for firm size. In addition, we control for the level of HA premium just prior to policy announcement, which may reflect other factors that are not explicitly controlled for in the regression analysis.

Table V reports estimation results from four sets of regression analysis. In Column 1, the dependent variable is the Shanghai share of total price adjustment ($ShAdj$). The coefficient estimates on the Hong Kong share of trading volume and the bid-ask spread ratio are 1.043 and -0.361, respectively, which have expected signs and are both statistically significant at the 5 percent level. Both results confirm the key findings in Eun and Sabherwal (2003) – increased competition and greater informativeness from the Hong Kong market will increase Shanghai's price adjustment share and therefore reduce its relative role of price discovery.[11]

The next two columns report estimation results related to the size of price adjustment coefficients in the Shanghai and Hong Kong markets (α^a and $-\alpha^h$), respectively. The results allow us to evaluate how the above factors are related to price adjustment in each individual market. The size of the price adjustment coefficient in the Shanghai market tends to be more related to the explanatory variables, as most of them are statistically significant. For instance, the Hong Kong share of trading volume is positively related to the size of price adjustment in the Shanghai market, but it has no significant relationship with the size of price adjustment in the Hong Kong market. The coefficient on the bid-ask spread ratio has expected sign and is statistically significant in both sets of regressions – a higher relative bid-ask spread in the Hong Kong market will reduce the size of price adjustment in the Shanghai market and increase the size of price adjustment in the Hong Kong market. By contrast, the coefficients on differential market sentiment ($VolRelative$) and information asymmetries ($BASRelative$) deliver mixed evidence, as both have positive signs in the Shanghai market, but have negative signs in the Hong Kong market. The last column of the table uses the *total*

[11] The coefficient on $BASRelative$ is positive and statistically significant. Since the dependent variable is the *share* of price adjustment, the expected sign of the coefficient is ambiguous in this regression.

magnitude of price adjustment (i.e., $\alpha^a - \alpha^h$) as the dependent variable. Not surprisingly, since the coefficients in the previous two regressions have opposite signs, the coefficients in this regression are generally close to zero and statistically insignificant.

The initial HA premium is not statistically significant at the 10 percent level in all regressions. As a robustness check, we also run the above regressions using the initial HA premium and log of market capitalization as the only explanatory variables (results not shown). The signs of the coefficients are the same as the original set of regressions, and the magnitudes remain similar. Interestingly, the initial HA premium becomes more statistically significant in the first three regressions. Therefore, the level of initial HA premium may merely reflect information about the stock's trading characteristics, and does not appear to play a critical role in directly determining the price adjustment process when other factors are taken into account.

5.4 Convergence of Price Disparity in Equilibrium

To further investigate the implications of the vector error-correction model, we estimate a restricted version of the model in which the cointegrating coefficient β is set a priori to -1. Under this restriction, the cointegrating equation can be written as:

$$log(P_t^H) - log(P_t^A) + \mu + \gamma t = 0,$$

which implies that the *equilibrium* level of HA premium is a simple exponential function of the time trend γt:

$$\frac{P_t^H}{P_t^A} - 1 = e^{-\mu-\gamma t} - 1.$$

Both the intercept and the trend coefficients have a straightforward interpretation. The equilibrium HA premium on the first day of policy announcement (April 10, or $t = 0$) is equal to a constant denoted by $e^{-\mu} - 1$. The trend coefficient γ can be interpreted as the average daily rate of change of the equilibrium HA premium.

The restricted model is estimated for each of the above 26 firms with cointegrated share prices. Figure 5 plots the restricted model's *equilibrium* HA premium on the first day of policy announcement ($e^{-\mu} - 1$) against the *actual* HA premium one day prior to announcement. The points form a positive relationship that is flatter than the 45 degree line, which implies that the equilibrium HA premia of these firms are closer to zero than the actual HA premia prior to policy announcement. Therefore, the price disparity between H-shares and A-shares has converged not only in the observed data but also in terms of the level of the equilibrium implied by the model. The results also reveal some interesting asymmetries regarding the degree of convergence. For instance, among firms with an initial HA premium of larger than +10 percent on April 9, the equilibrium is on average 40 percent lower than the initial premium; among firms with an initial HA premium of smaller than -10 percent on April 9, the equilibrium is on average 12 percent closer to zero than the initial premium.

The trend coefficients (γ) from the restricted model are very similar to the estimates from the unrestricted model. Among firms with an initial HA premium of larger than +10 percent on April 9, the average trend coefficient is -0.0009; Among firms with an initial HA premium of lower than -10 percent on April 9, the average trend coefficient is -0.0015. While both numbers imply that the equilibrium HA premium becomes larger over time, the change occurs 1.5 times as fast among firms with a negative initial HA premium. Interestingly, among firms whose H-shares were traded at a deep discount to A-shares, the trend coefficients are substantially more negative (and also highly statistically significant) – they range from -0.003 to -0.005 among the three firms with the most negative HA premium. The above results indicate that net of the overall market effect, the equilibrium price discount of H-shares diminishes over time, a finding that is broadly consistent with Cai et al. (2011).

5.5 Sensitivity Analysis

A number of sensitivity analysis are conducted on the baseline results. For instance, we estimate a vector error-correction model with more lags in the vector autoregressive component, with little change in estimation results. While our cointegration test results (e.g., trace statistic method in Table III) already rule out stationarity of both series, we conduct separate unit root tests on price data for robustness check, and confirm that almost all the data series have a unit root. We also conduct a two-step cointegration test (Engle and Granger (1987)), which reveals a similar pattern to Table III. Interestingly, the two-step method tends to identify more firms with cointegrated share prices than the trace statistic method at the same significance level. We also perform cointegration tests and estimation based on shorter sample periods, with qualitatively similar results. For instance, using June 9 as the last observation for the post-announcement period, there are 34 and 19 firms with cointegrated share prices under the SBIC and trace statistic methods, respectively. While the tests detect more firms with cointegrated share prices, estimation results from the vector error-correction model suggest that the cointegrating coefficient β tends to have larger standard errors and is generally farther away from the hypothesized value of -1.

We perform an empirical analysis on 15 firms that are concurrently listed in the *Shenzhen* and Hong Kong markets. Since the reform does not allow for cross-market investment between Shenzhen and Hong Kong markets, these firms are unaffected and they therefore form a natural control group for analysis. However, the results should be treated with caution, as investors may anticipate that the liberalization will be extended to the Shenzhen market eventually. The cointegration tests confirm our baseline results. During the pre-announcement period, there are one and zero firms with cointegrated share prices under the SBIC and trace statistic methods, respectively. The numbers increase slightly to three and two firms, respectively, during the post-announcement period.

An empirical analysis is also performed on the 35 remaining firms that are concurrently listed in Shanghai and Hong Kong, but do not have cointegrated share prices. Since these firms do not pass the cointegration tests in Table III, the results should be treated with caution because the vector error-correction model may be misspecified. Nevertheless, since a number of firms are on the borderline of passing the tests, the model estimates could be informative.

Upon estimation, we find that there are seven firms with rather extreme values of the cointegrating coefficient β (larger than 5 or smaller than -5) and large standard errors. To minimize the impact of outliers, these firms are removed from subsequent analysis. Of the remaining subsample, the average cointegrating coefficient is -1.26 with a standard deviation of 1.40. Therefore, the results confirm the validity of the relative law of one price, even though the distribution of the estimates tends to be wider.[12]

We also investigate the price adjustment coefficients (α^a and α^h) of these firms. Interest-

[12] Seven firms have a cointegrating coefficient of lower than -2, 18 firms have a value between 0 and -2, and three firms have a small positive value. The average standard error is 0.50, which is considerably larger than firms with cointegrated share prices (0.19).

ingly, the price adjustment coefficients tend to be smaller in magnitude. The average size of the price adjustment coefficients in the Hong Kong and Shanghai markets are -0.14 and 0.01, respectively. Therefore, the average *total* magnitude of price adjustment ($\alpha^a - \alpha^h$) is only 0.13, which is one-third as large as in firms with cointegrated share prices (0.407). The slow error correction dynamics is also fully consistent with the weaker equilibrium relationship as indicated by the cointegration tests.

6 Conclusion

In this paper, we studied the impact of the announcement of *Shanghai-Hong Kong Stock Connect* on the dynamic relationship between H- and A-share prices of firms that were concurrently listed on both stock exchanges. Through a vector error-correction model and a microscopic analysis on 61 pairs of price series, we obtained three major findings. First, there were substantially more cross-listed firms (40 percent of the baseline sample) that exhibited a cointegrating relationship between their H- and A-share prices after the policy announcement. The cointegrating coefficients were close to unity, indicating that the relative law of one price held in the post-announcement equilibrium. Second, by using the policy as a natural experiment and leveraging on the highly heterogeneous price disparity before the announcement, our analysis robustly revealed that the price disparity between H- and A-shares tightened under equilibrium, both statically right after the policy announcement and dynamically over time in the post-announcement period. Third, we compared the roles played by Hong Kong and Shanghai markets in price discovery. The analysis showed that, on average, a greater portion of disequilibrium adjustment occurred on H-share prices, suggesting that the Shanghai market acted as the "home market."We also found that the price discovery role of the Shanghai market was positively related to its share of trading volume and negatively related to its percentage bid-ask spread compared to the Hong Kong market. This corroborated with earlier studies on the price discovery of cross-listed stocks, which found that the home market played a larger role in information dissemination (e.g., Eun and Sabherwal, 2003).

Our findings shed new light on the effects of capital liberalization policy on financial markets. The announcement of *Shanghai-Hong Kong Stock Connect* set the perfect stage for analyzing the implications of capital control for pricing disparity and dynamics. Although the policy would not launch until six months after the announcement, investors' expectations seemed to have a quick impact on the prices of cross-listed stocks in both markets. In the short run, the prices of H- and A-shares reacted to disequilibrium shocks asymmetrically, but in the long-run, the prices followed the relative law of one price with a shrinkage in price disparity. This was in line with the original aims of the reform, which were to enhance financial integration and lower the barrier of capital flow between both financial markets. While the reform imposed upper limits on the daily and overall amounts of capital flow between both markets, our study will have important implications for the price dynamics of cross-listed stocks when there are further unanticipated attempts to lower the capital flow barrier in the future.

As a final note, our study only focused on the policy's impact on two markets. It would be interesting to extend the analysis to a multi-market level and investigate the policy implication for closely-knitted trading platforms such as Shenzhen and other international markets, on which stocks are cross-listed. This is left for future research.

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TABLE I

Summary Statistics of Market Variables in the Post-Announcement Period

Variables	Mean	St.Dev.	Percentiles 25th	Percentiles Median	Percentiles 75th
Price (in HKD) [a]					
H-share	10.08	12.17	3.18	4.94	12.92
A-share	10.43	10.71	4.05	5.75	12.80
Volume (in million HKD)					
H-share	180.52	283.88	23.36	52.87	187.48
A-share	170.50	210.51	55.44	126.32	185.48
Volume (in million shares)					
H-share *(HVol)*	27.31	55.03	3.65	10.32	19.52
A-share *(AVol)*	20.73	18.51	6.95	13.25	29.99
Percent bid-ask spread					
H-share (*Hbas)*	0.26%	0.15%	0.16%	0.21%	0.32%
A-share *(Abas)*	0.23%	0.14%	0.10%	0.22%	0.32%
HvolShare [b]	38.90%	20.49%	24.46%	36.30%	51.84%
SpreadRatio [c]	1.54	1.07	0.87	1.12	1.75
VolRelative [d]	0.40	0.23	0.24	0.36	0.54
BasRelative [e]	0.21	0.18	0.06	0.17	0.27
MktCap on April 9, 2014 [f]	65.79	184.69	5.36	11.97	42.52
HApremium [g]					
on April 9, 2014	-0.13	0.29	-0.33	-0.13	0.10
on April 10, 2014	-0.12	0.24	-0.29	-0.11	0.08

[a] *Price* is the average of the daily closing prices (in HKD) over the post-announcement period (April 10 to July 29, 2014).

[b] *HVolShare* is defined as *HVol* /(*HVol* +*AVol*), where *HVol* and *AVol* are the traded volumes (both in million HKD) of H-shares and A-shares, respectively.

[c] *SpreadRatio* is defined as *HBas* /*ABas* , where *HBas* and *ABas* are the percentage bid-ask spreads of H-shares and A-shares, respectively.

[d] *MktCap* is the market capitalization (in billion HKD) as at April 9, 2014.

[e] *VolRelative* is defined as |*HVol* -*AVol* |/(*HVol* +*AVol*).

[f] *BasRelative* is defined as |*HBas* -*ABas* |/(*HBas* +*ABas*).

[g] *HApremium* is defined as P_H/P_A-1, where both the price of H-shares (P_H) and A-shares (P_A) are expressed in Hong Kong dollars.

TABLE II

Summary Statistics of Daily Returns of H-shares and A-shares

	HA premium on April 9, 2014[a]			
	Lower than -10%	Between -10% and +10%	Higher than +10%	All
Number of firms	32	14	15	61
Daily returns of H-shares				
on 8 April	1.11%	2.51%	1.03%	1.37%
on 9 April	0.14%	0.79%	0.46%	0.35%
on 10 April	9.46%	1.16%	-0.49%	5.22%
on 11 April	-0.67%	-1.87%	-3.24%	-1.58%
on 12 April	-0.94%	-0.20%	0.72%	-0.36%
Daily returns of A-shares				
on 8 April	1.53%	2.03%	1.90%	1.73%
on 9 April	0.22%	0.47%	0.12%	0.24%
on 10 April	1.13%	1.06%	4.87%	2.10%
on 11 April	-1.13%	-0.46%	-0.49%	-0.83%
on 12 April	-0.05%	0.07%	-1.12%	-0.31%

[a]HA premium is defined as P_H/P_A-1, where both the price of H-shares (P_H) and A-shares (P_A) are expressed in Hong Kong dollars.

TABLE III

Results of Cointegration Tests[a]

HA premium on the day prior to policy announcement (April 9, 2014):	Number of Firms	Number of Firms with Cointegrated Share Prices			
		Pre-Announcement Data (Jan 2 to April 9)		Post-Announcement Data (April 10 to July 29)	
		Schwarz Bayesian Information Criterion	Trace Statistic Method (1% sig. level)[b]	Schwarz Bayesian Information Criterion	Trace Statistic Method (1% sig. level)[b]
Lower than -10%	32	4	0	9	6
-10% to +10%	14	2	0	5	3
Larger than +10%	15	2	1	12	7
All	61	8	1	26	16

a The HA premium is P_H/P_A - 1, where both the price of H-shares (P_H) and A-shares (P_A) are expressed in Hong Kong dollars. A positive HA premium implies that H-shares are more expensive. A negative premium implies that A-shares are more expensive.

b See Johansen (1995).

TABLE IV

Summary Statistics of Key VECM Estimates[a]

Mean of parameter estimates (standard deviation in parentheses)	All	By HA Premium on April 9, 2014: Lower than -10%	Between -10% and +10%	Higher than +10%
Cointegrating equation:				
Log-price of A-shares (β)	-1.237	-1.632	-1.158	-0.973
	(0.611)	(0.665)	(0.597)	(0.439)
Intercept (μ)	0.490	1.588	0.302	-0.255
	(1.434)	(1.482)	(0.929)	(1.074)
Linear time trend (γ)	-0.0012	-0.0014	-0.0017	-0.0009
	(0.0013)	(0.0016)	(0.0013)	(0.0009)
	[17]	[5]	[4]	[8]
Daily return of H-shares equation:				
Deviation from equilibrium (α_h)	-0.273	-0.355	-0.265	-0.215
	(0.143)	(0.101)	(0.155)	(0.145)
	[21]	[9]	[3]	[9]
Lagged daily return of H-shares (π_{hh1})	0.065	0.026	0.201	0.036
	(0.176)	(0.165)	(0.142)	(0.180)
	[6]	[2]	[2]	[2]
Lagged daily return of A-shares (π_{ha1})	-0.154	-0.037	-0.324	-0.170
	(0.181)	(0.185)	(0.122)	(0.138)
	[4]	[0]	[1]	[3]
Intercept (c_h)	0.0008	0.0002	0.0012	0.0010
	(0.0012)	(0.0003)	(0.0019)	(0.0011)
	[0]	[0]	[0]	[0]
Daily return of A-shares equation:				
Deviation from equilibrium (α_a)	0.140	0.075	0.101	0.204
	(0.134)	(0.069)	(0.136)	(0.148)
	[14]	[4]	[2]	[8]
Lagged daily return of A-shares (π_{aa1})	-0.009	0.029	-0.058	-0.017
	(0.178)	(0.166)	(0.305)	(0.126)
	[2]	[1]	[1]	[0]
Lagged daily return of H-shares (π_{ah1})	0.018	-0.035	0.144	0.007
	(0.128)	(0.093)	(0.165)	(0.107)
	[3]	[1]	[2]	[0]
Intercept (c_a)	0.0007	0.0007	0.0006	0.0007
	(0.0008)	(0.0009)	(0.0011)	(0.0007)
	[0]	[0]	[0]	[0]
Number of firms with cointegrated share prices	26	9	5	12

[a] The HA premium is P_H/P_A - 1, where both the price of H-shares (P_H) and A-shares (P_A) are expressed in Hong Kong dollars. Numbers in parentheses are the standard deviations of parameter estimates among all firms with cointegrated shares. Numbers in squared brackets are the number of firms with a parameter estimate that is different from zero at the five percent significance level. Coefficient estimates on second-order lagged daily returns are not reported.

TABLE V

Determinants of Error-Correction Dynamics[a]

Dependent variable:	ShAdj $\alpha^a/(\alpha^a-\alpha^h)$ (1)	α^a (2)	$-\alpha^h$ (3)	$\alpha^a-\alpha^h$ (4)
Intercept	0.235	0.082	0.234 **	0.316 ***
	(0.231)	(0.087)	(0.110)	(0.117)
HA premium on April 9	0.300	0.174	-0.072	0.102
	(0.291)	(0.110)	(0.139)	(0.148)
LMktCap	-0.186 **	-0.064 **	0.006	-0.058
	(0.067)	(0.025)	(0.032)	(0.034)
HVolShare	1.043 **	0.343 **	-0.046	0.297
	(0.413)	(0.156)	(0.197)	(0.209)
SpreadRatio	-0.361 **	-0.102 *	0.153 *	0.051
	(0.155)	(0.058)	(0.074)	(0.079)
VLMRelative	0.448	0.236	-0.006	0.231
	(0.371)	(0.140)	(0.177)	(0.188)
BASRelative	2.726 **	0.853 **	-0.841	0.012
	(1.028)	(0.388)	(0.491)	(0.521)
R-square	0.536	0.519	0.328	0.198

[a] *LMktCap* is the logarithm of market capitalization (MktCap). *HVolShare* is defined as *HVol* /(*HVol* +*AVol*), where *HVol* and *AVol* are the trading volumes of H- and A-shares, respectively. *SpreadRatio* is defined as *HBas* /*ABas* , where *HBas* and *ABas* are the percentage bid-ask spreads of H- and A-shares, respectively. *VLMRelative* is defined as |*HVol* -*AVol* |/(*HVol* +*AVol*). *BASRelative* is defined as |*HBas* - *ABas* |/(*HBas* +*ABas*). Standard errors are given in parentheses. *, Significant at the 10 percent level; **, significant at the 5 percent level; ***, significant at the 1 percent level.

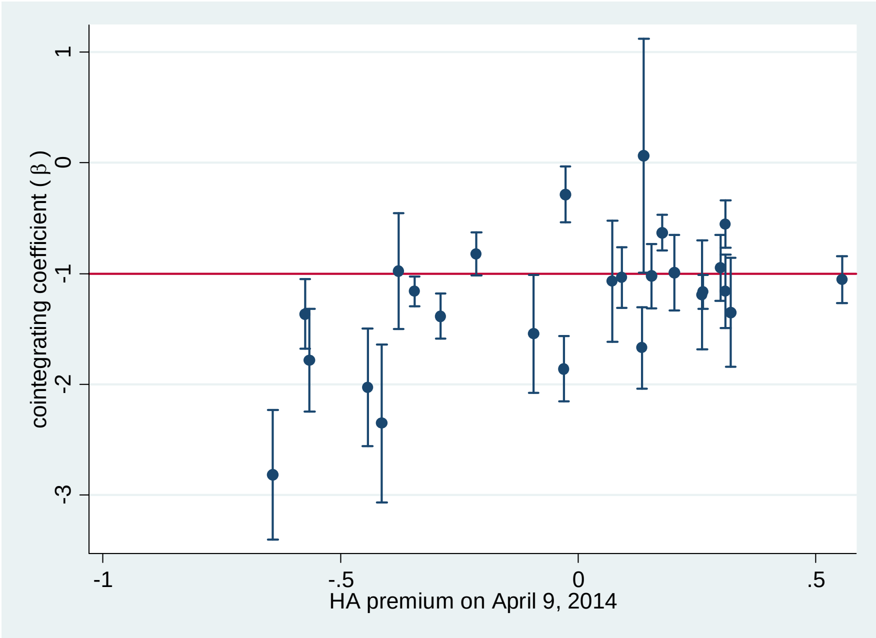

FIGURE 1. --- Estimate of Cointegrating Coefficient β
(Error Bars Denote 95-Percent Confidence Interval).

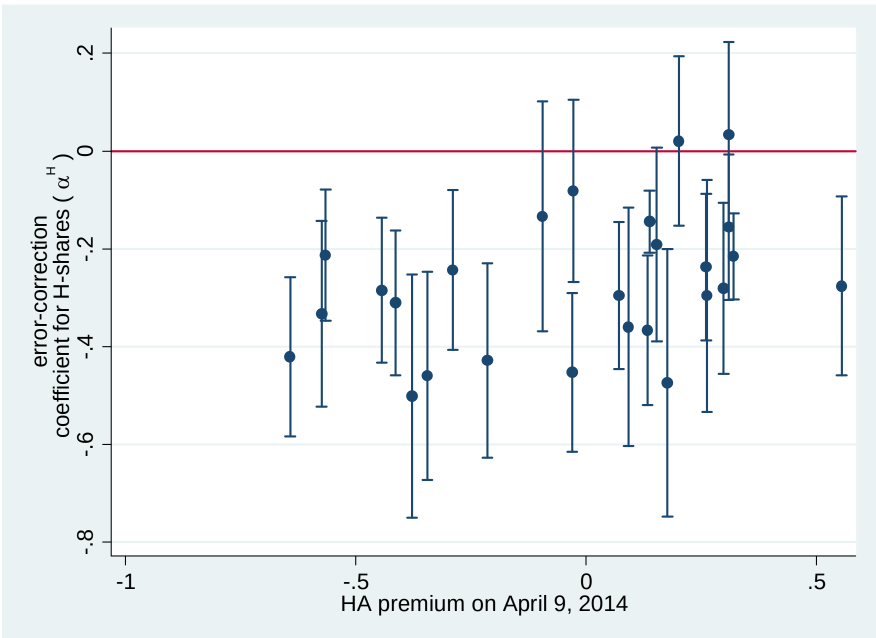

FIGURE 2. --- Estimate of the Error Correction Coefficient in the H-Share Market α^h
(Error Bars Denote 95-Percent Confidence Interval).

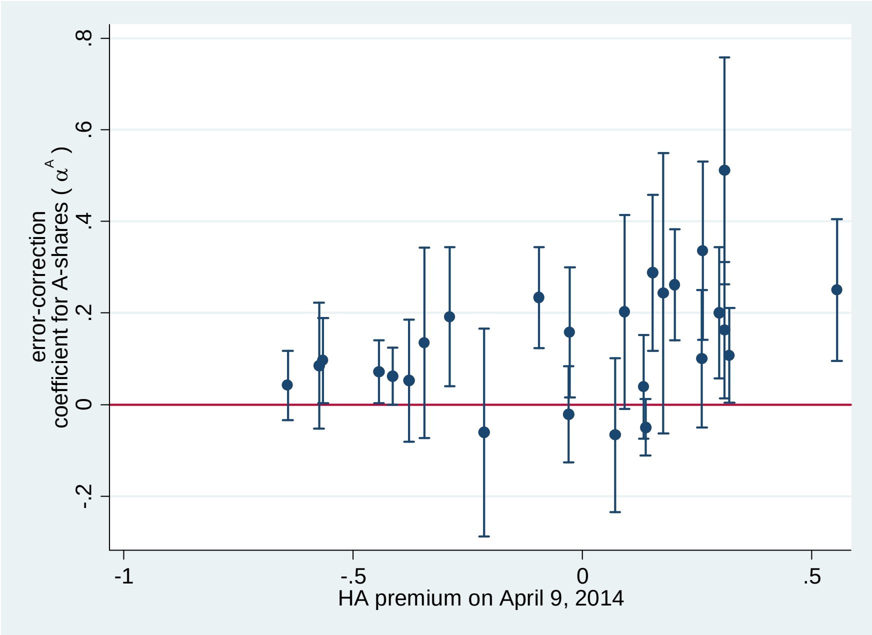

FIGURE 3. --- Estimate of the Error Correction Coefficient in the A-Share Market α^a (Error Bars Denote 95-Percent Confidence Interval).

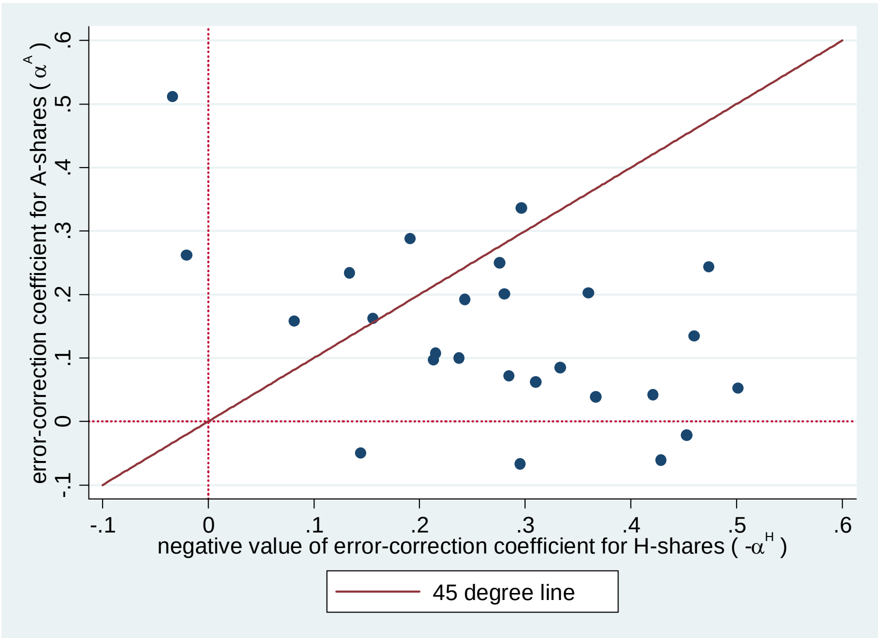

FIGURE 4. --- Plot of Error Correction Coefficients in both Markets (α^a versus $-\alpha^h$).

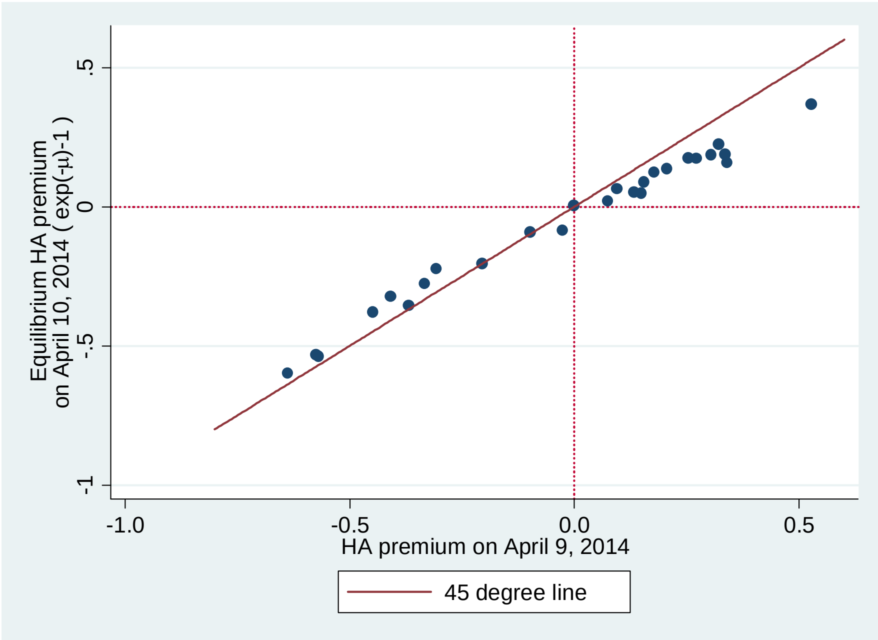

FIGURE 5. --- Convergence of Price Disparity in Equilibrium.