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A revisit of price discovery dynamics across Australia and New Zealand

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Abstract

This study re-investigates the price discovery dynamics of selected stocks cross-listed on the Australian Stock Exchange (ASX) and the New Zealand Stock Exchange (NZX) during a bear trading phase from January 2008 to December 2011. A differing price discovery dynamic in a bear market versus a bull market may occur because of variations in investor sentiments and disparities in the role of the stock prices. Using intraday data, we employ the vector error correction mechanism, Hasbrouck's (1995) information share and Grammig *et al.*'s (2005) conditional information share methods. Consistent with previous research, we find that price discovery takes place mostly on the home market for the Australian firms and for all but one of the New Zealand firms. However, not seen in existing studies, we show that the NZX has grown in importance for both the Australian and New Zealand firms. This suggests that the NZX is deviating from being a pure satellite market.

Keywords: Price discovery, Cross-listings, Market microstructure, International stock markets

Introduction

Reinkensmeyer (2007) and Langridge (2006) raise the question of whether investing strategies in stock markets should change during different trading phases. In this vein, researchers such as Miaoxin (2012) and Hodgson *et al.* (2003) have investigated whether price discovery dynamics change in bear versus bull markets. They generally find that price discovery varies with the trading phase.

Much of the research on price discovery in cross-listed stocks on multiple exchanges has focused on the US markets. Most of these exchanges are dealer, or hybrid, markets with less than full automation. However, the New Zealand Stock Exchange (NZX) and the Australian Stock Exchange (ASX) are fully automated order-driven trading systems. Price discovery dynamics may be quite different in such a system. Frijns *et al.* (2010) examine price discovery dynamics in the New Zealand and Australian markets during a bull market. They find that both markets contribute to price discovery with the home market tending to be dominant.

The present study examines price discovery dynamics in Australian and New Zealand markets during a bearish trend, and examines the direction of the leadership in price discovery between the two markets to determine which one of them is dominant. Our study is topical because the NZX has expressed an interest in improving price discovery in the New Zealand market. We attempt to provide a benchmark against which the recent movement to a NASDAQ OMX X-stream trading platform can be measured in terms of enhancing price discovery on the NZX. Specifically, we:

1. appraise the existence of short and long term dynamic linkages between the selected cross-listed stocks in the NZX and the ASX;
2. evaluate the direction of the price discovery relationships; that is whether, the home market tends to lead changes in the foreign market, or vice versa;
3. examine the price discovery of cross-listed stocks in New Zealand and Australia in a bear market using Hasbrouck's (1995) information share (IS) approach and Grammig *et al.*'s (2005) conditional information share (CIS) approach; and
4. compare to see whether the price discovery dynamics change in different trading phases.

Consistent with previous research, we find that the price series of the selected cross-listed stocks on the ASX and the NZX are co-integrated. Price discovery takes place mostly on the home market for both the Australian domiciled firms and for all but one of the New Zealand domiciled firms. This is true in terms of both Hasbrouck's (1995) IS and Grammig *et al.*'s (2005) CIS.

When evaluating price discovery dynamics across subsample periods using the IS approach, we find that there is an upward trend in the significance of the NZX for the Australian as well as New Zealand domiciled companies. The increased importance of the NZX during a bear trading phase means that the NZX is not a pure satellite market. This is an important finding alerting financial institutions, policy makers and investors of the need to be aware of the trading phase of the market and to monitor information flows in the New Zealand market.

The rest of this paper is organised as follows. Section 2 reviews the existing literature on price discovery as related to the study. Section 3 discusses the methodology adopted for this research. Section 4 provides a description of the data set. Section 5 conducts econometric analyses and explains the results obtained. Section 6 offers conclusions.

Literature Review

Many researchers have focused on the dynamic linkages amongst international stock markets and have managed to empirically identify price discovery dynamics. See, for example, Turkington and Walsh (2000), Eun and Sabherwal (2003), Zeynel and Esin (2007), Morana and Beltratti (2008) and Zeynel (2009). Others such as Longin and Solnik (2001) and Lukmanto *et al.* (2009) examine correlation patterns, whilst Rittler (2012) evaluates volatility spillovers and Loretan and English (2000) appraise correlation breakdowns in international stock markets.

Price discovery is a central question in market microstructure, and it has been studied for stock markets by Gagnon and Karolyi (2010), Morana and Beltratti (2008), Hasbrouck (1995), Harris *et al.* (1995), for options markets by Hsieh *et al.* (2008), Simaan and Wu (2007), for futures markets by Rosenberg and Traub (2009), Brandt *et al.* (2007), De Jong and Donders (1997), for bond markets by Griffin and Hong (2012), Biais and Declerck (2007), Miyanoya (1999), for commodity markets by Bhatt (2012), for various trading forums by Ates and Wang (2005), and for multiple global markets by Chen *et al.* (2013), Zeynel (2009).

In the literature, two major approaches to determining the price discovery of cross-listed stocks have been identified. The first focuses on the lead/lag relationships between markets for cross-listed stocks. For example Eun and Shim (1989) examine the transmission mechanics of nine international stock markets using vector autoregression (VAR) systems. Harris *et al.* (1995) examine transmission of new information on price discovery for shares of IBM listed on three stock exchanges.

The second approach focuses on how new information is transmitted to different exchanges. Hasbrouck's (1995) Information share (IS) approach and Gonzalo and Granger's (1995) permanent transitory (PT) approach are two popular models that are used to investigate the price discovery process of cointegrated time series.

Many researchers such as Baillie *et al.* (2002), De Jong (2002), Lehmann (2002), Grammig *et al.* (2004), Grammig et al. (2005), Pascual *et al.* (2006), Yan and Zivot (2010) use the IS and the PT approaches. The vector error correction model (VECM) forms the basis for both the Hasbrouck and Gonzalo and Granger models. But IS and PT use different definitions for price discovery.

Most researchers studying price discovery across countries have treated the exchange rate as exogenous. For example, Hupperets and Menkveld (2002) investigating Dutch stocks that are cross-listed on the New York stock exchange (NYSE) converted all price series into Dutch Guilders. Similarly, Eun and Sabherwal (2003) analysed price discovery for 62 Canadian stocks listed on both the Toronto Stock Exchange (TSE) and on the U.S. exchange (NYSE, AMEX and Nasdaq). They converted all price series into Canadian Dollars.

Grammig *et al.* (2005) argue that the effects of exchange rate fluctuations on stocks cross-listed in international markets cannot be properly measured if the exchange rate is treated as exogenous. Thus, they emphasise that the exchange rate should be treated as endogenous in price discovery analysis. They propose a modification to the IS approach that they call the conditional information share (CIS) approach.

Despite the abundant literature on price discovery dynamics for internationally cross-listed stocks, there is no clear conclusion as to where price discovery occurs. Harris *et al.* (1995) use an error correction model to evaluate price discovery for shares of IBM on the NYSE, Pacific, and Midwest exchanges and find that all three markets contribute to price discovery for IBM. In contrast, Hasbrouck (1995) uses data for thirty Dow stocks that were traded on the NYSE and other regional exchanges and concludes that price discovery predominantly occurs on the NYSE. Hupperets and Menkveld (2002) investigate Dutch stocks cross-listed on the Amsterdam stock exchange (ASE) and on the NYSE and find mixed results. Eun and Sabherwal (2003) evaluate the price discovery of 62 Canadian stocks listed on both the Toronto Stock Exchange (TSE) and on U.S. exchanges (NYSE, AMEX and Nasdaq) and find price discovery largely occurs in the home market. Grammig *et al.* (2005) evaluate the price discovery dynamics of three blue-chip German stocks traded on the Exchange Electronic Trading (XETRA) in Germany and on the NYSE combined with an endogenized exchange rate. They find that price discovery mainly occurs in the home market and the New York prices bear almost all of the adjustment to exchange rate changes. Pascual *et al.* (2006) examine the price discovery of Spanish cross-listed stocks on the Spanish Stock Exchange (SSE) and the NYSE and find that the home market is dominant. Su and Chong (2007) investigate price discovery of eight Chinese stocks on the NYSE and on the Stock Exchange of Hong Kong (SEHK). Using PT and IS approaches, they find that the home exchange (SEHK) contributes more to the price discovery. Flad and Jung (2008) use PT decomposition to evaluate price discovery dynamics for the Dow Jones Industrial Average (DJIA) and the Deutsche Aktien index (DAX) during overlapping trading hours. They find that global economic news is first integrated in the U.S. and then transmitted to the German stock market.

Walter Zimmermann (2012) argues that bullish sentiments tend to drive prices higher and bearish sentiments tend to drive prices lower. Therefore an analyst must understand the effect that human psychology, such as bullish and bearish collective moods has on the determination of prices in different markets. A bullish (bearish) collective mood may drive prices well above (below) levels anticipated by financial principles. Thus, the role of bullish and bearish moods on the price discovery should be of interest to investors and analysts.

Researchers also have investigated the investment behavior of market participants and price discovery changes in different trading phases. For example Hodgson *et al.* (2003) investigate whether the price discovery dynamics change from a bull trading phase to a bear trading phase in Australian stock and futures markets. They find that the prices of stocks contain additional information and perform a relatively active role in the price discovery process during a bull trading phase. However, during a bear trading phase, the prices of stocks tend to free ride on futures and take a relatively passive role in the price discovery process. Miaoxin (2012) examines the price discovery roles of option markets in different conditions. He finds that stock markets lead option markets during a bull trading phase whilst option markets lead stock markets during a bear trading phase. Chang *et al.* (2000) examine the investment behavior of market participants. They find that investors are more optimistic and behave as envisaged by asset pricing models (with a growth in dispersion of returns) during a bullish trend. However, during a bearish trend investors become more pessimistic and exhibit herding behaviour (with a decline in dispersion of returns).

A sizeable portion of the literature citing the above studies deals with cross-listed stocks linked to U.S. markets during bullish as well as bearish trends. However, most of these exchanges are dealer or hybrid markets with less than full automation. The ASX and the NZX are fully automated order-driven trading systems. Only limited attempts have been made to study price discovery for cross-listed stocks in fully computerised competitive order-driven markets. Ding *et al.* (1999) use the PT approach to analyse price discovery on the Kuala Lumpur Stock Exchange (KLSE) and the Stock Exchange of Singapore (SES). Both exchanges are fully automated and both countries are in the same time zone. They find that approximately 70% of the price discovery for a stock occurs in the home country (Malaysian market) and there is evidence of strong error correction from Singapore prices to Malaysian prices. Agarwal *et al.* (2007) use a sample of the Hong Kong listed stocks that are also traded on the London Stock Exchange (LSE) to determine the source of price discovery. Both exchanges are fully automated and there is overlap in the trading hours of the LSE and the Hong Kong Stock Exchange. They find that Hong Kong trading determines the price discovery in London but not vice versa.

A few studies have focused on price discovery for cross-listed stocks on the Australian and New Zealand stock markets. Lok and Kalev (2006) use intraday prices of 38 Australian and 25 New Zealand stocks to investigate the price discovery dynamics for these markets. They adopt an analysis of error correction mechanism and used data from May 2000 to December 2002. Their research confirms that the markets are integrated, both markets contribute to price discovery but a greater amount of price discovery occurs in the home market. Frijns *et al.* (2010) use Hasbrouck's IS approach and Grammig *et al.*'s CIS approach to evaluate price discovery for cross-listed stocks in New Zealand and Australia. They used data from January 2002 to December 2007 when both markets behaved bullishly (see Figure 1A). They find that the home market is dominant in the price discovery process and the New Zealand market was moving in the direction of becoming a pure satellite market. Frijns *et al.* (2013) extend Frijns *et al.* (2010) to evaluate the bidirectional price discovery dynamics during 1998 to 2012. They use Gonzalo and Granger (1995) Component Shares and Hasbrouck (1995) Information Shares and find that a noticeable decrease in the NZX's contribution to the price discovery for both New Zealand and Australian firms.

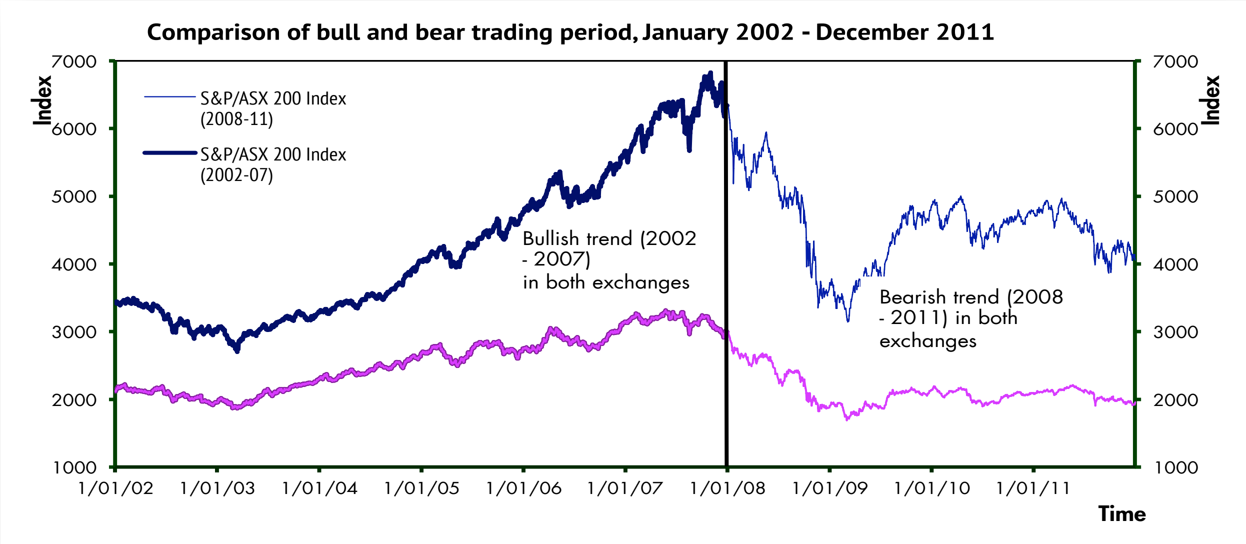


Figure 1A
Time plots of S&P/ASX 200 Index and NZX 50 Index during January 2002 –December 2011

Note The graph above shows the time plots of Australian S&P/ASX 200 index and New Zealand NZX-50 index during the sample periods January 2002 – December 2007 and January 2008 – December 2011.

Our study endeavours to use the same cross-listed stocks and the same econometric techniques as in Frijns *et al.* (2010), but evaluates the price discovery dynamics during the period January 2008 to December 2011. Figure 1A shows that during this time period both markets were primarily in a bearish trend. Prices initially dropped sharply, recovered somewhat and returned to gradual losses. We then compare our bearish-trend results with the bullish-trend results of Frijns *et al.* (2010), to address the issue of whether price discovery dynamics change when the market changes between the bearish and the bullish phases.

Methodology

Three techniques are commonly used to analyse price discovery: 1) the lead/lag approach, 2) the information share (IS) of Hasbrouck (1995), and 3) the permanent transitory (PT) of Gonzalo and Granger (1995). The present study employs the lead/lag approach, the IS of Hasbrouck (1995) and the CIS of Grammig *et al.*'s (2005).

Lead-lag approach

We apply the vector error correction model (VECM) to investigating lead-lag relations, as follows:

$$\begin{cases} \Delta \mathrm{P}_t^h = \alpha_0^h + \kappa^h u_{t-1} + \sum_{i=1}^{n} \delta_i \Delta \mathrm{P}_{t-i}^h + \sum_{i=1}^{n} \varpi_i \Delta \mathrm{P}_{t-i}^f + \varepsilon_t^{\mathrm{h}} & (1a) \\ \text{or} & \\ \Delta \mathrm{P}_t^f = \alpha_0^f + \kappa^f u_{t-1} + \sum_{i=1}^{m} \delta_i \Delta \mathrm{P}_{t-i}^f + \sum_{i=1}^{m} \varpi_i \Delta \mathrm{P}_{t-i}^h + \varepsilon_t^f & (1b) \end{cases}$$

where u_{t-1}^h is the one period lagged error correction term from the cointegration regression that involves P_t^h (the price of the stock listed on the NZX) and P_t^f (the price of the same stock listed on the ASX), provided that P_t^h and P_t^f are cointegrated. If P_t^h and P_t^f are cointegrated, then Granger causality exists in at least one direction via a significant estimate of κ^h or κ^f, which enables one variable to forecast the other (Granger, 1988). There is, however, an additional channel for Granger causality to materialise: the sum of the lagged differenced causal variables (i.e., $\sum_{i=1}^{n} \varpi_i \Delta P_{t-i}^{f}$ for predicting ΔP_t^h, or $\sum_{i=1}^{m} \varpi_i \Delta P_{t-i}^{h}$ for predicting ΔP_t^f). The test of the causality via this channel is performed using the standard Wald F test.

Note, however, that the lead-lag relationship does not say anything about how the ASX prices and the NZX prices contribute to the price discovery. To examine this question, we resort to Hasbrouck's (1995) IS and Grammig *et al.*'s (2005) CIS.

Information share (IS) of Hasbrouck (1995)

Hasbrouck (1995) assesses the IS of the price discovery by the proportion of innovations to the prices that occur on each market. Thus, the IS model measures each market's relative contribution to this variance. The information shares are not distinctively defined if the price innovations on the ASX and the NZX are correlated; therefore it is necessary to compute upper and lower bounds for the information shares by attributing information to each market.

When estimating the price discovery model, we first use a restricted price vector, in which the exchange rate is treated as exogenous by first converting the prices into a common currency. Hasbrouck estimates the restricted regression that has a cointegrating vector, $\beta' = (1, -1)$. Adopting Hasbrouck's (1995) IS approach, we use this formula:

$$IS_j = \frac{\Psi_j C_{jj}}{\Psi \Omega \psi'} \tag{2}$$

where Ω = var (ε_t) and C is the lower triangular Cholesky factorization of Ω (Ω = CC'). As Ω is not usually a diagonal matrix, Cholesky decomposition is employed. This enables decomposition of the permanent information variance (Var($\psi\varepsilon_t$) into two parts (attributable to the home market and attributable to the foreign market). If in the long run the domestic market and the foreign market value $\psi\varepsilon_t$ differently, then both will still have an IS as given in the IS_j equation above.

Grammig *et al.*'s (2005) conditional information share (CIS)

Grammig *et al.* (2005) expand Hasbrouck's IS (1995) by endogenizing the exchange rate, and so evaluate the cointegration of the exchange rate, the home price series and the foreign price series. They estimate the unrestricted regression that has a cointegrating vector $\beta' = (1,\ -1,\ 1)$.

It is possible to calculate the IS of the market i with respect to price series j, CIS_{ji}.

$$CIS_{ji} = \frac{\left[\left(\Psi(1)\ C \right)_{ji} \right]^2}{\left(\Psi(1) \Omega \psi(1)' \right)_{jj}} \tag{3}$$

As there appears to be one cointegrating equation between three variables this would mean that the rows of ψ (1) are not identical. This means it is not possible to obtain one IS for each of the three series as in Hasbrouck (1995). Thus, Grammig *et al.* (2005) propose an IS for each market which they refer to as the conditional information share (CIS).

Impulse response functions (IRFs)

Yan and Zivot (2006) have extensively used IRFs in their analysis of the dynamics of price discovery. IRFs provide a device to visualise the time path of how each market impounds the new information during the price discovery process. The Impulse Response Function (IRF) is calculated as

$$y_{t+n} = \sum_{i=0}^{\infty} \Psi_i \varepsilon_{t+n-i}$$
$$\{\Psi_n\}_{i,j} = \frac{\partial y_{it+n}}{\partial \varepsilon_{jt}} \tag{4}$$

where the response of $y_{i,t+n}$ to a one time impulse in $y_{j,t}$ with all other variables dated t or earlier held constant. With the aid of an IRF it is possible to visualise the time path of how each market impounds the new information during the price discovery process. The IRF is derived using the Cholesky decomposition on stationary VAR residuals with the assumption that the preceding innovations in variables in the VAR will have considerable effects on the subsequent variables in the VAR.

Data

One can use either the most recent transaction prices or quote prices to analyse price discovery dynamics. Because transactions in the NZ market are often infrequent in our study we use quote midpoints instead of transaction prices. The same strategy is adopted by Eun and Sabherwal (2003), Grammig *et al.* (2005), Buhr *et al.* (2007) and Frijns *et al.* (2010 and 2013). As noted in Roll (1984), an advantage of this approach is that it removes any spurious negative autocorrelation due to bid/ask bounce.

The accurate estimation of information share needs rich data. Frijns et al. (2010) used four Australian firms [Australian Mutual Provident Society (AMP), Australia and New Zealand Banking Group (ANZ), Lion Nathan (LNN) and Telstra (TLS)] and five New Zealand firms [Auckland International Airport (AIA), Fletcher Building (FBU), Telecom (TEL), Tower (TWR) and Warehouse (WHS)] because their shares are relatively frequently traded in both markets.

We use the same firms as Frijns et al. (2010) with one exception. Lion Nathan (LNN) which was used in their study was delisted from the Australian Securities Exchange on 28 October 2009. Thus, our study does not include LNN.

Frijns et al. (2010) used NZX prices, ASX prices and the currency exchange rates at one minute intervals. But during the bear market from January 2008 to December 2011, the selected stocks were not traded regularly. Thus, the use of a one-minute return time series would yield a large number of zeros, leading to serious econometric issues such as serial correlation. This would generate biased results making statistical inferences about the populations unreliable. Further, the results generated from a return series containing many zeros is less informative thereby creating negative economic consequences. After a careful investigation on how best to eliminate these econometric and informativeness issues, we conclude that the most frequent intraday data that can be reliably used for our analysis is hourly data.

We obtain the intraday trade and quote data for the selected firms and the NZD/AUD exchange rate from Securities Industry Research Centre of Asia-Pacific (SIRCA). Trading days between 1st January 2008 to 31st December 2011 are selected excluding public holidays and days when there was no trading in either market. The exchange rate data are based on *Greenwich Mean Time* (GMT) thus they have been adjusted for the relevant time zones. We used trading data from the overlapping time when both markets were open.

Wellington (where the NZX is based) and New South Wales (where the ASX is based) are in different time zones. There is a two hour time difference. Figure 1B contrasts the ASX trading hours of 10.00 am to 4.00 pm Australian Eastern Standard Time (AEST) with the NZX trading hours from 10.00 am to 5.00 pm New Zealand time. From the figure, one can see that there are five hours of overlapping trading hours between 10.00 am AEST (12.00 noon NZ time) till 3.00 pm AEST (5.00 pm NZ time). However, due to the slight differences in starting and ending days of daylight savings in Wellington and New South Wales, the actual overlapping trading hours can vary from 4 hours to 5 hours but for most of the analysis 5 hours of overlapping trading hours are observable.

Figure 1A shows time plots for the S&P/ASX 200 index and the NZX 50 Index. The S&P/ASX 200 index is the main investible equity index of Australia whilst the NZX 50 index is the major benchmark index for the New Zealand equity market. Both indices indicate the markets were in a bull stage during the January 2002 to December 2007 time period studied by Frijins *et al.* (2010). In contrast the graph indicates both markets were in a bear phase for the January 2008 to December 2011 period covered by the current study.

Results

Descriptive summary statistics

For the analysis of cointegration and Hasbrouck's (1995) IS we convert all of the price series of the cross-listed stocks into Australian dollars (AUD). For the analysis of Grammig *et al.*'s (2005) conditional information share, we use three time series, namely, the price series on the ASX in AUD, the price series on the NZX in NZD and the exchange rate between AUD and NZD.

Tables 1A and 1B provide the summary statistics of the overlapping time period for the three Australian firms and the five New Zealand firms for the sample period January 2008 to December 2011. Table 1A shows that for all of the selected Australian firms the average

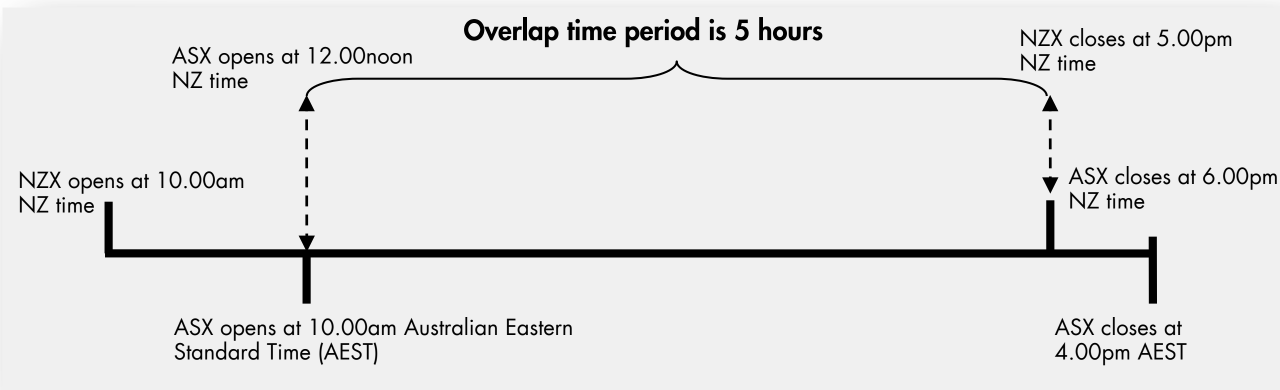


Figure 1B Trading hours of the NZX and the ASX

Australian domiciled firms	Quote average price	Average number of trades	Average daily volume	Percentage of average bid-ask spread
ANZ				
ASX	20.67	1,668.92	1,176,946.53	0.0002
NZX	26.01	2.61	34,523.56	0.0208
AMP				
ASX	5.73	605.68	1,097,804.50	0.0015
NZX	7.19	2.04	11,333.54	0.0242
TLS				
ASX	3.43	755.11	6,889,458.64	0.0027
NZX	4.27	1.96	127,096.99	0.0335

Table 1A
Summary statistics for Australian domiciled firms

Note Table 1A provides the summary statistics for three Australian firms for the period January 2008 to December 2011. The table shows the quote average price, the average number of daily trades, the average number of daily volume and the percentage of average bid-ask spread. The quote average prices in each market are reported in their local currency denomination.

New Zealand domiciled firms	Quote average price	Average number of trades	Average daily volume	Percentage of average bid-ask spread
AIA				
ASX	1.62	4.87	15,429.24	0.0256
NZX	2.03	15.09	233,170.74	0.0014
FBU				
ASX	6.05	86.28	74,126.85	0.0047
NZX	7.59	25.72	224,095.75	0.0032
TEL				
ASX	2.08	155.42	664,044.88	0.0034
NZX	2.60	29.55	980,312.24	0.0034
TWR				
ASX	1.42	7.3	14,256.21	0.0225
NZX	1.79	4.1	38,070.80	0.0096
WHS				
ASX	3.12	2.77	7,123.20	0.0609
NZX	3.90	5.49	29,695.71	0.0054

Table 1B
Summary statistics for New Zealand domiciled firms

Note Table 1B provides the summary statistics for five New Zealand firms for the period January 2008 to December 2011. The table shows the quote average price, the average number of daily trades, the average number of daily volume and the percentage of average bid-ask spread. The quote average prices in each market are reported in their local currency denomination.

number of trades and the average daily trading volume are substantially higher on the ASX in comparison to the NZX. In terms of daily volume, TLS is the most active firm in both exchanges whilst in terms of average number of trades ANZ is the most active firm in both exchanges.

Table 1B shows that for all of the selected New Zealand firms the average daily trading volume is substantially higher on the NZX than on the ASX. The average number of trades for TEL, FBU and TWR are higher on the ASX in comparison to the NZX. TEL is the most active firm in terms of the average number of trades and the average daily volume.

The co-movements of prices on the two exchanges are illustrated in Figures 2A and 2B. Figure 2A superimposes a graph of hourly prices on the two exchanges for Australian firm ANZ and Figure 2B for New Zealand firm FBU. A representative section is presented to observe the movements of the ASX and NZX price series more closely. All the price series are converted into AUD. Each chart shows that the ASX and the NZX prices tend to move together with minimal deviations. A similar pattern with minimal variations exists for each of the other companies evaluated in this study and they are not reproduced here. This is a signal of a long term co-movement for the price series of each company. It is also a preliminary indication of a cointegration relationship between the price series on the ASX and the NZX.

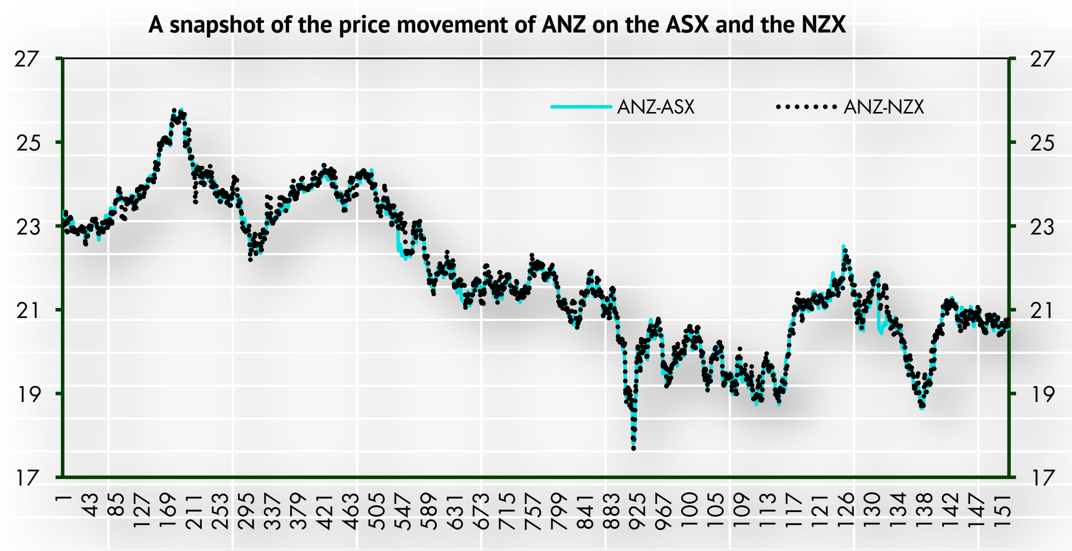


Figure 2A
Plot of hourly closing prices of the Australian domiciled firm ANZ.

Note Figure 2A shows the lead/lag relationship between the hourly closing prices of ANZ on the ASX and the NZX.

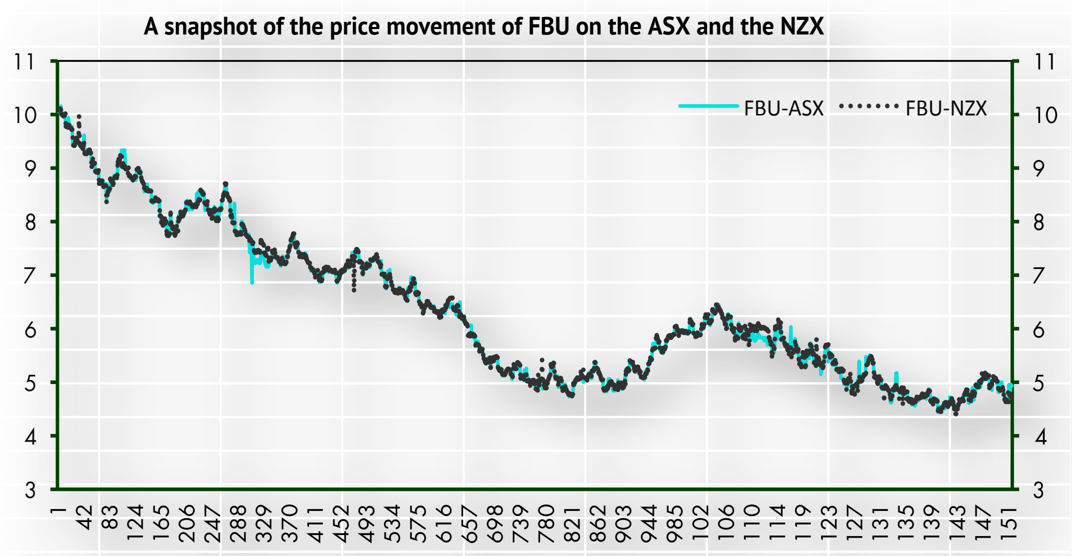


Figure 2B Plot of hourly closing prices of the New Zealand domiciled firm FBU.

Note Figure 2B shows the lead/lag relationship between the hourly closing prices of FBU on the ASX and the NZX.

Tests for Stationarity

The Augmented Dickey Fuller unit root test (ADF) (Dickey and Fuller 1979; 1981) and Phillips-Perron (Perron 1987, Phillips-Perron 1988) nonparametric unit root test are carried out as two formal tests for stationarity. The Akaike Information Criteria (AIC) is carried out to ascertain the optimum number of lags for ADF and Phillips-Perron tests.

The *ADF and* Phillips-Perron test results for Australian and New Zealand domiciled firms confirm that the price series are not stationary at levels; however, the first difference of each of the price series is stationary based on MacKinnon one sided p-values at the 1% significance level (detailed results are available on request). These results provide strong evidence that the price series examined in the study are integrated of order 1. Additionally, the ADF and Phillips-Perron tests reinforce each other.

Tests for Cointegration

Gonzalo and Lee (2000) point out that the Johansen (1995) and the Engle-Granger (1987) cointegration tests are based on two different rationales. Thus, Gonzalo and Lee (2000) recommend using both tests as a robustness check.

The Engle-Granger (1987) cointegration test is carried out. The null hypothesis of no cointegration between the two price series is rejected at 1%, 5% and 10% level of significance for Australian and New Zealand firms confirming that each of the price series on the ASX and the NZX are cointegrated. Thus, it is possible to conclude that the OLS regression generated from $Y_t = a + bX_t + e_t$ is not subject to spurious regression. Therefore the residuals of the regression will be stationary and hence, the error correction regression can be estimated.

The trace statistic and eigenvalue test statistic of the Johansen (1991; 1995) cointegration test confirm that there is one cointegrating relationship between the prices of the Australian and New Zealand firms on the ASX and the NZX at 5% significance. This confirms that each of the price series of Australian and New Zealand domiciled firms on the ASX and the NZX are cointegrated.

Vector Error Correction and Granger Causality

The estimated vector error correction models for the Australian (New Zealand) domiciled firms show the influence of the ASX (NZX) prices on the NZX (ASX) prices. The estimated coefficients for the error correction terms are statistically significant and negative. This indicates that the NZX (ASX) prices typically move towards the lagged ASX (NZX) prices. These results provide strong evidence that the prices on the NZX (ASX) follow the price discovery arising in the prices of the ASX (NZX).

The Granger causality test is performed to determine whether the home market leads the foreign market or vice versa. Two tests are evaluated to determine Granger causality, the F statistic and the t statistic of the error correction term [ECT (-1)]. Based on the results of F statistics and the t-statistics of ECT (-1) for all the companies under investigation have varying degrees of bi-directional Granger causality between New Zealand (Australian) prices and Australian (New Zealand) prices. (The test results are available on request).

Information share (IS) of Hasbrouck (1995)

The results of Hasbrouck's information shares (ISs) are presented in Table 2. The table shows the upper bounds, lower bounds and the averages of all permutations for the Cholesky factorization of ISs.

For the Australian domiciled firms, we find that the price discovery mostly takes place on the home (ASX) market. ANZ (90.58%), AMP (92.00%) and TLS (99.88%) yield a midpoint range of IS between 90.58% to 99.88% and the mean midpoint IS of 94.15% for the Australian firms. This confirms that during the sample period, the price discovery for Australian firms mainly takes place on the ASX. These findings are consistent with Frijns *et al.* (2010).

For the New Zealand domiciled firms except TEL, we find that the price discovery mostly takes place on the home (NZX) market. With the average ISs for AIA (99.65%), FBU (76.08%), TWR (92.92%) and WHS (96.57%) confirming that the price discovery for these New Zealand firms mostly takes place on the home (NZX) market. However a significant proportion of the price discovery for TEL (92.21%) takes place on the foreign (ASX) market. In addition, 40% of trading volume and 84% of the number of trades for TEL transpire on the ASX confirming TEL is significantly different to the rest of the New Zealand companies in the study. This is different from Frijns *et al.* (2010) who find that the price discovery for TEL takes place on the NZX. The midpoint of the IS for the New Zealand firms range between 7.79% (TEL) to 99.65% (AIA) and have a mean midpoint IS of 74.60%. The range between upper and lower bounds are not significantly different for all the stocks except FBU. This suggests that contemporaneous correlation does not generate serious econometric issues. Additionally upper and lower bounds of the prices on the NZX and the ASX do not overlap confirming the home market is dominant in price discovery.

The results in Table 2 confirm that more extensive price discovery takes place for Australian domiciled firms on the ASX than for the New Zealand domiciled firms on the NZX. These findings are consistent with Frijns *et al.* (2010).

Analysis of impulse response functions (IRF)

The IRFs of all Australian companies confirm that the ASX is dominant for Australian domiciled firms and strongly contributes to the price discovery.

The IRFs of New Zealand companies except for TEL confirm that the NZX is dominant for the New Zealand domiciled firms and contributes largely to the price discovery. These results are consistent with the findings from the Hasbrouck's (1995) IS analysis. (The IRFs are available on request).

Information share (IS) of Hasbrouck (1995) over time

Table 3 shows the results of how the yearly midpoints for ISs have changed over time. During the sample period, the trends in the ISs for the Australian firms on the ASX exchange are decreasing by varying degrees. TLS experienced the most significant downward trend and AMP encountered the least significant downward trend. However, somewhat mixed trends in the ISs exist for the New Zealand firms on the ASX. AIA, FBU and TWR experienced decreasing trends whilst TEL and WHS experienced increasing trends. In addition, the IS of TEL is larger on the ASX (foreign market) in comparison to the NZX (home market) and it has also been growing significantly.

Information Share for Australian and New Zealand cross-listed stocks

	Percentage in ASX exchange			Percentage in NZX exchange			
	Upper bound	Lower bound	Average (Mid point)	Upper bound	Lower bound	Average (Mid point)	Cointegration relationship
Australian domiciled Firms							
ANZ	99.995%	81.167%	90.581%	18.833%	0.005%	9.419%	1.0000, -0.9973
AMP	97.378%	86.614%	91.996%	13.386%	2.623%	8.004%	1.0000, -0.9972
TLS	99.992%	99.773%	99.883%	0.227%	0.008%	0.118%	1.0000, -0.9352
New Zealand domiciled Firms							
AIA	0.499%	0.196%	0.347%	99.804%	99.501%	99.653%	1.0000, -0.9593
FBU	41.581%	6.258%	23.920%	93.742%	58.419%	76.081%	1.0000, -0.9991
TEL	98.372%	86.039%	92.206%	13.961%	1.628%	7.794%	1.0000, -0.9974
TWR	13.627%	0.536%	7.082%	99.464%	86.373%	92.919%	1.0000, -1.0016
WHS	5.521%	1.345%	3.433%	98.655%	94.479%	96.567%	1.0000, -1.0034

Table 2 Hasbrouck (1995) IS results for the prices of Australian and New Zealand cross-listed stocks

Note Table 2 shows the lower bounds, upper bounds and averages (midpoints) of Hasbrouck's (1995) IS.

$$IS_j = \frac{\Psi_j C_{jj}}{\Psi \Omega \psi'}$$ Where the proportion of IS for market j relative to the total variance is defined as market j's IS.

Information Share for Australian and New Zealand Cross-listed Stocks Over Time								
	Australian Stock Exchange (ASX)				New Zealand Stock Exchange (NZX)			
Australian domiciled firms	2008	2009	2010	2011	2008	2009	2010	2011
AMP	88.46%	92.32%	91.52%	86.77%	11.54%	7.68%	8.48%	13.23%
ANZ	93.38%	79.86%	86.76%	85.97%	6.62%	20.14%	13.24%	14.03%
TLS	99.60%	98.86%	78.41%	93.93%	0.40%	1.14%	21.59%	6.07%
Average of Australian domiciled firms	**93.81%**	**90.35%**	**85.56%**	**88.89%**	**6.19%**	**9.65%**	**14.44%**	**11.11%**
New Zealand domiciled firms	2008	2009	2010	2011	2008	2009	2010	2011
AIA	12.18%	0.16%	5.32%	5.44%	87.82%	99.84%	94.68%	94.56%
FBU	86.22%	20.76%	43.51%	12.38%	13.78%	79.24%	56.49%	87.62%
TEL	73.40%	74.02%	96.02%	96.23%	26.60%	25.98%	3.98%	3.77%
TWR	63.82%	68.23%	0.33%	4.57%	36.18%	31.77%	99.67%	95.43%
WHS	7.20%	2.54%	5.98%	72.16%	92.80%	97.46%	94.02%	27.84%
Average of New Zealand domiciled firms	**48.56%**	**33.14%**	**30.23%**	**38.16%**	**51.44%**	**66.86%**	**69.77%**	**61.84%**

Table 3 Hasbrouck (1995) IS results for the prices of Australian and New Zealand cross-listed stocks over time

Note Table 3 shows the averages (midpoints) of Hasbrouck's (1995) annual information share (IS).

Figures 3A and 3B depict the average midpoint of ISs for the New Zealand and Australian firms on the ASX and the NZX. They show the overall trend more clearly. Throughout the sample period there is a growing significance for the NZX exchange for both Australian and New Zealand domiciled companies.

The above findings differ from those in Frijns *et al.* (2010). They find that the ISs of Australian and New Zealand firms on the ASX increased over time. In our study, we find the ISs of Australian and New Zealand firms on the NZX have increased over time.

Although there were certain regulatory changes on the ASX and NZX during the bullish (2002 – 2007) and bearish (2008 – 2011) trends, none of them were differentially or obstinately impacting on the price discovery of the companies in the current study. Thus, these variations between the findings of our study and the findings of Frijns *et al.* (2010) can be attributed to the differences in investor sentiments (investor psychology, optimism to pessimism, bullish and bearish collective moods) and disparities in the role of stock prices in bull and bear markets. However, differences in the frequency of the data sets used in the two studies might affect the comparability of the results.

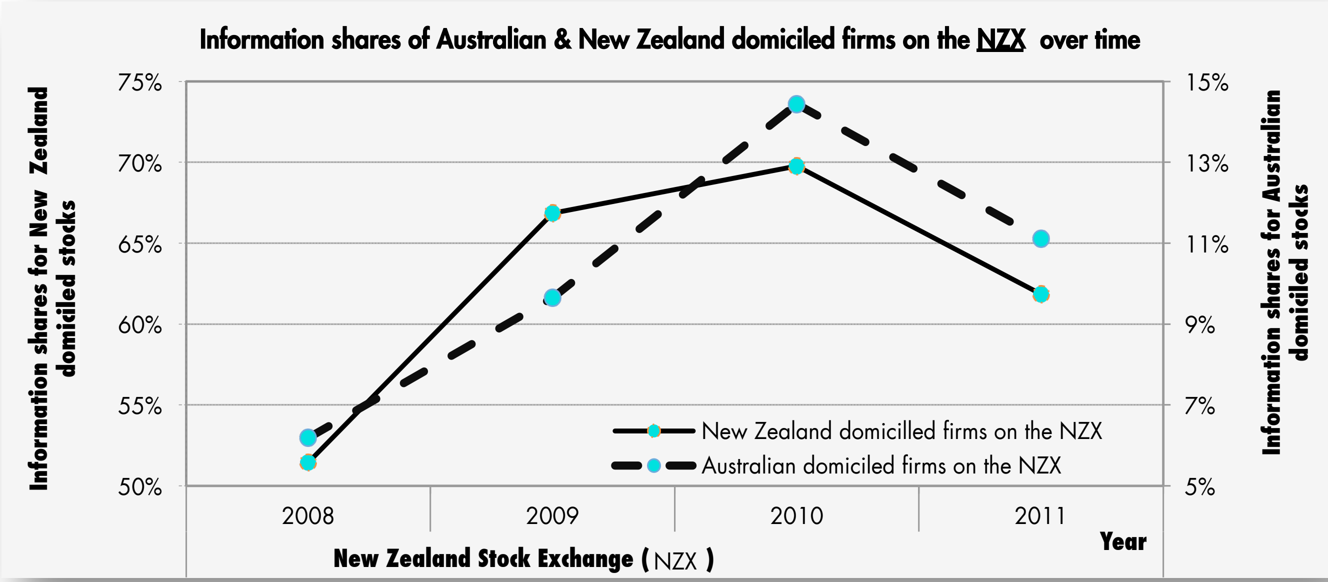


Figure 3A Information shares on the NZX over time

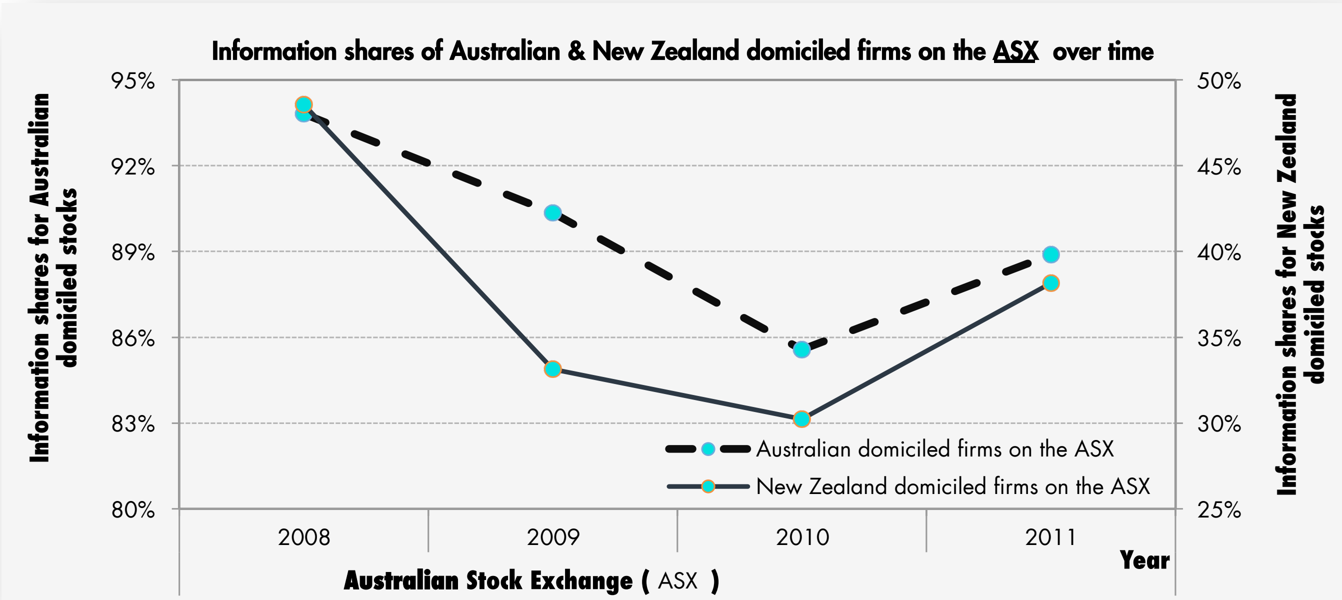


Figure 3B Information shares on the ASX over time

Note The figures above show the average midpoint of ISs for Australian and New Zealand firms on the NZX and the ASX.

Endogenizing the exchange rate and Conditional information share (CIS)

We endogenize the exchange rate in the vector error correction model (VECM) and calculate the CIS per each market. The data support one cointegrating vector and the estimated cointegrating vectors are close to the theoretical expectation of the vector $\beta' = (1,\ -1,\ 1)$ for all the Australian and New Zealand domiciled firms.

Analysis of impulse response functions (IRF)

Including the exchange rate in the analysis gives rise to three IRFs. To confirm the convergence of the long run influence of a one unit shock on other variables, we calculate the impulse responses for 5000 steps ahead.

The IRFs for the Australian domiciled firms are presented in Figure 4A and the IRFs for the New Zealand domiciled firms are presented in Figure 4B. The plots in the first column show the impact that a one unit shock in the exchange rate has on ASX and NZX prices. The plots in the second column show the impact that a one unit shock in ASX prices has on the exchange rate and on the corresponding NZX prices. The plots in the third column show the impact that a one unit shock in NZX prices has on the exchange rate and on the corresponding ASX prices.

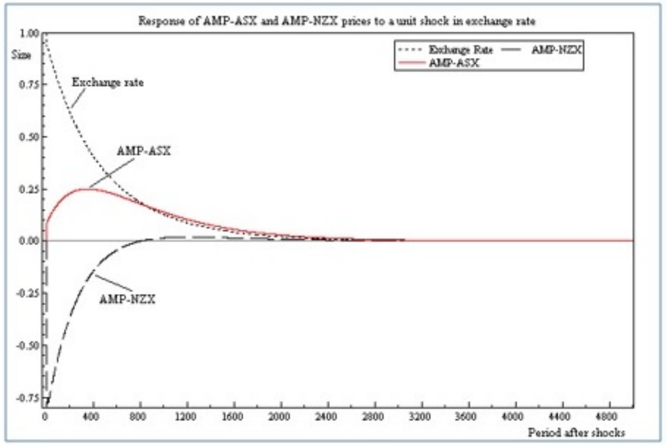
The IRFs for the Australian firms show that a larger initial response to an exchange rate shock occurs for the NZX prices than for ASX prices. This confirms that exchange rate shocks generate more correction in the prices of the NZX (foreign) market. This finding is consistent with Frijns *et al.* (2010) but differs from Grammig *et al.* (2005) who find that the reaction to exchange rate shocks is present only in the prices of the foreign market. The NZX prices adjust to the ASX shocks and then tend to follow the ASX prices. Additionally it is evident that the ASX shocks have very little impact on the exchange rate. This is in line with Grammig *et al.* (2005) as well as Frijns *et al.* (2010). The NZX shocks are only momentary and the ASX prices and the exchange rate barely react to NZX shocks. These findings confirm that the ASX exchange (the NZX exchange) is the dominant (satellite) market for the Australian firms. These findings are in line with our earlier findings for the IRFs using two price series (single currency) as well as with the conclusions reached by Frijns *et al.* (2010).

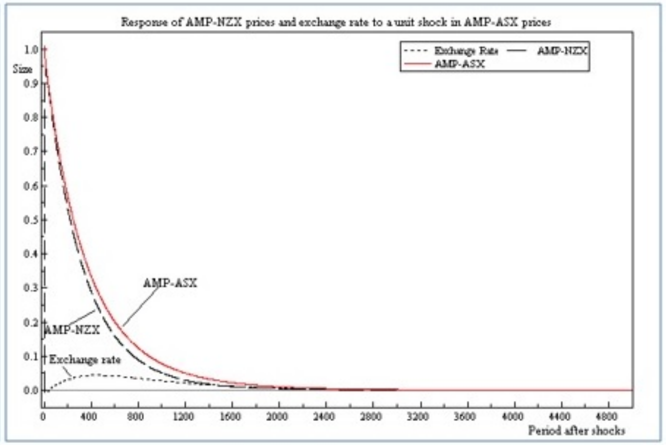
The IRFs for the New Zealand firms show that the exchange rate shocks have a slightly larger impact on ASX prices than on NZX prices excluding TEL. This confirms that more correction for exchange rate shocks occurs in the prices for the ASX (foreign) market. This finding is again in line with Frijns *et al.* (2010) but differs from Grammig *et al.* (2005) who find that the response to exchange rate shocks is present only in the prices of the foreign market. However, the TEL prices on the NZX (home) respond more significantly to exchange rate shocks than the TEL prices on the ASX (foreign) exchange. This finding for TEL prices is in line with our earlier findings when analysing IRFs for two price series (single currency) and with the analysis of IS by Hasbrouck (1995). However, this finding for TEL prices differs from Frijns *et al.* (2010) who find that more correction for exchange rate shocks occurs in the prices for the ASX (foreign) market. The ASX shocks are just momentary for AIA and WHS and the NZX prices and the exchange rate barely react to these ASX shocks. The ASX shocks for TWR and FBU persist for about 800 to 1,600 periods after the shock and the NZX prices react slightly to these shocks whilst the exchange rate barely reacts to the shock. However, the NZX price of TEL reacts significantly to the ASX shock and the exchange rate also moderately reacts to the ASX shocks. The ASX prices for all the New Zealand stocks except TEL react significantly to the NZX shocks. These findings confirm that the NZX exchange (the ASX exchange) is the dominant (satellite) market for New Zealand firms except for TEL. These findings are in line with our earlier findings in the analysis of IRFs for two price series (single currency) and with the analysis of IS by Hasbrouck (1995). These conclusions are in line with the findings of Frijns *et al.* (2010) except for TEL.

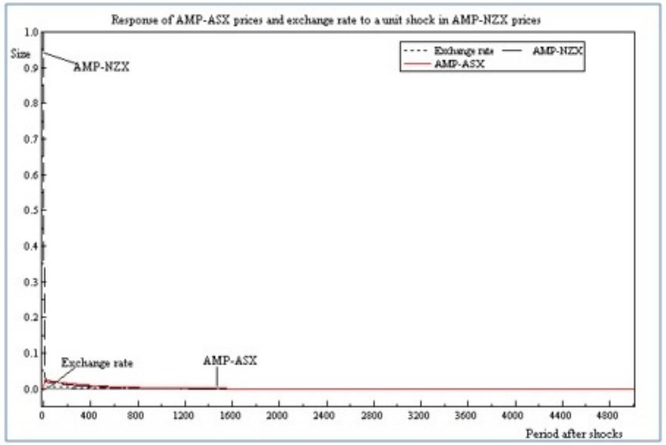
Responses of ASX and NZX prices to a unit shock in the exchange rate

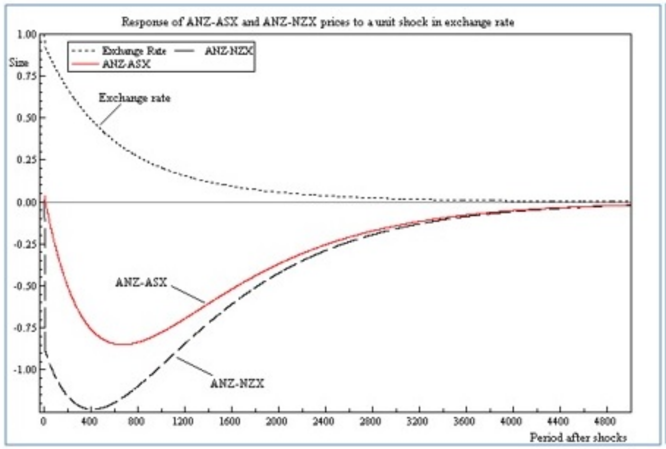
Responses of exchange rate and NZX prices to a unit shock in the ASX prices

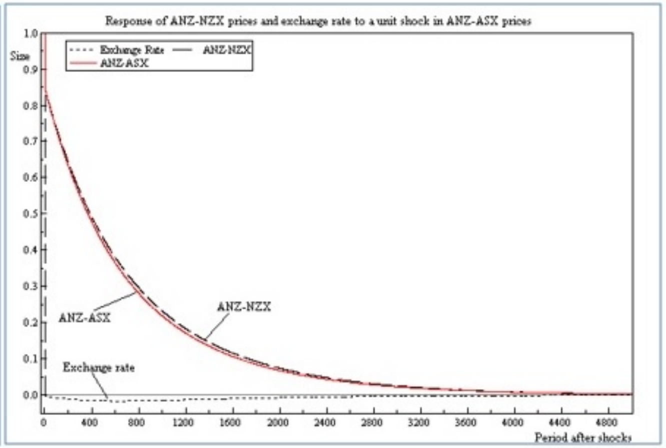
Responses of exchange rate and ASX prices to a unit shock in the NZX prices

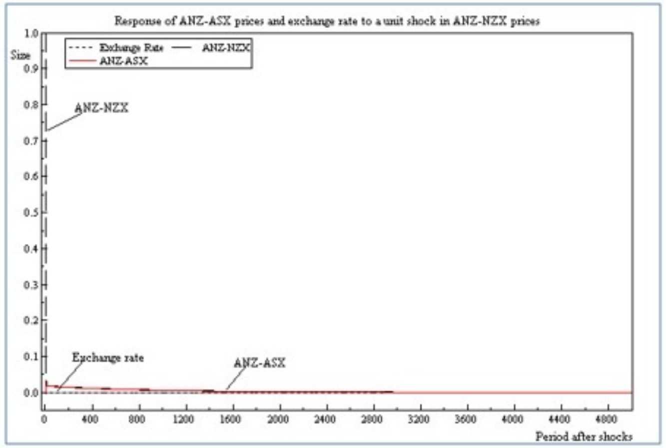












Responses of ASX and NZX prices to a unit shock in the exchange rate

Responses of exchange rate and NZX prices to a unit shock in the ASX prices

Responses of exchange rate and ASX prices to a unit shock in the NZX prices

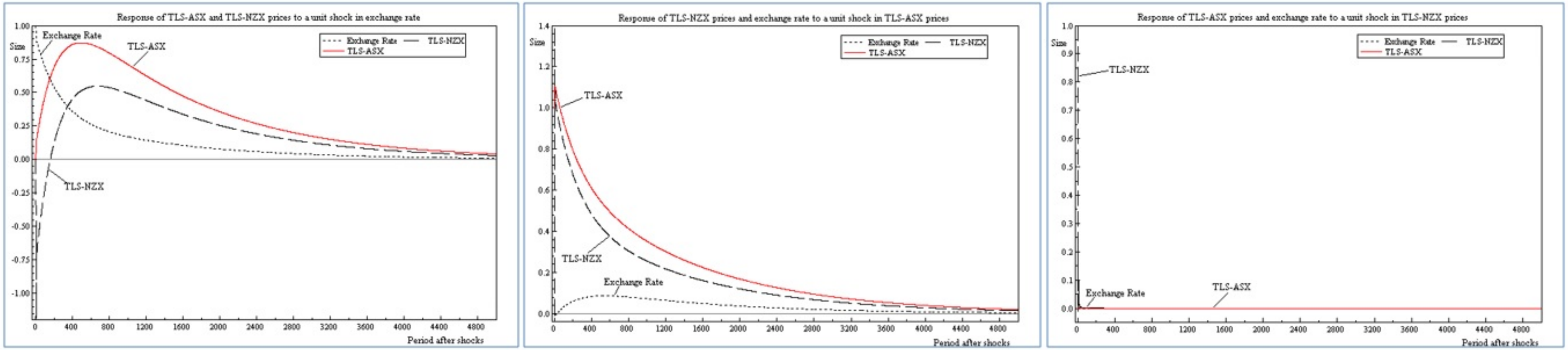
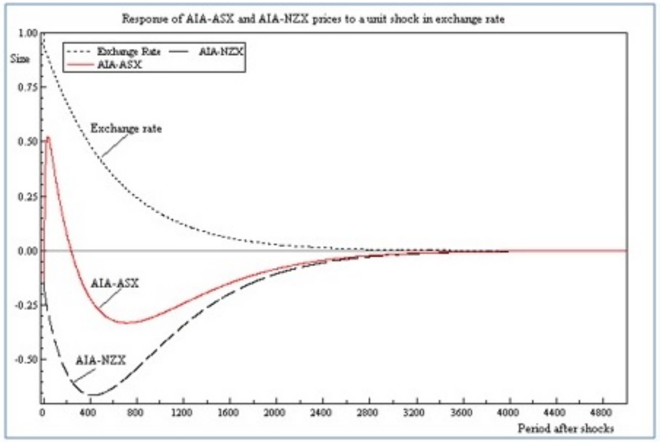
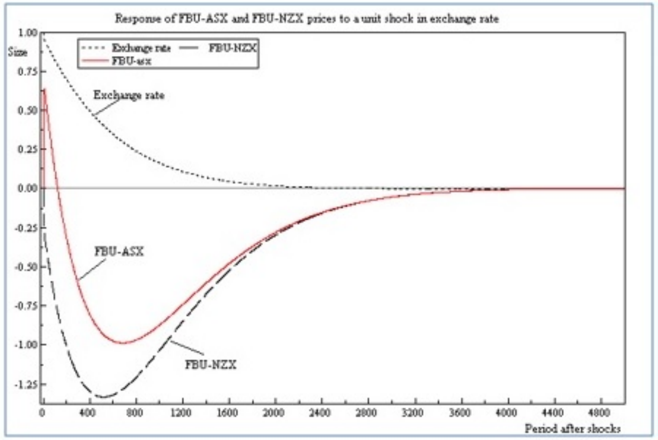


Figure 4A Impulse Response Functions (IRFs) for Australian domiciled forms (ANZ, AMP and TLS)

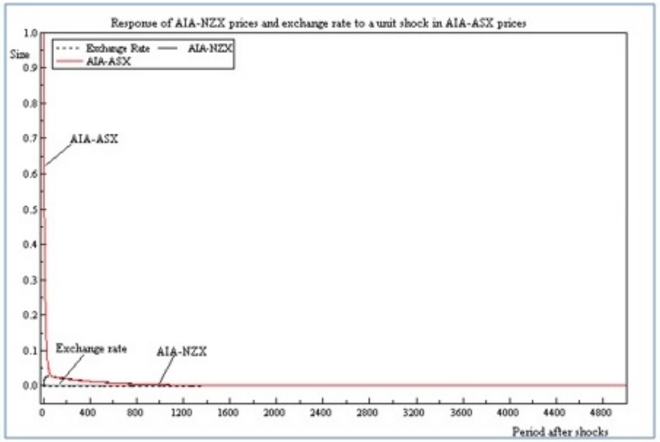
Note If a system of equations is stable any shock should quickly disappear whilst an unstable system of equations would produce an explosive time path.

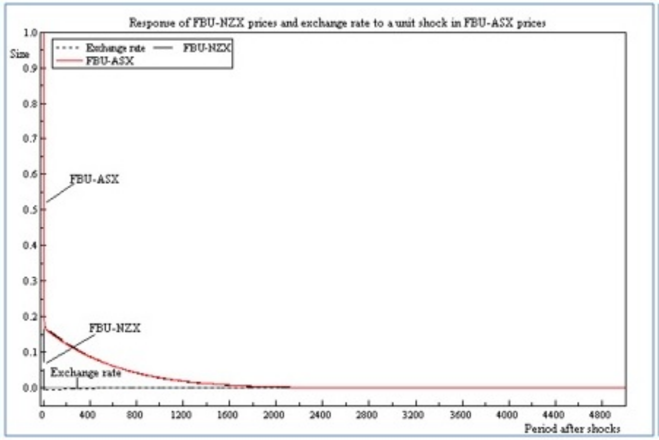
Responses of ASX and NZX prices to
a unit shock in the exchange rate



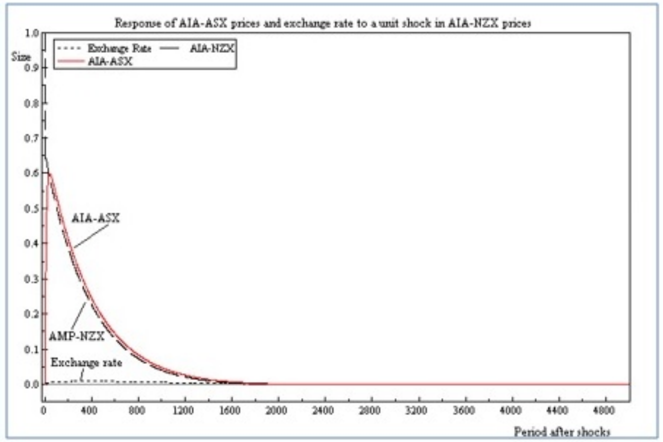


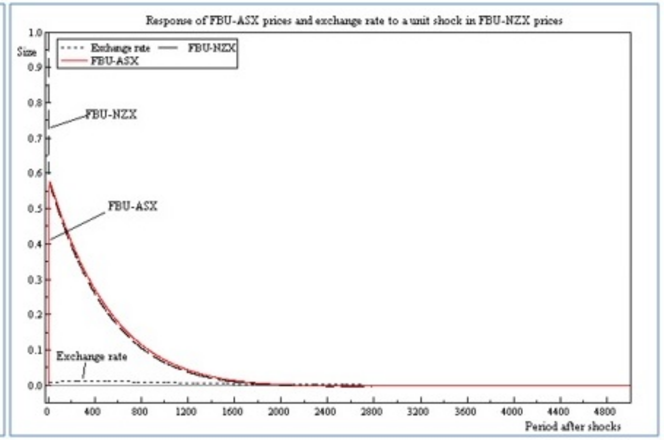
Responses of exchange rate and
NZX prices to a unit shock in the ASX prices





Responses of exchange rate and
ASX prices to a unit shock in the NZX prices

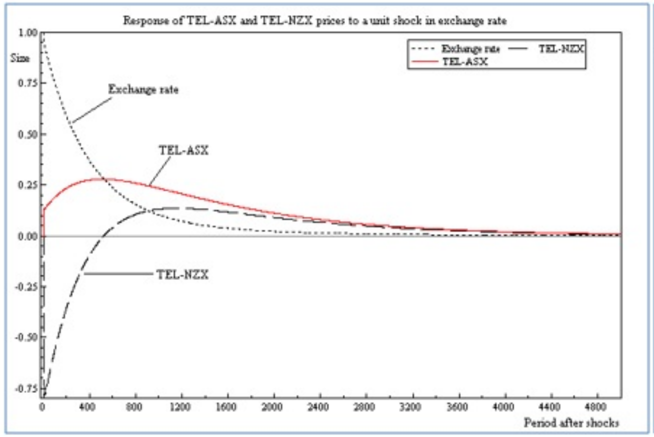


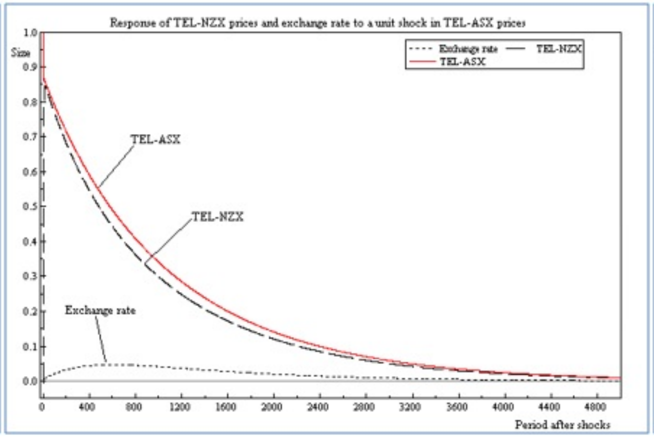


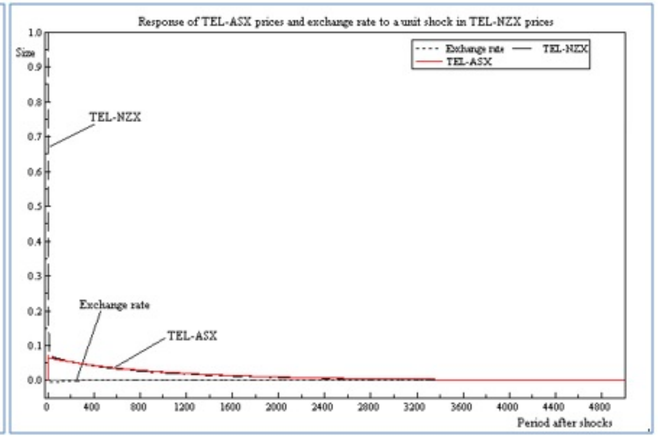
Responses of ASX and NZX prices to a unit shock in the exchange rate

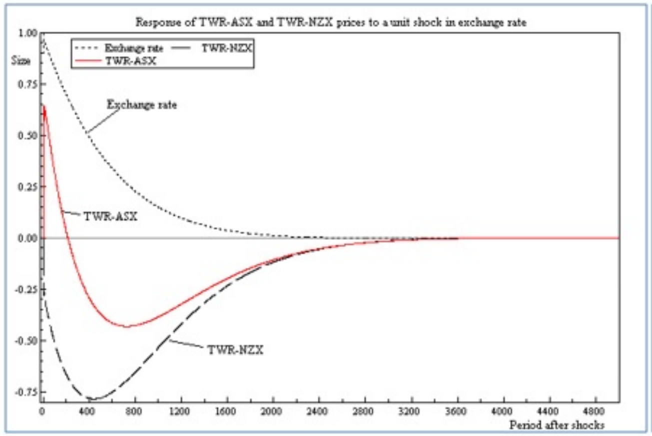
Responses of exchange rate and NZX prices to a unit shock in the ASX prices

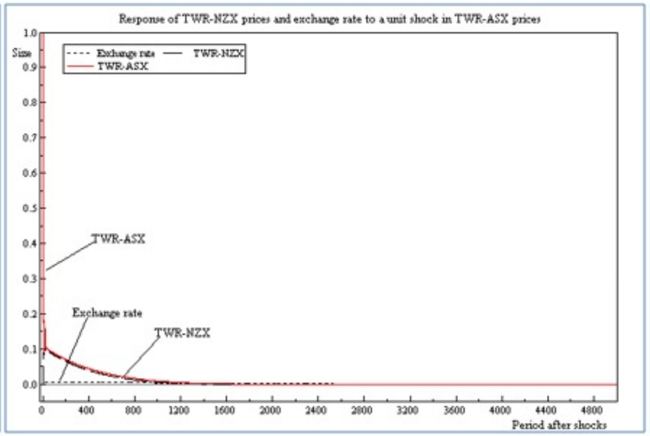
Responses of exchange rate and ASX prices to a unit shock in the NZX prices

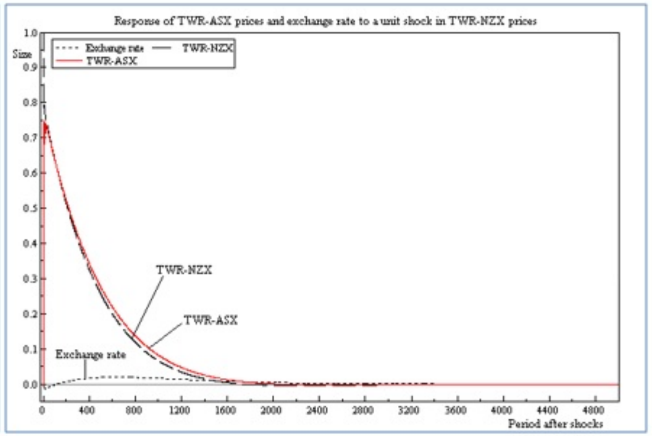












Responses of ASX and NZX prices to a unit shock in the exchange rate | Responses of exchange rate and NZX prices to a unit shock in the ASX prices | Responses of exchange rate and ASX prices to a unit shock in the NZX prices

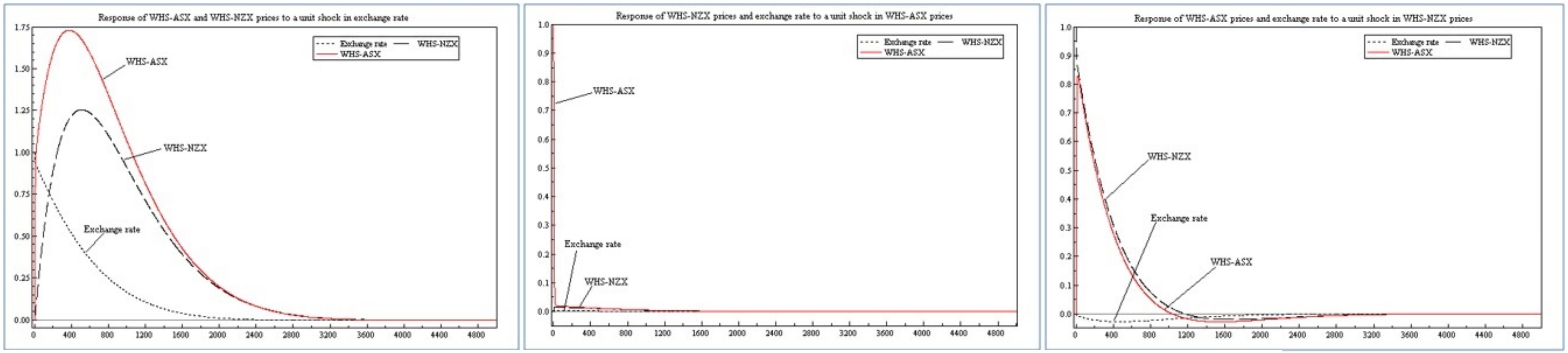


Figure 4B Impulse Response Functions (IRFs) for New Zealand domiciled forms (AIA, FBU, TEL, TWR and WHS)

Note If a system of equations is stable any shock should quickly disappear whilst an unstable system of equations would produce an explosive time path.

Grammig *et al.*'s (2005) Conditional information share (CIS)

To determine upper and lower bounds for the CIS we permute all six possible orderings of the three time series, [the ASX prices (in AUD), the NZX prices (in NZD) and the exchange rates]. Due to the triangularization of the innovation variance-covariance matrix, specific ordering must be carried out to establish the upper and lower bounds of CIS. Similar to Grammig *et al.* (2005) and Frijns *et al.* (2010), the upper bound (lower bound) for the estimated IS of each variable is obtained by selecting the value that comes first (last) in the ordering.

Tables 4A and 4B show the averages (midpoints) of the CIS. Each column in these tables shows how quote prices in the selected market respond to different shocks and therefore every column should add up to one. Each row shows the IS for the ASX, the NZX and the exchange rate. Thus the numbers in the first column indicate that ASX price changes contribute 82.71% of the price discovery for AMP on the ASX exchange; the NZX price changes contribute 14.07% of the price discovery for AMP on the ASX exchange and the changes in the exchange rate contribute the remaining 3.22% of the price discovery for AMP on the ASX exchange. The first number in the second column (81.52%) shows that the IS of AMP for the ASX price shock is 81.52% on the NZX exchange. Similarly, the first number in the third column is 12.38% which shows the IS that the ASX shock has on the exchange rate.

Table 4A shows the midpoint of CIS for Australian domiciled firms. It shows that the ASX IS is higher in the Australian (home) market than in the New Zealand (foreign) market for AMP and ANZ. This is in line with Frijns *et al.* (2010). However, for TLS we find that the ASX IS is lower in the Australian market than in the New Zealand market which is not in line with Frijns *et al.* (2010). The influence of ASX price shocks on the determination of the exchange rate is insignificant for AMP and ANZ but is moderately significant for TLS. This is in line with Frijns *et al.* (2010) and Grammig *et al.* (2005). The ISs for the NZX are shown in the second row of Table 4A and they are higher in the home market in comparison to the foreign market albeit the difference is trivial. The exchange rate seems to be exogenous to NZX price shocks. When we compare the ISs for the ASX to the NZX and the NZX to the ASX, it is clear that the ASX significantly contributes to price discovery on both the ASX and the NZX. This finding is qualitatively compatible with the conclusions we find based on IS Hasbrouck (1995). Further, these findings are in line with Frijns *et al.* (2010). The ISs of the exchange rate are shown in the last row of Table 4A. The price adjustment as a result of exchange rate changes is substantial for ANZ and TLS in both the ASX and NZX exchanges; however, it is insignificant for AMP in both exchanges. This finding is not in line with Frijns *et al.* (2010) where they find that the price adjustment to exchange rate changes is observable on the NZX but not on the ASX.

Table 4B shows the midpoint of CIS for New Zealand domiciled firms. It shows that for the New Zealand companies (except TEL and WHS), the shocks on NZX prices have a smaller influence on the home (New Zealand) market than on the foreign (Australian) market. Thus, for AIA, FBU and TWR, we find that the NZX ISs are higher in the Australian (foreign) market than in the New Zealand (home) market. This confirms the significance of NZX price shocks in the ASX market. However, this finding is not in line with Frijns *et al.* (2010) who find that ASX ISs are higher in the New Zealand market than in the Australian market. However, for TEL and WHS, we find that the NZX ISs are higher in the New Zealand (home) market than in the Australian (foreign) market. When we compare the ISs for the NZX to the ASX and ASX to the NZX, it is clear that the NZX significantly contributes to price discovery on both the ASX and the NZX, except for TEL. This finding is qualitatively compatible with the conclusions we find based on IS Hasbrouck (1995). Further, these findings are in line with Frijns *et al.* (2010). The ISs of the exchange rate are shown in the last row of Table 4B. We find that the price adjustment to exchange

Midpoints of conditional information shares [CIS] per market

Australian domiciled firms

AMP		**ASX MARKET %**	**NZX MARKET %**	**EXCHANGE RATE %**
	ASX SHOCK	82.71%	81.52%	12.38%
	NZX SHOCK	14.07%	16.09%	2.00%
	FX SHOCK	3.22%	2.40%	85.62%
ANZ		**ASX MARKET %**	**NZX MARKET %**	**EXCHANGE RATE %**
	ASX SHOCK	65.20%	53.67%	4.72%
	NZX SHOCK	10.28%	11.48%	2.45%
	FX SHOCK	24.52%	34.85%	92.83%
TLS		**ASX MARKET %**	**NZX MARKET %**	**EXCHANGE RATE %**
	ASX SHOCK	71.65%	81.41%	32.95%
	NZX SHOCK	0.07%	0.28%	0.05%
	FX SHOCK	28.27%	18.31%	67.01%

Table 4A
Midpoints of Grammig *et al.*'s (2005) CIS results for the prices of Australian domiciled firms

Note Table 4A shows averages (midpoints) of Grammig *et al.*'s (2005) CIS.

$$CIS_{ji} = \frac{\left((\Psi C)_{ji}\right)^2}{(\Psi \Omega \psi')_{jj}}$$

It is possible to calculate the IS of the market i with respect to price series j, CIS_{ji}. The first row shows each of the market in which CIS is measured. The first column shows the market on which CIS is reported.

Table 4B
Midpoints of Grammig *et al.*'s (2005) CIS results for the prices of New Zealand domiciled firms

Midpoints of conditional information shares [CIS] per market			
New Zealand domiciled firms			
AIA	**ASX MARKET %**	**NZX MARKET %**	**EXCHANGE RATE %**
ASX SHOCK	9.39%	3.12%	0.01%
NZX SHOCK	79.85%	55.24%	0.52%
FX SHOCK	10.77%	41.64%	99.47%
FBU	**ASX MARKET %**	**NZX MARKET %**	**EXCHANGE RATE %**
ASX SHOCK	13.96%	9.38%	0.83%
NZX SHOCK	40.50%	28.21%	0.84%
FX SHOCK	45.53%	62.42%	98.34%
TEL	**ASX MARKET %**	**NZX MARKET %**	**EXCHANGE RATE %**
ASX SHOCK	81.68%	83.70%	36.42%
NZX SHOCK	14.53%	15.47%	4.41%
FX SHOCK	3.79%	0.83%	59.17%
TWR	**ASX MARKET %**	**NZX MARKET %**	**EXCHANGE RATE %**
ASX SHOCK	12.28%	7.10%	2.17%
NZX SHOCK	75.98%	55.64%	2.79%
FX SHOCK	11.74%	37.26%	95.03%
WHS	**ASX MARKET %**	**NZX MARKET %**	**EXCHANGE RATE %**
ASX SHOCK	2.65%	2.31%	0.64%
NZX SHOCK	10.56%	22.79%	4.16%
FX SHOCK	86.79%	74.90%	95.20%

Note Table 4B shows averages (midpoints) of Grammig *et al.*'s (2005) CIS.

$$CIS_{ji} = \frac{\left((\Psi C)_{ji}\right)^2}{\left(\Psi \Omega \psi'\right)_{jj}}$$

It is possible to calculate the IS of the market i with respect to price series j, CIS_{ji}. The first row shows each of the market in which CIS is measured. The first column shows the market on which CIS is reported.

rate changes mostly occurs on the NZX for New Zealand companies except TEL and WHS. In addition, the exchange rate ISs for FBU and WHS are significantly greater confirming that substantial price adjustments to exchange rate changes occur on both the ASX and NZX. These findings are in contrast to the findings in Frijns *et al.* (2010) where they find that the price adjustment to exchange rate changes primarily occurs on the ASX.

We also find that ASX ISs are generally greater than the NZX ISs for Australian domiciled firms whilst on average the NZX ISs are greater than the ASX ISs for New Zealand domiciled firms except TEL. This finding is qualitatively consistent with the conclusions we find based on IS Hasbrouck (1995).

Additionally we find that the average IS for the ASX shocks for the Australian domiciled firms (72.69%) is greater than the average IS for NZX shocks for New Zealand domiciled firms (39.87%). Similarly we find that on average the IS for the NZX shocks for Australian domiciled firms (8.71%) is less than the average IS for ASX shocks for New Zealand domiciled firms (22.56%). Despite the negative effect of TEL on NZX shocks, these findings confirm the significance of the ASX shocks on the NZX.

Conclusion

Motivated by the question of whether investing strategies in stock markets should change during different trading phases this study investigates the price discovery dynamics of cross listed stocks on the Australian and New Zealand exchanges during 2008 to 2011.

Consistent with previous research, we find that price discovery mostly takes place on the home market for both the Australian domiciled firms and for all but one of the New Zealand domiciled firms. This is true in terms of both Hasbrouck's (1995) IS and Grammig *et al.*'s (2005) CIS.

We find that in a bear market the price adjustment to exchange rate changes occurs on both exchanges for Australian domiciled companies whilst the price adjustment to exchange rate changes mostly occurs on the NZX for New Zealand domiciled companies. An exception is TEL which is a significant outlier to the rest of the New Zealand firms in terms of the price discovery, trading volume and number of trades. We also find a growing importance of the NZX exchange for both the Australian domiciled firms and the New Zealand domiciled firms. This finding also differs from Frijns *et al.* (2010 and 2013) who find an increasing trend in the importance of the ASX exchange over time. While the use of minute-by-minute versus hourly data may contribute to this difference the mechanism for why it would is unclear.

Our study's findings reinforce the conclusions of Miaoxin (2012) and Hodgson *et al.* (2003) who find that price discovery dynamics vary when a market changes from a bull trading phase to a bear trading phase or vice versa. These differing price discovery dynamics in a bear market versus a bull market may be due to variations in investor sentiments (investor psychology, optimism to pessimism, bullish and bearish collective moods) and the disparities in the role of the stock prices in bull and bear markets.

However our conclusions must be viewed cautiously as there may have been unrecognized changes in market dynamics other than investor sentiment between the two time periods being compared.

The growth in importance of the NZX during a bear market suggests that it is moving away from being a pure satellite market. An interesting extension of this work will be to see whether New Zealand's recent move towards a NASDAQ OMX X-stream *trading platform* will improve price discovery and make it an even more important independent market.

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