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Article

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Price discovery of South African stocks cross-listed on the New York Stock Exchange

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Abstract: The number of South African firms that have sought cross-listing in regional and global markets has been increasing. Many firms increase their presence beyond local markets, and one of these avenues is through cross-listing; however, it remains unclear whether the home or host market contributes more to the incorporation of information in cross-listed stocks. This study examined the price discovery process of Johannesburg Stock Exchange (JSE) domiciled stocks with a cross-listing on the New York Stock Exchange (NYSE). The price discovery of cross-listed stocks was tested using Johansen's and Phillips-Ouliaris' cointegration, the vector error correction model and common factor weights. Long-term relationships consistent with the law of one price were found. Contrary to the home bias hypothesis, results indicated that the NYSE dominated price discovery. Fund managers and investors who have included JSE cross-listed stocks in their portfolios should devote more attention to the NYSE as information flows appear to occur mainly from the NYSE to JSE. Further, results suggest that there is co-movement and integration between the USA and South Africa which diminishes diversification benefits for investors.

ABOUT THE AUTHOR

Kudakwashe J. Chipunza is pursuing a PhD (Development Finance) focusing on financial inclusion and financial vulnerability. His research interests lie in asset pricing in emerging markets, and development finance focused on household welfare, financial inclusion and financial literacy. Professionally, he has worked in non-governmental organisations undertaking monitoring and evaluation of various projects. Kudzanai R. Tsunga is in the process of completing his PhD (Finance) at the University of KwaZulu-Natal, focusing on the impact of the financial economy on real economic growth in South Africa. His key research interests are on growth and asset pricing in emerging financial markets. He is employed as an investment administrator for an investment reporting firm in Johannesburg. Kerry F. McCullough is a Senior Lecturer (Finance) at the University of KwaZulu-Natal. Her research interests are capital markets, exchange traded funds, and higher education. This study was inspired by Mr Chipunza and Mr Tsunga's preparations for pursuing their doctoral dissertations.

PUBLIC INTEREST STATEMENT

This paper investigates the price discovery of shares with a primary listing on the Johannesburg Stock Exchange (JSE) and a secondary listing on the New York Stock Exchange (NYSE). Our study was inspired by South African firms seeking to cross-list their shares internationally. A long-run relationship between the JSE and NYSE indicates co-movement and integration between these markets, which may diminish diversification benefits for investors using both markets. We then quantified the amount that the NYSE and JSE contribute to price discovery and find that, contrary to the home bias hypothesis, the NYSE has a higher contribution to price discovery of JSE domiciled shareholders' equity. Fund managers and investors who have included JSE cross-listed stocks in their portfolios should devote more attention to the NYSE as information flows appear to occur mainly from the NYSE to JSE.

Subjects: Econometrics; Finance; Investment & Securities

Keywords: Cross-listed stocks; price discovery; JSE; NYSE

1. Introduction

Globalisation has provided firms with opportunities to access international capital markets. One of the avenues through which capital markets have been able to become more integrated is through cross-listing (Levine & Schmukler, 2006). Cross-listing is the establishment of a secondary listing on a foreign exchange in addition to listing on the firm's domestic exchange (Chisadza, 2014). This, however, should not be confused with dual listing. Dual listing occurs when two companies incorporated in different countries contractually agree to operate their businesses as if they were a single enterprise, while retaining their separate legal identity and existing stock exchange listings (Adelegan, 2008).

Several advantages are associated with cross-listing of stockholders' equity which may encourage managers to pursue this route of accessing foreign capital markets. One of these is that listing on foreign stock exchanges exposes firms to heightened exposure and financial disclosure (Baker et al., 2002). Consequently, cross-listed stocks tend to experience more news coverage and decreasing agency costs (Doidge et al., 2004), increased share liquidity (Domowitz et al., 1998; Karolyi, 2006), lower firm's cost of capital (Hail & Leuz, 2009), lower market segmentation (Domowitz et al., 1997), wider investor base (Merton, 1987) and decline in earnings forecast errors (Miller, 1999).

Due to the additional exposure and disclosure impacts of cross-listed firms being asymmetric, it may be hypothesised that the prices on one market (with greater informational efficiency) lead the prices in other markets. It is unclear whether the home or host market will contribute more to price discovery of a share which is traded on multiple markets and which has multiple prices. Price discovery, in a multiple market context, is the process through which markets determine equilibrium prices for cross-listed firms and the roles played by home and foreign markets in determining these prices (Schreiber & Schwartz, 1986).

There are two key theories relevant to this issue. The home-bias hypothesis proposes that the home market will dominate the price discovery process (it will reflect new information first), because substantial information originates in the home market (Ammer et al., 2012). That is, information could originate from the home market before it is filtered into the host market *ceteris paribus* (Bacidore & Sofianos, 2002). This claim was corroborated empirically in studies that investigated price discovery of stocks with a cross-listing on US markets with primary listing in European markets (Grammig et al., 2005; Hupperets & Menkveld 2000; Pascual et al., 2006), North American markets (Eun & Sabherwal, 2003) and Asian markets (Hauser et al., 1998; Qadan & Yagil, 2012).

Contrary to the home-bias hypothesis, the extent to which the home market occupies a dominant role in the price discovery of stockholders' equity trading on multiple markets is dependent on the disclosure requirements and size of the capital market (Yang & Kun, 2014). For example, firm's that cross-list on the USA capital markets have to adhere to the Sarbanes-Oxley Act, which has relatively more stringent and rigorous financial disclosure requirements (in juxtaposition to numerous other capital markets). As a result, the USA capital markets would have superior quality of information as compared to other stock markets, which could suggest that the USA market (even if it is the host) will lead in the price discovery process of cross-listed shareholders' equity (Chen et al., 2010). Additionally, the USA capital markets, particularly the NYSE, are considered to be the largest and most liquid and, as a result, they tend to be more influential in impounding information into stock prices (Karolyi, 2006). These claims that contradict the home-bias hypothesis are supported by studies that use stocks with primary listing in the USA markets

(Blume & Goldstein, 1991; Hasbrouck, 1995; McInish et al., 1995), European markets (Flad & Jung, 2008; Phylaktis & Korczak, 2010) and Asian markets (Duppati et al., 2017; Yang & Kun, 2014).

2. Research purpose and objectives

Empirical literature on price discovery of stocks listed and trading on multiple markets is currently inconclusive as it is unclear whether the host or home market occupies a dominant role in the incorporation of information of cross-listed shares. Additional studies have focused on price discovery of stocks with primary listings in Europe, Asia and North America with cross-listing on the USA markets. A dearth of studies have explored the price discovery process of cross-listed stocks from an emerging African market's perspective. In order to fill this void, this study investigated the price discovery of shares with a primary (home) listing on the Johannesburg Stock Exchange (JSE) and a cross-listing (hosted) on the NYSE. Additionally, an investigation of a long-run relationship between each pair of cross-listed shares on the JSE and NYSE would be indicative of market integration between the US and South Africa which is yet to be examined using cross-listed shareholders' equity.

From South Africa's macro-level perspective, the findings are significant as evidence of a long-run relationship between the price series of JSE-domiciled stocks cross-listed on the NYSE may be indicative of the level of market integration between South African and the USA markets. Market integration between major developed and emerging markets are a potential avenue of increasing the level of capital inflows into an emerging market, which may also have implications on the exchange rate of the South African Rand (see Bekaert, 1995). A finding of market integration between SA and the USA markets may suggest a lower cost of capital for cross-listed firms that seek to raise capital due to the less information asymmetry surrounding the firms' stocks (Yang & Kun, 2014). In addition, the findings from this study are invaluable to fund managers who may want to include cross-listed stocks from emerging markets in their investment portfolios. Information on price discovery allows for greater attention to be afforded to the market where information regarding that stock originates from.

3. Literature review

Several studies provided evidence in support of the view that the host market contributes more to price discovery of stocks cross-listed on the USA markets. Blume and Goldstein (1991) employed a sample of USA stocks trading on multiple USA exchanges and showed that there was more price movement on the NYSE for non-NYSE stocks, which indicated that the NYSE (home market) contributed more to the price discovery process. McInish et al. (1995) investigated IBM stock traded on multiple markets (New York, Pacific and Mid-West Stock Exchanges) and showed that all three exchanges adjusted to retain long-run equilibrium. This implied that all three exchanges contributed to price discovery, although NYSE played a more dominant role. Hasbrouck (1995) used a sample of 30 Dow Jones stocks dually listed on NYSE to show that the NYSE made a higher contribution to price discovery.

A number of studies have shown that European stocks cross-listed on the USA exchanges were dominated by the USA exchanges in the price discovery process. For example, Phylaktis and Korczak (2010) employed a sample of 64 British and French stocks cross-listed on the NYSE and found that the USA share in price discovery was greater relative to the home market's contribution. Similarly, Flad and Jung (2008) demonstrated that the USA market occupied a dominant role in price discovery of German cross-listed stocks, noting that the DJIA contributed approximately 95% to the price innovation.

Studies on Asian stocks cross-listed on NYSE have demonstrated that the host market occupied a dominating role in the price discovery process. Yang and Kun (2014) investigated the price discovery dynamics of 11 Chinese stocks cross-listed on the NYSE, Stock Exchange of Hong Kong (SEHK) and Shanghai Stock Exchange. Their findings suggested that the NYSE played a dominant role in impounding information into stock prices; but failed to find integration between the

Chinese, US and Hong Kong markets. More recently, Duppati et al. (2017) determined that the NYSE had considerably more contribution to price discovery than the nine Chinese shares these authors examined that were cross-listed on NYSE. Interestingly, a paper by Hansda and Ray (2003) found bi-directional causality between the cross-listed stocks on MSE and NYSE which is technically in contradiction with the home bias hypothesis.

In contrast, there have been studies of stocks cross-listed on the USA markets, which have corroborated the home bias hypothesis. Grammig et al. (2005) examined the price discovery dynamics of three German stocks cross-listed on the NYSE and showed that NYSE occupied a relatively smaller role in the price discovery process. Hupperets and Menkveld (2000) investigated seven Dutch cross-listed stocks on the NYSE and found that the host market's contribution to price discovery was lower relative to the home market. Similar results were found of five Spanish stocks cross-listed on the NYSE (Pascual et al., 2006). Eun and Sabherwal (2003) found that the price adjustments between the stocks they considered were bi-directional with the domestic (home) Canadian market occupied a dominant role in a sample of 62 Canadian stocks listed on the NYSE, NASDAQ and AMEX.

Similarly, a number of studies investigated price discovery of stocks with primary listing in Asian markets and cross-listed in the US markets and showed that the home market dominated the price discovery process. For example, Hauser et al. (1998) investigated five stocks on the Tel Aviv Stock Exchange (TASE) that were also listed on NASDAQ and found information was transmitted from the TASE to the host market unidirectionally. Echoing Hauser et al.'s (1998) findings, Qadan and Yagil (2012) demonstrated that TASE dominated the price discovery of Israeli stocks cross-listed on the NASDAQ as indicated by the domestic market's higher contribution to price mean and variance.

In addition to the empirical literature which considers a US host/home market, several additional papers examined whether a non-USA market occupied a leading role in price informativeness. Su and Chong (2007) demonstrated that non-US host exchanges had a higher contribution to price discovery of cross-listed stockholders' equity using a sample of eight stocks domiciled on the Chinese markets that were cross-listed on the Stock Exchange of Hong Kong (SEHK). Frijns et al. (2010) showed that the home market was more dominant in the price discovery process for four Australian stocks cross-listed on the New Zealand Stock Exchange and five New Zealand stocks that were cross-listed in Australia. Chen et al. (2016) evidenced that the home market contributed more to price discovery using a sample of 67 Chinese stocks cross-listed on the SEHK.

A number of studies refuted claims of the home bias hypothesis using a sample of stocks that were cross-listed on non-US markets. Ding et al. (1999) demonstrated that the Stock Exchange of Singapore dominated the price discovery of nine Malaysian stocks with primary listing on the Kuala Lumpur Stock Exchange. Agarwal et al. (2007) investigated the price discovery of 17 stocks with primary listing on the SEHK dually listed on the London Stock Exchange (LSE) and showed that the LSE occupied a limited role in the price discovery of Hong Kong's stocks. Kadapakkam et al.'s (2003) examined 23 Indian stocks' equity with primary listing on the Mumbai Stock Exchange (MSE) and cross-listed on LSE, and showed that each market played a similar role in price discovery of shares.

The extant literature is currently inconclusive. A number of studies supported the home bias hypothesis while others refuted the claim that home markets dominated the incorporation of information into cross-listed share prices. The exact contribution to this price discovery process also remains mixed, with uni-directional, various contribution sizes, and bi-directional information flows noted in various papers. Highlighting further the need to address this in an emerging African market context, these inferences were based on stocks with a primary listing predominantly in European and Asian capital markets, with substantially less known about price discovery of cross-listed stocks domiciled in emerging African markets. As a result, this study addressed this gap by determining the direction of, and relative contribution to, price discovery of stocks cross-listed on the NYSE with a primary listing on the JSE. Such an investigation also allows for comment on the level of integration between the JSE and NYSE, which is yet to be explored using cross-listed stocks.

4. Research methodology

4.1. Data and sample

This section details the sample construction and data employed by this study. Foreign firms are usually traded and listed on US equity markets through American Depository Receipts (ADR). An ADR represents shares of a company held on deposit by a custodian bank in the company's home country which carry the corporate and economic rights of the foreign shares, subject to the terms specified on the ADR certificate (Domowitz et al., 1998). For this study, the focus was on level II and III South African ADRs with primary listing on JSE cross-listed on the NYSE.

Stockholders' equity was selected based on availability of historical trading data on both the JSE and NYSE for at least five years prior, to permit analysis over a sufficiently long time period (Yang & Kun, 2014; Duppati et al., 2017). To enable meaningful inferences, the stock had to have been frequently traded to avoid too many missing observations. Applying these criteria yielded a sample of six stocks (out of a population of nine stocks) (n = 6) which is comparable to that of Pascual et al. (2006) (n = 5), Grammig et al. (2005) (n = 3) and Su and Chong (2007) (n = 8). The final sample comprises Anglo-Gold Ashanti (AU), Gold Fields (GFI), Sasol (SSL), Sibanye Gold (SBGL), Harmony Gold (HMY) and DRD Gold (DRD). The number of mining firms cross-listed on the NYSE in our sample is explained by South Africa's strong mining sector focus, given the key role that gold mining occupies in the South African economy (Neingo & Tholana, 2016).

As shown in Table 1, NYSE and JSE function in two different time zones which have common trading hours in both markets for 1.5 hours between 3.30 p.m. and 5.00 p.m. South African time. The analysis considered this overlapping trading times with synchronous trading in both markets in line with comparable studies, including Grammig et al. (2005), Yang and Kun (2014), and Duppati et al. (2017) (who specifically chose their market for an overlapping common period).

Quoted closing intraday trade data were obtained from Bloomberg for six months for the period 1 June 2018 to 30 November 2018 during overlapping trading hours on the JSE and the NYSE. Due to daylight saving between 4 November 2018 and 30 November 2018, this overlapping time was adjusted to account for this hour. Price series were synchronously observable for 30-minute intervals in a -trading day on both exchanges between 4 November 2018 and 30 November 2018. A sample of 463 observations for each price series on JSE and NYSE resulted. The 30-minute interval was employed due to lower trading frequencies on the JSE relative to NYSE; however, the mentioned 30-minute intervals were considered to allow for the timeous incorporation of new information in each market (Dassanayake et al., 2013). In instances where a price at a specific matched point of time was not available, the most recently quoted closing price was used following Pascual et al. (2006).

Non-trading days (weekends and public holidays) on the JSE and NYSE were eliminated from the analysis. The intraday price series on the NYSE were converted to South African Rands (ZAR) as a common currency using the quoted close intra-day rand/dollar exchange rate at 30-minute intervals acquired from Bloomberg during the overlapping hours (Yang & Kun, 2014; Duppati et al., 2017). Exchange rate data were also adjusted for the relevant time zones and daylight savings.

Table 1. Trading Hours for JSE and NYSE

	JSE Opens	JSE Closes	NYSE Opens	NYSE Closes
Johannesburg Time	0900	1700	1530	2200
New York Time	0300	1100	0930	1600

Source: Authors' Own Illustration

4.2. Lag order selection and stationary tests

Following Duppati et al. (2017) and Yang and Kun (2014), the price series and exchange rate were converted into their natural logarithms to reduce positive skewness and within group variability. Prior to testing for a long-run relationship between the cross-listed stocks in the home and foreign (host) markets, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) were used to test whether the log price series contained a unit root.

The null hypothesis of the ADF and PP tests was that the log price series had a unit root (non-stationary) against an alternative hypothesis that the log price series is stationary. The expectation was that the log price series would have a single unit root as most financial time series data are integrated of order one (Brooks, 2008).

It was necessary to ascertain the optimal number of lags that would have been employed in testing for stationarity and cointegration. In this article, a single lag refers to a time frame of 30 minutes (the observational interval), and, given that the common trading interval is 90 minutes, the economically sensible approach is to set the maximum lag as 3. However, it should be noted that these are highly liquid markets and securities, and so it is quite possible that price discovery occurs within 30 minutes (a single lag). Preliminarily, time lags were included to compensate for the time series nature of data (Brooks, 2008). To also determine the optimal number of lags in the VAR model econometrically, the Schwarz Bayesian Information Criterion (SBIC) and the Akaike Information Criterion (AIC) were employed as previously used by Phylaktis and Korczak (2010), Dassanayake et al. (2013), and Yang and Kun (2014).

4.3. Cointegration

Consistent with the law of one price, stock prices series in the domestic and foreign markets should be identical, otherwise arbitrageurs might earn above normal profits from trading in cross-listed stocks (Su & Chong, 2007). As such, it can be argued that share price series in the home $(P_{JSE,t})$ and foreign market $(P_{NYSE,t})$ will follow a random walk including a white noise process. In addition, stock price series in the home and foreign markets are presumed to share the same stochastic trend (P_t) which also follows a random walk process. This presumed relationship between the stock price series in the home and host capital markets can be depicted by the following set of equations:

$$P_{JSE,t} = P_t + \varepsilon_{JSE,t} \tag{1}$$

$$P_{NYSE,t} = P_t + \varepsilon_{NYSE,t} \tag{2}$$

$$P_t = P_{t-1} + w_t \tag{3}$$

where $\varepsilon_{JSE,t}$, $\varepsilon_{NYSE,t}$ and $w_t$denote are independently distributed white-noise disturbances. Based on the no arbitrage argument and the law of one price, the set of equations 1–3 can be reformulated as shown below:

$$P_{JSE,t} - P_{NYSE,t} = \varepsilon_{JSE,t} - \varepsilon_{NYSE,t} = 0 \tag{4}$$

The relationship depicted in equation 4 suggests that prices of cross-listed stocks should be equal across the secondary and primary markets over the long run. Therefore, it can be reasoned that the non-stationary stock price series in the home and host markets ought to have a stationary linear combination. Accordingly, following Duppati et al. (2017) and Dassanayake et al. (2013), it is appropriate to employ Johansen's cointegration cointegration technique with an intercept and trend to investigate the existence of a long-run relationship between the log price series of stocks

cross-listed on JSE and NYSE. This has an advantage over the Engle-Granger approach as it does not require that the variables be assigned as dependent or independent (Brooks, 2008). The Johansen's Trace and Max-Eigenvalue statistics were employed to find the number of cointegrating relationships between $P_{JSE,t}$and $P_{NYSE,t}$. These statistics were employed to test the null hypothesis that rank = 0; however, as there are two price series (JSE and NYSE), there is at most one cointegrating vector (rank = 1).

4.4. Vector error correction model (VECM)

Following the determination of a long-run cointegrating relationship, short-run and long-run causality effects were examined with a Vector Error Correction Model (VECM):

$$\Delta P_t = c + \sum_{i=1}^{k} \Gamma_i \Delta P_{t-1} + \alpha \beta' P_{t-1} + \varepsilon_t \quad (5)$$

where: c denotes (2×1) vector of a constant term; P_t is the 2×1 vector of log prices $P_{JSE,t}$and $P_{NYSE,t}$ (price series of JSE and NYSE, respectively); Δ signifies the first difference operator; Γ_i denotes (2×2) coefficient matrices measuring short-run adjustment of the system to changes in P_t; $\alpha$is the (2×1) vector of error correction coefficients which measures the adjustment speed from previous price deviations of $P_{JSE,t}$ and $P_{NYSE,t}$ to restore the long-run equilibrium; β' is a cointegrating vector (1,-1) such that $\beta' P_{t-1} = P_{JSE,t} - P_{NYSE,t}$ is a stationary process 1(0); ε_t is a (2×1) vector of stationary residuals.

The error correction term takes the form $z_{t-1} = P_{NYSE,t-1} - P_{JSE,t-1} = P_{NYSE,t-1} > P_{JSE,t-1}$.

There are two specific areas of interest within the VECM. The first is the error correction terms (α_{NYSE} and α_{JSE}) as these explain the long-run relationship between each pair of cross-listed shares, specifically, the speed at which that adjustment back to equilibrium occurs. This is the element which speaks to price discovery (Kadapakkam et al., 2003). The larger the absolute value of the error correction coefficient, the faster that share price would adjust to restore long-run equilibrium (Alexander, 2008), with a finding greater than 1 showing variables that move apart in the long-run (and are not cointegrated). Hence, $|\alpha_{JSE}|$ proxies the speed the JSE price adjusts to the NYSE price and $|\alpha_{NYSE}|$ signifies the speed at which the NYSE share price converges towards the JSE price. Within each pair of error correction terms, at least one must be statistically significantly different from zero, as this demonstrates that the cointegrating relationship is present (Alexander, 2008). Without this, the two shares are not cointegrated. Significance of an α in one market suggests only that market adjusts to restore disequilibrium.

The second point of interpretation within the VECM is the lagged values of the two price series as these allow for the short-run, or Granger causality dynamics to be determined. If lags of the NYSE listed share are significant to the current JSE listed shares price, NYSE prices are said to Granger cause, or lead, the JSE prices (and *vice versa*). If both NYSE and JSE lags are significant, both markets provide information relevant to JSE prices. Further, for robustness, the study tested for the long-run relationship between the log series of the JSE and NYSE for each stock using the Phillips-Ouliaris (1990) residual-based test for cointegration with an intercept and trend. Similar to the Johansen's (1990) cointegration procedure, the AIC was employed to determine the optimal number of lags.

4.5. Contribution to price discovery

The VECM described in equation 5 allows for the direction of the price discovery process to be determined, which allows for comment on a leading market to the process (or a bi-directional feedback mechanism). It can be helpful, however, to determine a numerical contribution to this process to determine whether the home or host market is as dominant as the direction alone implies. Several measures of estimating the size of each market's contribution have been

suggested with no consensus yet on a single best measure to use (McCullough, 2018). Schwarz and Szakmary's (1994) Common Factor Weights (CFW) and Gonzalo and Granger's (1995) Component Share (CS) approaches are related and as a result the CFW method was adapted in this article to estimating the extent of the contributions made by the NYSE and/or JSE to the price discovery process between the sampled cross-listed stocks following Phylaktis and Korczak (2010) and Duppati et al. (2017). This approach builds from the understanding that there are two components to this relationship: permanent and transitory. The latter is associated with the error-correction process, where the error-correction coefficient matrix and the cointegrating matrix are normalised such that the sum of the resultant vector is 1, where the contribution that each market makes to price discovery process is a fraction of that whole (Duppati et al., 2017).

A market is understood to contribute to price discovery if prices from that market influence prices in the other market. That is, if the total adjustment to restore the equality of prices is reflected by the sum of the absolute values of α_{JSE} and α_{NYSE}, then the contribution of a market can be measured by the proportion of the total adjustment which occurs. For each cross-listed stock, contribution to price discovery was determined with the following formula (adapted and modified from Phylaktis & Korczak, 2010; Duppati et al., 2017; McCullough, 2018), which adjusts the absolute error correction terms from the vector error correction model into a quantifiable measure of contribution to the price discovery process:

$$CFW_{JSE} = \frac{|\alpha_{NYSE}|}{|\alpha_{JSE}| + |\alpha_{NYSE}|} \qquad CFW_{NYSE} = 1 - CFW_{JSE} = \frac{|\alpha_{JSE}|}{|\alpha_{JSE}| + |\alpha_{NYSE}|} \tag{6}$$

where α_{JSE} is the error correction coefficient for JSE and $\alpha_{NYSE}$the error correction coefficient for NYSE. If the NYSE market is the sole contributor to the pricing process, all the adjustments to maintaining the long-run equilibrium take place at the JSE. *A priori*, this study envisaged that the NYSE contributed more to the price discovery of the South African stocks as it has greater informational efficiency and is a more liquid market (Chen et al., 2010; Karolyi, 2006). The following section provides a discussion on the empirical results and implications thereof.

5. Results

5.1. Descriptive statistics

Table 2 shows the summary statistics of mean prices and trading volume for the cross-listed stocks on the JSE and NYSE over the sample period. The results show that Gold Fields was the most liquid stock as it exhibited an average of 884 445 shares per day in trading volume on the JSE but, contrary to expectations, NYSE only dominated trading activity across two of the six stocks. That is, despite the relatively higher media attention and analyst coverage associated with NYSE, it exhibited greater activity in half of the cross-listed stocks.

The discussion in the following section points to the lag selection criteria tests that were administered on the data to ascertain the optimal number of lags that were employed in the stationarity and cointegration tests, and the VECM model.

5.2. Lag order selection

5.3. Stationarity tests

Stationarity tests were conducted on an individual log price series on JSE and NYSE for each stock, results are shown of those using one lag; however, results were not sensitive to lag length. The null hypothesis of unit root was accepted for all stock series in levels which suggested that the log price series were integrated of order one or higher. Thereafter, unit root tests in the first differences showed *t*-values greater than critical values in absolute terms at all significance levels, showing that the price series were indeed integrated of order one.

Table 2. Average Stock Prices of South African Stocks Cross-listed on the NYSE

Stock Market	Open	Close	High	Low	Volume
Anglo-Gold Ashanti (AU)					
JSE	12,068.87	12,070.25	12,114.52	12,023.65	39,203
NYSE	8.65	8.65	8.69	8.60	307,616
DRD Gold (DRD)					
JSE	339.63	340.65	341.87	338.22	22,794
NYSE	2.40	2.40	2.42	2.38	6605
Gold Fields (GFI)					
JSE	4191.83	4190.88	4208.21	4175.19	884,445
NYSE	3.04	3.04	3.06	3.02	404,003
Harmony Gold (HMY)					
JSE	2380.28	2380.86	2392.24	2369.46	86,879
NYSE	1.72	1.72	1.73	1.70	402,338
Sibanye Gold (SBGL)					
JSE	888.87	889.27	895.24	883.31	419,705
NYSE	2.57	2.567926	2.59	2.55	367,354
Sasol (SSL)					
JSE	51,336.47	51,337.96	51,505.29	51,172.74	83,486
NYSE	36.65	36.65	36.76	36.55	18,968

JSE and NYSE prices are denoted in South African Rand cents and US Dollar, rounded off to two decimal places.

Table 3. Lag Length Criteria Tests

Price Series	AIC	SBIC
Anglo-Gold Ashanti (AU)	−11.99818(1)	−11.94385(1)
DRD Gold (DRD)	−0.167012(2)	−9.076456 (2)
Gold Fields (GFI)	−11.61746(5)	−11.52325(1)
Harmony Gold (HMY)	−10.83408(4)	−10.76054(1)
Sibanye Gold (SBGL)	−9.993022(1)	−9.938689(1)
Sasol (SSL)	−13.54821(4)	13.47360(1)

AIC: Akaike Information Criterion, SBIC: Schwarz Bayesian Information Criterion.
Lag order selected by model is in parentheses.

5.4. Cointegration tests

The results from the Trace and Maximum Eigen Value Tests failed to reject the null hypothesis that there is one cointegration relationship between the JSE and NYSE price series for all stocks for all stocks. Similarly, the null hypothesis of no cointegration between the JSE and NYSE price series for all stocks was rejected at the 1% significance level based on the Phillips-Ouliaris cointegration test. This implies that there is a long-run relationship between the JSE and NYSE similar to the findings by Duppati et al. (2017) and Phylaktis and Korczak (2010), and as would be expected for a single asset traded on two exchanges. It was noted that the Trace and Maximum Eigenvalue results for DRD and SBG are borderline; however, the Phillips-Ouliaris results support cointegration between these series. The presence of a cointegrating relationship in the pair of JSE and NYSE price series for DRD and SBG is also evidenced in the vector error correction estimation produced in the below.

In light of the foregoing, it can be inferred that, while there could be deviations between the home and host price series for each stock, there will be an error correction mechanism that will result in the price series restoring long-run equilibrium. Following this finding of cointegration between all cross-listed

Table 4. Augmented Dickey-Fuller and Phillips Perron Unit Root Tests

Stationarity Test	Integration Order	JSE Listed	NYSE Listed
AU			
Augmented Dickey Fuller	Level	−2.628	−2.824
	First Difference	−16.146	−16.208
Phillips-Perron	Level	−2.702	−2.94
	First Difference	−22.641	−23.215
DRD			
Augmented Dickey Fuller	Level	−2.656	−3.003
	First Difference	−19.07	−16.266
Phillips-Perron	Level	−3.036	−3.168
	First Difference	−27.859	−23.674
GFI			
Augmented Dickey Fuller	Level	−1.075	−1.631
	First Difference	−15.947	−16.436
Phillips-Perron	Level	−1.121	−1.649
	First Difference	−22.036	−21.798
HMY			
Augmented Dickey Fuller	Level	−1.148	−0.894
	First Difference	−14.987	−15.992
Phillips-Perron	Level	−1.169	−1.059
	First Difference	−21.511	−23.458
SBGL			
Augmented Dickey Fuller	Level	−2. 161	−2.143
	First Difference	−16.195	−15.373
Phillips-Perron	Level	−2.217	−2.21
	First Difference	−22.234	−22.42
SSL			
Augmented Dickey Fuller	Level	0.808	0.094
	First Difference	−13.217	−16.74
Phillips-Perron	Level	0.804	0.057
	First Difference	−20.625	−21.952

ADF and PP critical values are −3.982, −3.422 and −3.130 at the 1%, 5% and 10% significance levels, respectively.

pairs, a VECM was estimated for each pair to enable an analysis of the long run and short-run dynamics between these NYSE and JSE price series. The results are discussed in the following section.

5.5. Vector error correction model

Cointegration between the series was confirmed by the fact that in each pair of error correction terms (α), at least one was statistically significantly different from zero as required (see Table 6). None of the error corrections terms (ECTs) were so large as to suggest that prices diverge from their long-run equilibrium over time. In the pairs with two significant error correction terms (DRD, GFI, SBG and SSL) the expected signs were present, with one negative and one positive coefficient demonstrating a functional error correction process. The two marginal cointegration results in Table 5 now both show a cointegrating error correction relationship under the VECM.

Noteworthy in this instance, was the direction of the relationship. Four of the six pairs have α (ECTs) which indicated the presence of bi-directional feedback between the NYSE and the JSE, as both α_{NYSE} and α_{JSE} are significant. This lends support to the next stage of analysis where the size

Table 5. Cointegration Results

Price Series	Johansen's Cointegration			Phillips-Ouliaris Cointegration
	Rank	Trace	Max-Eigen Value	
AUJSE and AUNYSE	0	89.89256*	88.71263*	−8.648416* Cointegrated
	1	1.1799932 (0.2774)	1.179932 (0.2774)	
DRDJSE and DRDNYSE	0	31.10901*	26.97267*	−5.053948* Cointegrated
	1	4.136337 (0.0420)**	4.13637 (0.0420)**	
GFIJSE and GFINYSE	0	138.2760*	136.8278*	−10.09559* Cointegrated
	1	1.448216 (0.2288)	1.448216 (0.2288)	
HMYJSE and HMYNYSE	0	86.88470*	84.91446*	−10.04774* Cointegrated
	1	1.970240 (0.1604)	1.970240 (0.1604)	
SBGLJSE and SBGLNYSE	0	88.29471*	84.52144*	−10.03592* Cointegrated
	1	3.773268 (0.0521)***	3.773268 (0.0521)***	
SSLJSE and SSLNYSE	0	89.94946*	89.79566*	−10.39739* Cointegrated
	1	0.153892 (0.6949)	0.153892 (0.6949)	

*Parentheses () are p-values. *Significant at 1%; **Significant at 5%; *** Significant at 10%.*

Phillips-Ouliaris Cointegration presents the tau-statistic based on MacKinnon (1996) Critical Values

of these markets respective contributions is estimated so as to better quantify which market is contributing more to this process. The ECTs (α), which describe the process through which the long-run equilibrium price is maintained, found α_{NYSE} to be insignificant in the remaining two instances, indicating that the JSE was mainly responsible for adjusting and maintaining the long-run equilibrium between these two markets.

Within the six pairs of NYSE and JSE price series, focusing on the lags and the short-term feedback mechanism where X Granger-causes Y, three were seen to not support the home bias hypothesis: AU, GFI and HMY all have significant information in past NYSE prices feeding into the current JSE price. In an informationally efficient market, no previous lags would be relevant to current prices. The three remaining cross-listed pairs showed two outcomes: DRD and SSL had significant price information from the JSE feeding into both JSE and NYSE prices, indicating the JSE leads, supporting the home bias hypothesis.

Finally, SBG found no significant past price information, however, it may be that this pair had a more rapid price discovery process than 30 minutes (that is, price discovery is occurring within the interval rather than between intervals).

5.6. Contribution to the price discovery process

The results from the VECM output above highlight the benefit of continuing to measure the contribution made by each market in order to gain deeper insight to these dynamics, especially in the case of bi-directional feedback between the two markets. The CFW contributions to this process are presented in Table 7.

It can be inferred from the size of the contribution to price discovery that the host market dominated the price discovery process of the cross-listed stocks with an average of 73.41% contribution correcting towards the long-run equilibrium. This finding refutes the claims by

Table 6. Vector Error Correction Model

	JSE Series	NYSE Series	Price Discovery
α (ECT)	**−0.285258 * (−8.123295)**	0.051352 (1.26070)	JSE Leads
AUJSE (t-1)	0.002295 (0.04679)	−0.044419 (−0.78070)	Previous NYSE relevant to current JSE (10% stat.sig.)
AUJSE (t-2)	−0.016329 (−0.33913)	−0.02897 (−0.50665)	
AUNYSE (t-1)	**−0.128488*** (−2.52346)**	−0.037000 (0.62647)	
AUNYSE (t-2)	−0.056379 (−1.15375)	0.006203 (0.10943)	
α (ECT)	**−0.077217 * (−4.56256)**	**0.041004 ** (2.40287)**	Bi-Directional
DRDJSE (t-1)	**−0.256447 * (−5.57536)**	**−0.089601 ** (−1.93196)**	Previous JSE relevant to current JSE and NYSE. (5% stat.sig.)
DRDJSE (t-2)	**−0.105800** (−2.31492)**	**−0.088217 *** (−1.91429)**	
DRDNYSE (t-1)	−0.032911 (−0.69645)	−0.072564 (−1.50105)	
DRDNYSE (t-2)	−0.006090 (−0.12850)	0.005029 (0.10522)	
α (ECT)	**−0.382277 * (−9.00417)**	**0.124799 ** (2.25631)**	Bi-Directional
GFIJSE (t-1)	0.061856 (1.21298)	0.007355 (0.11072)	Previous NYSE relevant to current JSE. (1% stat.sig.)
GFIJSE (t-2)	0.021873 (0.44132)	0.028422 (0.44017)	
GFINYSE (t-1)	**−0166484 * (−3.41983)**	0.039656 (0.62526)	
GFINYSE (t-2)	**−0.152257 * (−3.25178)**	−0.037613 (−0.61660)	
α (ECT)	**−0.285163 * (−8.07302)**	0.057252 (1.37480)	JSE Leads
HMYJSE (t-1)	0.057445 (1.17312)	0.066678 (1.15500)	Previous NYSE relevant to current JSE. (10% stat.sig.)
HMYJSE (t-2)	0.0475559 (1.00356)	0.012928 (0.23138)	
HMYNYSE (t-1)	**−0.096298 *** (−1.91761)**	−0.076713 (−1.29574)	
HMYNYSE (t-2)	−0.075313 (−1.59361)	0.000440 (0.00790)	
α (ECT)	**−0.297848 * (−6.46069)**	**0.104843 ** (2.10721)**	Bi-Directional
SBGLJSE (t-1)	0.033654 (0.60269)	0.029158 (0.48384)	No significant lags. Potential for any lead to be less than 30 mins.
SBGLJSE (t-2)	−0.044777 (−0.83551)	−0.031500 (−0.54461)	
SBGLNYSE (t-1)	−0.096356 (−1.62489)	−0.012789 (−0.19983)	
SBGLNYSE (t-2)	0.005480 (0.09766)	0.052762 (0.87129)	
α (ECT)	**−0.240825 * (−6.76771)**	**0.175965 * (3.32826)**	Bi-Directional
SSLJSE (t-1)	0.050706 (1.05633)	−0.028038 (−0.39313)	Previous JSE relevant to current JSE and NYSE. (5% stat.sig.)
SSLJSE (t-2)	**0.106953 ** (2.28986)**	**0.146848 ** (2.11608)**	
SSLNYSE (t-1)	−0.044035 (−1.10081)	0.087786 (1.47704)	
SSLNYSE (t-2)	0.026825 (0.69893)	−0.038443 (−0.67417)	

Significant at 1%; **Significant at 5%; * Significant at 10%.*

t-statistics in parentheses to the right of each ECT and lag coefficient.

Ammer et al. (2012) and Bacidore and Sofianos (2002) that the home market will have greater influence in the price discovery process since it is presumed that information will originate from the home market before it is filtered into the host market.

These findings were consistent with those by Hasbrouck (1995), Flad and Jung (2008), Yang and Kun (2014), and Duppati et al. (2017) who showed that the NYSE was more dominant in the price discovery. In this context, it could be inferred that, since the US is the leading financial centre and global trading venue, information will be incorporated from the NYSE market before it goes to the JSE. These findings (comparing ECTs and CFWs) are consistent with Duppati et al. (2017) who found similar results, where their smaller in magnitude error correction coefficient market (SSE), also showed a larger contribution to the price discovery process using CFWs.

It is worth noting that, for DRD and SSL, the CFWs indicate that the NYSE is the primary contributor to the price discovery process, while the VECM suggested the JSE leads. It is possible

Table 7. Common Factor Weights

Price Series	Primary Contributor to Price Discovery (CFW)	Contribution of NYSE	Contribution of JSE
AU	NYSE	0.8474	0.1525
DRD	NYSE	0.6532	0.3468
GFI	NYSE	0.7539	0.2461
HMY	NYSE	0.8328	0.1672
SBGL	NYSE	0.7396	0.2604
SSL	NYSE	0.5778	0.4222
Average	NYSE	0.7341	0.2659

that the results for these conflicted firms are affected by unseen firm-specific factors, which were outside the scope of this article's particular considerations.

6. Conclusion

Cross-listing has enabled firms to access foreign capital in international financial markets. There are several motivations for cross-listing that have been cited, but it is not yet certain whether the home or host market determines the price discovery process of stocks, especially within an emerging South African context. This study investigated the price discovery process of JSE-domiciled stocks that are cross-listed on the NYSE during their common trading hours.

Results indicated that there is strong evidence of a long-run equilibrium between the JSE and NYSE which corroborates the law of one price as well as findings from previous studies. This is confirmed through the use of a VECM which showed significant error correction terms. Resultant CFWs indicated that the shares considered in this instance were led by the NYSE, as all were shown to dominate the price discovery process when the size of their contribution to the price discovery process was estimated. This highlights the additional information that considering the relative contributions to the price discovery process that CFWs are able to provide, as these move the findings away from being mixed, showing that the NYSE leads and that the home bias hypothesis does not apply for South African cross-listed firms.

7. Practical implications

The results from this study offer several insights to market participants and policymakers. Firstly, findings in this study suggest there is a long-run relationship between the price series of stocks domiciled on the JSE and cross-listed on the NYSE. Secondly, the cointegrating relationship between stock price series of cross-listed stocks suggest the existence of co-movement between the US and South African equity markets, which diminishes diversification benefits between these two markets, particularly when considering that the majority of this sample demonstrated a lead-lag relationship of 30 minutes (or less).

Evidence of cointegration between the JSE and NYSE suggested that there is possibly less information asymmetry surrounding the stocks of cross-listed firms, which could yield benefits of lowering their cost of capital. In addition, the study demonstrated that the NYSE leads the JSE in the price discovery process of cross-listed shares.

From an investor's point of view, the findings suggest that there is a need to afford more attention to the NYSE market considering that information flow appears to be occurring mainly from the NYSE to the JSE prices, despite the JSE being the home market. Additionally, the findings suggest that the two markets, JSE and NYSE, are integrated which implies that South Africa's economic performance and rand exchange rate might be tied to the USA economy, which supports

other areas of research that have noted contagion effects flowing from major markets to developing ones. In this context, from a policymaker's standpoint, policies ought to be made taking into account the forecasted and current economic performance in the USA as this might have ramifications for South Africa's economy.

8. Limitations of the study and future research opportunities

There are several considerations for future studies which could form the basis of future research. This study relied on a relatively shorter period of analysis and, as such, future studies could employ longer time series intra-day data to disentangle the time-varying price discovery dynamics of these stocks. In addition, it is possible that a cross-sectional analysis accounting for firm-specific factors that could explain differences in the price discovery process of cross-listed stocks could offer additional insight. Considering price discovery of stocks cross-listed on the JSE with primary listing in foreign markets, as well as level 1 ADRs, may also be future considerations. Lastly, a potentially fruitful area of research would be to consider trading strategies during the times markets are dark, when the price discovery process is forced to "pause" while the markets operate in non-overlapping time zones.

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References

Adelegan, O. J. (2008). Can regional cross-listings accelerate stock market development? Empirical evidence from Sub-Saharan Africa. *International Monetary Fund Working Paper* 09/99. Retrieved March 3, 2019, from https://www.imf.org/external/pubs/ft/wp/2009/wp0999.pdf

Agarwal, S., Liu, C., & Rhee, S. G. (2007). Where does price discovery occur for stocks traded in multiple markets? Evidence from Hong Kong and London. *Journal of International Money & Finance*, *26*(1), 46–63. https://doi.org/10.1016/j.jimonfin.2006.10.011

Alexander, C. (2008). *Practical financial econometrics: Market risk analysis*. John Wiley & Sons.

Ammer, J., Holland, S. B., Smith, D. C. & Warnock, F. E. (2012). US international equity investment. Journal of Accounting Research, 50(5), 1109–1139

Bacidore, J. M., & Sofianos, G. (2002). Liquidity provision and specialist trading in NYSE-listed non-U.S. stocks. *Journal of Financial Economics*, *63*(1), 133–158. https://doi.org/10.1016/S0304-405X(01)00092-7

Baker, H. K., Nofsinger, J. R., & Weaver, D. G. (2002). International cross-listing and visibility. *Journal of Financial & Quantitative Analysis*, *37*(3), 495–521. https://doi.org/10.2307/3594990

Bekaert, G. (1995). Market integration and investment barriers in emerging equity markets. The World Bank Economic Review, 9(1), 75–107 doi:10.1093/wber/9.1.75

Blume, M. E., & Goldstein, M. A. (1991). Differences in execution prices among the NYSE, the regionals, and the NASD. *White Center for Financial Research Paper* No. 4/92. Retrieved March 26, 2019, from https://papers.ssrn.com/sol3/papers.cfm?Abstract_id=979072

Brooks, C. (2008). *Introductory econometrics for finance*. Cambridge University Press.

Chen, J., Tourani-Rad, A., & Yi, R. (2016). Short sales and price discovery of Chinese cross-listed firms. International Journal of Managerial Finance, 12(4), 408–421

Chen, K. C., Li, G., & Wu, L. (2010). Price discovery for segmented US-listed Chinese stocks: Location or market quality? *Journal of Business Finance & Accounting*, *37*(1), 242–269. https://doi.org/10.1111/j.1468-5957.2009.02153.x

Chisadza, M. W. (2014). *Regional financial integration in Africa: Cross-listings as a form of regional financial integration*. Anchor Academic Publishing.

Dassanayake, W., Li, X., & Buhr, K. (2013). *An investigation of the price discovery for cross-listed stocks: Evidence from New Zealand and Australian stock markets* [Paper presentation]. Auckland region accounting conference, Auckland, New Zealand. Retrieved March 27, 2019, from https://unitec.researchbank.ac.nz/handle/10652/2791

Ding, D. K., Harris, Frederick H.deB.., Lau, S. T., & McInish, T. H. (1999). An investigation of price discovery in informationally-linked markets: equity trading in Malaysia and Singapore. Journal of Multinational Financial Management, 9(3-4), 317–329 doi:10.1016/S1042-444X(99)00005-5

Doidge, C., Karolyi, G. A., & Stulz, R. M. (2004). Why are foreign firms listed in the United States worth more? *Journal of Financial Economics*, *7*(12), 205–238. https://doi.org/10.1016/S0304-405X(03)00183-1

Domowitz, I., Glen, J., & Madhavan, A. (1997). Market segmentation and stock prices: Evidence from an emerging market. *The Journal of Finance*, *5*(23),

1059–1085. https://doi.org/10.1111/j.1540-6261.1997.tb02725.x

Domowitz, I., Glen, J., & Madhavan, A. (1998). International cross-listing and order flow migration: Evidence from an emerging market. *The Journal of Finance*, *5*(36), 2001–2027. https://doi.org/10.1111/0022-1082.00081

Duppati, G., Hou, Y. G., & Scrimgeour, F. (2017). The dynamics of price discovery for cross-listed stocks evidence from US and Chinese markets. *Cogent Economics & Finance, 5*(1), 1–23. Retrieved March 25, 2019, from. https://doi.org/10.1080/23322039.2017.1389675.

Eun, C. S., & Sabherwal, S. (2003). Cross-border listings and price discovery: Evidence from U.S.-listed Canadian stocks. *Journal of Finance*, *5*(82), 549–575. https://doi.org/10.1111/1540-6261.00537

Flad, M., & Jung, R. C. (2008). A common factor analysis for the US and the German stock markets during overlapping trading hours. *Journal of International Financial Markets, Institutions & Money*, *18*(5), 498–512. https://doi.org/10.1016/j.intfin.2007.07.005

Frijns, B., Gilbert, A., & Tourani-Rad, A. (2010). Price discovery, cross-listings and exchange rates: Evidence from Australia and New Zealand. *Journal of Banking & Finance*, *34*(3), 498–508. https://doi.org/10.1016/j.jbankfin.2009.08.014

Gonzalo, J., & Granger, C. (1995). Estimation of common long-memory components in cointegrated systems. Journal of Business & Economic Statistics, 13(1), 27–35 doi:10.1080/07350015.1995.10524576

Grammig, J., Melvin, M., & Schlag, C. (2005). Internationally cross-listed stock prices during overlapping trading hours: Price discovery and exchange rate effects. *Journal of Empirical Finance*, *12*(1), 139–164. https://doi.org/10.1016/j.jempfin.2003.10.004

Hail, L., & Leuz, C. (2009). Cost of capital effects and changes in growth expectations around US cross-listings. *Journal of Financial Economics*, *93*(3), 428–454. https://doi.org/10.1016/j.jfineco.2008.09.006

Hansda, S., & Ray, P. (2003). Stock market integration and dually listed stocks: Indian ADR and Domestic stock prices. *Economic and Political Weekly*, *38*(8), 741–754.

Hasbrouck, J. (1995). One security, many markets: Determining the contributions to price discovery. *The Journal of Finance*, *50*(4), 1175–1199. https://doi.org/10.1111/j.1540-6261.1995.tb04054.x

Hauser, S., Tanchuma, Y., & Yaari, U. (1998). International transfer of pricing information between dually listed stocks. Journal of Financial Research, 21(2), 139–157 doi:10.1111/jfir.1998.21.issue-2

Hupperets, E., & Menkveld, B. (2000). Intraday Analysis of Market Integration. Tinbergen Institute Discussion Paper, No. 00-018/2, Tinbergen Institute, Amsterdam and Rotterdam. http://hdl.handle.net/10419/85501

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration with application to the demand for money. *Oxford Bulletin of Economics and Statistics*, *52*(2), 169–209. https://doi.org/10.1111/j.1468-0084.1990.mp52002003.x

Kadapakkam, P. R., Misra, L., & Tse, Y. (2003). International price discovery for emerging market stocks: Evidence from Indian GDRs. *Review of Quantitative Finance & Accounting*, *21*(2), 179–199. https://doi.org/10.1023/A:1024843500510

Karolyi, G. A. (2006). The world of cross-listings and cross-listings of the world: Challenging conventional wisdom. *Review of Finance*, *10*(1), 99–152. https://doi.org/10.1007/s10679-006-6980-8

Levine, R., & Schmukler, S. L. (2006). Internationalisation and stock market liquidity. *Review of Finance*, *10*(1), 153–187. https://doi.org/10.1007/s10679-006-6981-7

McCullough, K. (2018). Intraday information transmission in the South African equities market. *African Finance Journal*, *20*(2), 1–20. https://hdl.handle.net/10520/EJC-139fddb738

McInish, T. H., Shoesmith, G. L., & Wood, R. A. (1995). Cointegration, error correction, and price discovery on informationally linked security markets. *Journal of Financial & Quantitative Analysis*, *30*(4), 563–579. https://doi.org/10.2307/2331277

Merton, R. C. (1987). A simple model of capital market equilibrium with incomplete information. *The Journal of Finance*, *4*(23), 483–510. https://doi.org/10.1111/j.1540-6261.1987.tb04565.x

Miller, D. P. (1999). The market reaction to international cross-listings: Evidence from depositary receipts. *Journal of Financial Economics*, *51*(1), 103–123. https://doi.org/10.1016/S0304-405X(98)00045-2

Neingo, P. N., & Tholana, T. (2016). Trends in productivity in the South African gold mining industry. *Journal of the Southern African Institute of Mining & Metallurgy*, *11*(63), 283–290. http://dx.doi.org/10.17159/2411-9717/2016/v116n3a10

Pascual, R., Pascual-Fuster, B., & Climent, F. (2006). Cross-listing, price discovery and the informativeness of the trading process. *Journal of Financial Markets*, *9*(2), 144–161. https://doi.org/10.1016/j.finmar.2006.01.002

Phylaktis, K., & Korczak, P. (2010). Related securities and price discovery: Evidence from NYSE-Listed non-U.S. *Stocks Maastricht Meetings Paper: Cass Business School Research Paper*. Retrieved February 20, 2019, from http://dx.doi.org/10.2139/ssrn.567104

Qadan, M., & Yagil, J. (2012). Main or satellite? Testing causality-in-mean and variance for dually listed stocks. *International Journal of Finance & Economics*, *17*(3), 279–289. https://doi.org/10.1002/ijfe.458

Schreiber, P. S., & Schwartz, R. A. (1986). Price discovery in securities markets. *The Journal of Portfolio Management*, *12*(4), 43–48. https://doi.org/10.3905/jpm.1986.409071

Schwarz, T. V., & Szakmary, A. C. (1994). Price discovery in petroleum markets: Arbitrage, cointegration, and the time interval of analysis. The Journal of Futures Markets (1986-1998), 14(2), 147 doi:10.1002/(ISSN)1096-9934

Su, Q., & Chong, T. (2007). Determining the contributions to price discovery for Chinese cross-listed stocks. *Pacific-Basin Finance Journal*, *15*(2), 140–153. https://doi.org/10.1016/j.pacfin.2006.07.002

Yang, X., & Kun, P. (2014). Cross-border listings and price discovery. Evidence from Chinese companies triple-listed in Shanghai, Hong Kong and New York. *Journal of Advanced Studies in Finance*, 5(1), 66–103. https://journals.aserspublishing.eu/jasf/article/view/98

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