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THE INTERNATIONAL TRANSMISSION OF ARBITRAGE INFORMATION ACROSS FUTURES MARKETS

Chris Bilson [a], Tim Brailsford[b] and Twm Evans [c]

a School of Finance & Applied Statistics, Australian National University, Canberra 0200, Australia
b UQ Business School, University of Queensland, St Lucia 4072, Australia
c University of Wales (Swansea), Wales, United Kingdom

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Last revision date:	9/9/02
Contact author:	Dr Chris Bilson School of Finance and Applied Statistics The Australian National University Canberra ACT 0200 AUSTRALIA Fax +61 2 6125 0087 Email chris.bilson@anu.edu.au

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Abstract

The paper examines whether deviations from a domestic spot-futures relation, as identified through mispricing series in stock index futures, spillover international boundaries. Such spillovers suggest that information from a mispricing series in one market conveys a signal of similar mispricing in another market. In the presence of arbitrage traders and in the absence of market frictions, mispricing series should be independent across international boundaries. The study employs a VAR analysis of stock index futures mispricing across Australia, the UK and USA. Using time zone differences, tests are conducted for the daily transmission of arbitrage information. The results reveal the relationship between mispricing series is bi-directional. Based on this finding, a trading strategy is employed to examine the economic significance of apparent profits. The results show that some profits are possible but that a long horizon, probably beyond the scope of most traders, is required to exploit the spillover information.

1. Introduction

The existence of linkages across international markets has been well documented, particularly in relation to stock markets in developed economies. The decline in international investment barriers experienced over the past two decades, combined with the move toward globalisation of financial markets, have increased international capital movements which in turn has accelerated inter-market correlations of economic activity. Associated with these changes has been an apparent higher degree of market integration and correlation of asset price movements across markets. A substantial focus of research in this area has been concentrated on equity price movements, both in relation to return co-movements and volatility spillovers. The evidence from these studies supports the existence of contagion effects and "meteor showers" across markets (eg. Hamao et al 1990).

The development of derivative securities has allowed investors to more effectively manage their exposures. In the presence of arbitrage forces, the prices of derivative instruments are generally regarded as a function of the prices of their underlying asset. Hence, to the extent that international relations exist between price movements in spot market assets, it can be reasonably expected that such relations should also be present in the associated derivative assets. For instance, if two equity markets exhibit co-movement then their stock index futures contracts should also exhibit the same relation. If this were not the case, then there would appear to be arbitrage opportunities between the spot and futures in at least one of the domestic markets. This concept can be thought of more formally in the context of cointegration. Specifically, if two spot markets are cointegrated then it is reasonable to expect their futures markets to be similarly cointegrated. However, there is limited evidence on international linkages between derivative markets.

As an alternative to testing for international relations across derivative markets, a more direct and potentially revealing test would be to examine spillovers between mispricing series. This is the purpose of this paper. Specifically, the study focuses on stock index futures and their mispricing series. Evidence has shown small but persistent patterns of mispricing in domestic futures markets (eg. Cornell and French, 1983). The aim of the paper is to examine whether potential arbitrage opportunities identified in one market carry information such that they can predict subsequent potential arbitrage opportunities in another market. As an example, the futures and spot markets became delinked in October 1987 and the question arises as to whether such instances are widespread and whether they flow over market boundaries.[1] The reason for the deviation in the domestic spot-futures relation is not important here. Rather, given that a deviation exists, the paper seeks to examine whether the deviation spills across markets. Similarly, King and Wadhwani (1990) attempt to explain how common falls in stock market indices are observed around crash dates. Despite vastly differing economic conditions, they propose that price changes in foreign markets may be systematically interpreted as relevant information for the local market, even if the foreign market price change is induced by idiosyncratic events.

The study has implications as to the efficiency of international capital markets and whether international investors can exploit windows of arbitrage opportunity identified in one market in another market. The paper focuses on three markets on which there is evidence of existing correlations in the spot market – Australia, the UK and USA. Domestic mispricing series are constructed for each market and using the time zone differences between the three markets, a VAR is constructed to examine whether the domestic mispricing series are related.

The paper is constructed as follows. The next section reviews the literature on international market linkages. Section 3 discusses known features of stock index futures pricing. Section 4 documents the data used in the study and the construction of the VAR. Section 5 provides a description of the three mispricing series, while section 6 contains the results of the analysis. In short, all mispricing series exhibit autocorrelation and there is evidence of bi-directional spillovers across the markets. A trading strategy is employed to examine the economic significance of apparent profits. The results show that some profits are possible but that a long horizon, probably beyond the scope of most traders, is required to exploit the spillover information. The final section contains the conclusion.

[1] See the Brady Commission report for a discussion of the Crash of October 1987 (Presidential Task Force on Market Mechanisms, *Report of the Presidential Task Force on Market Mechanisms*, Washington: US Government Printing Office, 1988).

2. Linkages across international markets

Many studies have reported the existence of linkages among financial markets. Awad and Goodwin (1998) have found the evidence of dynamic linkages, particularly in the long run, among real interest rates of the markets of G-10 countries. Rouwenhorst (1999) reports a decrease in the interest rate spreads among the 12 European Monetary Union countries following the Maastricht Treaty in 1992. In the context of stock markets, it is well-known that international correlations exist. International asset pricing models predict that price spillover effects will occur as price changes in foreign markets are interpreted as relevant economic information which is subsequently incorporated into prices on the local stock market (see Stulz 1981, Solnik 1983, Cho et al 1986). Eun and Shim (1989) use a VAR model to study linkages among nine developed stock markets and find evidence of US market innovations flowing to the other markets, with limited evidence of foreign market influence back to the USA. Similarly, Copeland and Copeland (1998) study 29 countries across the Americas, Europe and the Pacific and report statistically significant one-day leads of the US market over the other markets. The developments in computer technology have been an impetus for high-speed information transmission across markets. In support, Solnik et al (1996) find that, on average, the correlations between national stock market indices of industrial countries have increased over time.

Interaction between financial centres has also been observed in price volatility. Engle et al (1990) first introduced the “heat wave” and “meteor shower” terminology, in an attempt to distinguish between country-specific autocorrelation and volatility spillovers across international borders. In the context of equity markets, Hamao et al (1990) find evidence of daily volatility spillovers between the share price indices on the London, New York and Tokyo exchanges. The spillover effects are unidirectional in nature, flowing from New York to London, but not from London to New York (Becker et al 1990, Hamao et al 1990). Koutmous and Booth (1995) report a strong market interdependence among the US, UK and Japanese markets and also note asymmetry in the relationship during good and bad news periods.[2]

[2] Other findings of volatility spillovers across equity markets are documented by Bae and Karolyi (1994), Lin et al (1994) and Karolyi (1995).

Spillover effects in price movements have not been limited to equity markets. Kim and Sheen (2000) find evidence of a lagged impact of US interest rate announcements on Australian interest rates. Similarly, Abhyankar (1995) examines mean return and volatility spillovers between the Eurodollar futures contracts traded on the Singapore Monetary Exchange (SIMEX) and Chicago Mercantile Exchange (CME), and finds evidence of both a lagged spillover effect in the mean flowing in a unidirectional form from the CME to the SIMEX. Speight and McMillan (2001) examine the foreign exchange rate black markets of five central European countries and find some evidence of volatility spillovers.

In the context of futures markets, Booth et al (1997) study volatility spillovers using daily data on the USA, UK and Japanese futures. In support of the 'meteor shower' hypothesis, they find significant spillovers between the USA and UK. However, Japanese futures volatility tends to follow an autoregressive trend, as suggested by the heat-wave hypothesis and as such is independent of US and UK volatility. Gannon and Choi (1998) report volatility spillovers in stock index futures from the USA to the Hong Kong futures market. Tse (1998), on the other hand, finds no evidence of volatility spillovers between the interest rate futures markets of the Eurodollar and Euroyen.

In summary, there is substantial evidence that price and price volatility spillovers exist across all types of markets. The strong evidence of stock market linkages means that due to the arbitrage relationship between the spot and futures markets, linkages should also exist between index futures markets. Indeed, the limited empirical evidence tends to support this claim.

3. Stock Index Futures Pricing

The price of a stock index futures contract can be given by the cost-of-carry, as follows:[3]

$$F^*_{t,T} = S_t\, e^{(r-d)(T-t)} \qquad \ldots(1)$$

where:

$F^*_{t,T}$	=	the theoretical futures price at time t for a futures contract expiring at T;
S_t	=	the underlying stock index price at t;
R(T-t)	=	the yield at time t of a discount risk-free bond maturing at time t; and
D(T-t)	=	the continuous dividend yield over time t to T.

The model can be transformed as in (2) to obtain the mispricing series:

$$MP_t = F_{t,T} - S_t\, e^{(r-d)(T-t)} \qquad \ldots(2)$$

$F_{t,T}$	=	the observed futures price at time t for a futures contract expiring at T.

A profitable arbitrage opportunity arises when the level of mispricing exceed the arbitrage boundaries. There is substantial evidence on the pricing of index futures. The bulk of the work in the US has investigated the S&P500 and reported small, negative mispricing (eg. Cornell and French 1983, Figlewski 1984, Chung 1991). Studies in other markets have also documented occurrences of small, negative mispr icing such as in the UK, Australia, Germany and Switzerland (Bowers and Twite 1985, Brailsford and Hodgson 1997, Kempf 1998, Stulz et al 1990, Yadav and Pope 1990). Positive mispricing is reported in Japan and Hong Kong (Bhatt and Cakici 1990, Brenner et al 1989) but overall, the results indicate a greater tendency of negative mispricing (underpricing).

Larger levels of mispricing are generally observed under circumstances where transactions costs are relatively high. For instance, Brailsford and Hodgson (1997) report a consistent negative mean pricing error in Australia, where transactions costs are relatively higher than the USA. But they

[3] The cost-of-carry model assumes that markets are perfect and frictionless, borrowing and lending can take place at a constant continuously compounded interest rate, deposit and performance margins can be posted in interest bearing assets and the underlying basket of shares pay dividends continuously. Relaxation of these assumptions does not have a substantial impact on the evidence concerning mispricing (see Sutcliffe 1997).

report no sustainable arbitrage profits due to the low frequency of large futures pricing errors. Fung and Draper (1999) report that relaxing the short sales restrictions could reduce the mispricing level in Hong Kong. Gay and Jung (1999) report a persistent underpricing in the Korean futures market, caused essentially by high transaction costs. Butterworth and Holmes (2000) examine mispricing of the FTSE 100 and FTSE 250 contracts. They find a small magnitude of mispricing in both futures contracts, but with a higher level of mispricing in the FTSE 250, and reduced arbitrage opportunities after the introduction of FTSE 250 in 1994.

Mispricing series have been found to exhibit systematic properties. MacKinlay and Ramaswamy (1988) note the presence of autocorrelation in the mispricing series. Yadav and Pope (1992) find a mean-reverting process in the mispricing series of the US and UK stock futures markets. Kempf (1998) documents a similar result in the German market. Vaidyanathan and Krehbiel (1992) explicitly recognise that the mispricing series exhibits systematic linear and non-linear trends, predominantly positive in some periods and negative in other periods. Non-synchronous trading in the constituent stocks can induce autocorrelation in the stock index which, in turn, can lead to arbitrage opportunities being falsely identified. Miller et al (1994) show that any mispricing series constructed from hypothetical arbitrage between the spot and futures could be contaminated and exhibit spurious mean reversion.

In summary, in the presence of arbitrage traders and the absence of market frictions, the expected value of any mispricing series is zero. Moreover, a mispricing series should exhibit small, random fluctuations. However, various factors that tend to be related to market microstructure, induce some small mispricing. As these factors are market-specific, any mispricing in one market should be independent of mispricing from another market. If relations between mispricing series exist across markets then arbitrage forces should eliminate them. If systematic relations across these series are found, it is prima facie evidence of the inefficiency of international capital markets.

4. Data and Method

The study requires a time series of mispricing on the three markets under investigation – Australia, the UK and USA. These markets are selected because of their known linkages.[4] There is little point testing for spillovers of arbitrage information if the underlying markets are not related. In order to generate the mispricing series, the cost-of-carry is used, as in (1) and (2). Daily closing data are obtained for both the spot and futures markets over a 13-year period, 2 January 1985 to 30 December 1998, yielding a total of 3471 matching daily observations. However, no dividends are available for the UK in the year 1985 so these dates are omitted. If any of the countries experiences a holiday, the data for that day is omitted for all three markets. After making these adjustments, 2996 observations remain.

In order to implement the cost-of-carry, dividend and interest rate series are also required. The dividend series is taken as the yield on the underlying index in each market. For the risk-free proxy, the following are used – 13-week Treasury bill rate for Australia; 3-month Treasury bill rate for the UK and the 3-month Treasury bill rate for the USA.

As noted earlier, evidence has shown that mispricing series can exhibit time-series properties such as autocorrelation. As such, the mispricing series for each market is assumed to be influenced both from its prior own-market mispricing in addition to the variables of interest, that is, the mispricing series from the other markets. A VAR model is used to test these relationships. The model is estimated using equal information lags, as follows:

$$MP_{AU,t} = a_{AU} + \sum_{i=1}^{n} ß_i^{AU} MP_{AU,t-i} + \sum_{i=1}^{n} ?_i^{AU} MP_{UK,t-i} + \sum_{i=1}^{n} ?_i^{AU} MP_{US,t-i} + e_{AU,t} \qquad \ldots(3a)$$

$$MP_{UK,t} = a_{UK} + \sum_{i=0}^{n-1} ß_i^{UK} MP_{AU,t-i} + \sum_{i=1}^{n} ?_i^{UK} MP_{UK,t-i} + \sum_{i=1}^{n} ?_i^{UK} MP_{US,t-i} + e_{UK,t} \qquad \ldots(3b)$$

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[4] The linkage between the UK and USA markets is well known and described in section 2. Linkages between Australia and the USA are also well documented (eg. Brooks and Henry 2000). Similarly, Australia and the UK are traditional trading partners and their financial markets are linked. For instance, Eun and Shim (1989) refer to the UK influence on the Australian stock market as a “Commonwealth factor”.

$$MP_{US,t} = a_{US} + \sum_{i=0}^{n-1} ß_i^{US} MP_{AU,t-i} + \sum_{i=0}^{n-1} ?_i^{US} MP_{UK,t-i} + \sum_{i=1}^{n} ?_i^{US} MP_{US,t-i} + e_{US,t} \qquad \ldots(3c)$$

where MP_{AU}, MP_{UK} and MP_{US} are the mispricing series from the Australian, UK and US futures markets respectively generated from (2).

An issue arises as to the impact of different trading times and different time zones. For the spot markets, the local trading times are as follows: Australia is open from 10am to 4pm, London from 8am to 4:30pm and the NYSE from 8:30am to 3:15pm. For the futures markets, the Australian market is open from 9:50am to 4:10pm, London is open from 8:35am to 4:10pm and the Chicago Exchange is open from 9:30am to 4pm.[5] The opening times are expressed in GMT in Figure 1.[6] The Australian market opens first, followed by the UK and then the USA. Given this sequencing, the VAR models in (3) only use observations from other markets that are available at the time (ie. close-to-close prices).

FIGURE 1

Trading Hours of the Markets (in GMT) – Spot and Futures

	Time	SPOT			FUTURES		
	GMT	AUS	UK	US	AUS	UK	US
Day t-1	2200						
	2300						
	2350				OPEN		
Day t	0000	OPEN					
	0100						
	0200						
	0300						
	0400						
	0500						
	0600	CLOSE					
	0610				CLOSE		
	0700						

[5] The Australian and London futures exchanges operate an automated trading system after the main hours of the exchange. In both cases, trading volume is relatively low after hours and hence we concentrate on the large volume day trading.

[6] The times in Figure 1 do not operate all year round due to the advent of daylight savings in the three countries. However, daylight savings does not alter the basic method as the order of the markets is unchanged and variations are small.

0800	OPEN			
0835			OPEN	
0900				
1000				
1100				
1200				
1230				OPEN
1300				
1330		OPEN		
1400				
1500				
1600				
1610			CLOSE	
1630	CLOSE			
1700				
1800				
1900				
1915				CLOSE
2000		CLOSE		
2100				
2200				
2300				
0000				

5. Mispricing Series

Table 1 reports descriptive statistics on the mispricing series. The table includes information on a scaled series where the mispricing is scaled by the spot series to account for differences in index values across the markets. The mispricing series for Australia and the UK are negative on average, whereas the USA exhibits positive average mispricing. The medians of the UK and US series are positive, whereas the Australian mispricing median is negative. Australia has the largest level of mispricing, a result which remains after the series are scaled. However, all series are small with the mean scaled mispricing less than 0.5% in all three markets, consistent with the presence of competitive and efficient markets. The larger absolute mispricing in Australia probably reflects greater arbitrage bounds in this market. That is, the smaller levels of mispricing in the UK and US markets may reflect lower transactions costs and higher liquidity compared with the Australian market. Moreover, the dominance of negative mispricing may be explainable by greater restrictions on short sales in the Australian market. Of note, graphs (not shown) of the three mispricing series show that the extreme values across the markets tend to cluster in time.

INSERT TABLE 1

Before examining the relations between the mispricing series, we conduct Augmented Dickey-Fuller unit root tests on the variables used in calculating the cost-of-carry using:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \varepsilon_t \qquad \text{...(4)}$$

The lag orders in the testing equations are determined by AIC, such that the errors are rendered white noise.[7] The results show evidence of a unit root in all series except the ratio of the futures closing price to the spot price and the mispricing series. These results are consistent across the Australian, UK and US markets.

Table 2 contains the results of cointegration tests on the cost-of-carry variables. The comparison of variables across markets is undertaken bearing in mind time zone differences so that markets are compared at common times (as per Figure 1). The approach used to test for a cointegrating relation follows that of Dickey and Fuller.[8] The test for no cointegration is obtained by testing for a unit root in the residuals of equation (4), viz:

$$?\ e_t = a_1 e_{t-1} + \sum_{j=1}^{p} ?_j ?\ e_{t-j} + u_t \qquad \text{…(5)}$$

INSERT TABLE 2

The futures closing prices are cointegrated across Australia and the UK, and across the USA and Australia but the UK-USA pairing is mildly insignificant. A similar result holds for the spot series and the ratio of futures-to-spot. These results confirm prior studies of closely related market movements. Of note is that the mispricing series are cointegrated across all market pairings. Recall that these series should prima facie be independent.

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[7] Examination of higher lag orders yields similar results.

[8] No time trend is fitted for the residual regression, and the lag order is that described for the ADF tests.

6. Mispricing Analysis Across Markets

Table 3 reports on the relations between the mispricing series in each market. An OLS regression is run for each market where the scaled mispricing series is regressed against its own lagged series and the lagged series from the two foreign markets. That is, the model assumes that each mispricing series is a function of a first-order autoregressive process and by the most recent available information from the foreign markets. The mispricing series is scaled by the spot series to avoid distortions from differing index values. At this stage of the analysis only one (daily) information lag is used.[9] The regressions are:

$$MP_{AU,t} = a_{AU} + ß_1^{AU} MP_{AU,t-1} + ?_1^{AU} MP_{UK,t-1} + ?_1^{AU} MP_{US,t-1} + e_{AU,t}$$

$$MP_{UK,t} = a_{UK} + ?_1^{UK} MP_{UK,t-1} + ß_1^{UK} MP_{AU,t} + ?_1^{UK} MP_{US,t-1} + e_{UK,t}$$

$$MP_{US,t} = a_{US} + \lambda_1^{US} MP_{US,t-1} + ß_1^{US} MP_{AU,t} + \gamma_1^{US} MP_{UK,t} + e_{US,t}$$

INSERT TABLE 3

From Table 3, the model appears to explain the relationship well, with all adjusted R-squared values in excess of 45%, with Australia exhibiting the highest value of 72%. The explanatory power of the model appears to be driven mainly by an own market influence, that is, mispricing appears to be persistent and positively related to its level in the previous period, consistent with prior evidence (eg. MacKinlay and Ramaswamy 1988). This result is consistent across all markets. Despite the presence of this strong autoregressive relationship, mispricing from the foreign markets also has an impact. The coefficients on the cross-market lagged mispricing series are generally significant. These results suggest that innovations in the mispricing series in one market spillover to the mispricing series in another market. Prima facie, these results are anomalous and inconsistent with the concept of integrated and competitive international capital markets. Of note, the intercepts are consistent with the results in Table 1, with Australia being negative, US positive and UK being small and slightly negative.

[9] The possibility of higher order relationships is investigated at a later stage.

To date, only first-order effects have been considered, such that it was assumed that only information contained in the period immediately proceeding the period of interest. Further, Table 3 reports on separate regressions for each market. We now consider a less restrictive model, whereby higher order impacts and cross-correlations are considered within a single estimation. The framework of equations (3a), (3b) and (3c) is employed, again using scaled mispricing. Consistent with most studies incorporating daily data, five lags are used for the VAR. The specification takes into account time zone differences between the markets such that only information that is known is included. For instance, in the UK regression, the contemporaneous Australian mispricing variable is included as an additional explanatory variable. In the US regression, contemporaneous variables for Australia and the UK are included. The results are presented in Table 4.

INSERT TABLE 4

The results in Table 4 confirm those in Table 3. First, own-country effects dominate whereby the lagged mispricing series in each market is generally significant. The coefficients on the first lag are large for each of the three markets. Second, lagged foreign mispricing again exerts a significant influence on domestic mispricing, with large positive coefficients on the most recent lag. The only exception is the impact of lagged US mispricing on the UK series. There is some evidence of reversals with the trend of a positive relation to the most recent mispricing and a negative relation to mispricing from prior periods.

In a VAR, reliance on individual coefficients can be misleading given the large number of parameters that are estimated. Hence, an F-test is conducted for the restriction that the mispricing coefficients for each market in each regression are jointly equal to zero. The F-values in Table 4 indicate that the null hypothesis that the coefficients are jointly equal to zero can be rejected for each market in each regression. That is, the mispricing coefficients in each market are jointly significant. This result confirms the influence of cross-market correlations in the mispricing series on each domestic market's mispricing series.

The key result to date is that the analysis consistently indicates that mispricing from foreign markets is related to current mispricing in each market. This evidence is consistent with potential arbitrage profits. We have been careful to use only known information so there is no look-ahead bias. One reason as to why the potential arbitrage profits are not realised is there may be barriers to investment across borders. However, given the developed nature of these markets, it is difficult to believe that such barriers exist for sophisticated investors. An alternative explanation is that while statistical significance is achieved, the potential profits are not economically significant either because transactions costs are sufficiently large to prevent exploitation of the arbitrage window or the frequency of occurrence is rare. To investigate this issue further, a trading strategy is developed below.

In order to exploit the cross-market correlation, a trader should execute a trade when the information from the foreign markets carries predictive ability. In Table 4, the largest coefficients on the foreign mispricing series are observed on the most recent information and in all cases these coefficients were positive. This observation translates into a trader taking the following position. Considering each market in turn, if both the foreign markets exhibit positive (negative) mispricing in the most recent period, then this information drives expectations of positive (negative) mispricing in the domestic market.

Depending on the expected value of the mispricing series from the trading rule, the trader would take the appropriate arbitrage position and hold it until either the mispricing series reverted to zero and or expiry. Under either approach, the gains from the strategy are the dollar value of the mispricing.

In order to investigate the potential returns that such a strategy would deliver, we first count the number of times that the trading strategy would be executed.[10] However, note that the means of the mispricing series are non-zero (as per Table 1) and hence the distributions of the series will not be symmetrical around zero. With this prior knowledge, we can estimate the number of times that the

[10] The analysis is repeated excluding those days where a holiday occurred in one of the foreign markets and the results are remarkably similar to those in Tables 5 and 6.

trading strategy would be implemented if the cross-market correlations in the mispricing series are zero. That is, if we assume that the three mispricing series are independent, then the incidence observing two immediately prior positive (negative) observations in the two foreign markets followed by a positive (negative) observation in the market of interest can be expressed as a proportion of the total number of observations. This number is reported in Table 5 in the column labelled as 'naïve' and represents a benchmark.

However, in the presence of cross-market correlations in the mispricing series, the proportion of observations that result in execution of the trading strategy (labelled as 'actual' in Table 5) will differ from the naïve proportion. This difference will be attributable to the extent of cross-market correlations in the series and can be tested using a z-test. Table 5 reports on such a test. Moreover, implementation of the trading strategy in reality would incur transactions costs. To account for these costs, several filters are applied such that the trading strategy is executed only when the mispricing series from the conditioned foreign markets exceed the filter.[11] These filters range from 0.1% to 1.0%. Given the positive correlation documented between the three mispricing series using the most recent information, then increases in the (absolute) magnitude of mispricing in the foreign markets should translate to a proportionate increase in the (absolute) magnitude of mispricing in the domestic market.

INSERT TABLE 5

The results in Table 5 are revealing. First, for every market, the trading strategy is significant when there is no filter. Prima facie, this indicates a large number of potential arbitrage opportunities. Second, as the filter increases in size, the difference between the actual and naïve proportions diminishes, and in most cases reverses such that the proportion of actual trades is less than that expected under the assumption of independence between the mispricing series. These cases are

[11] Recall that the mispricing series is scaled by the spot asset and transactions costs will be a function of the value of the spot market. To this extent, a transactions cost filter can be applied to the scaled mispricing series.

highlighted by a negative value on the z-statistics in the table.[12] Hence, there are few, if any, arbitrage opportunities once a filter is imposed. The implication of these findings is that the while there appears to be many potential arbitrage opportunities, they are probably insufficiently large to cover transactions costs. At the extreme end, there appears to be a few potentially large arbitrage profit opportunities (given the filter) but these are very infrequent.

As a final investigation, the magnitude of the potential dollar profits from the trading strategy is examined. Table 6 reports the average dollar profut in index points from the trading strategy. To illustrate, if we expect the mispricing series on a particular market at day t to be positive (negative) and it indeed is positive (negative) on day t then the value of the mispricing is a gain. Conversely, if we expect the mispricing series in a particular market at day t to be positive (negative) and it is negative (positive) on day t then the value of the mispricing is a loss. The figures in Table 6 are the average of the gains and losses per trade (and only from days when a trade occurs). The dollar value of the profit is then the number of contracts by the dollar value per index point (which differs across contracts) multiplied by the average mispricing figure in Table 6.

INSERT TABLE 6

First, note that in every market and in every case, the gain is positive implying that the trading strategy appears to work. Focusing on the no filter case, we observe a relatively large number of instances where the trading rule is invoked (as per Table 5) of somewhere between 1,500 and 2,000 or about half of the trading days in the sample. Ignoring transactions costs, the average profit in index points per day ranges from almost 5 in Australia to 0.29 in the USA. To put this in perspective, this translates to a dollar value per contract of $62 in Australia and $72 in the USA.[13] We believe these gains are modest and probably not sufficiently large enough to exceed transactions and execution costs. Moreover, on a year-by-year analysis, there is considerable

[12] The one exception is the US series using a 1% filter, however there are 90 instances of the trading strategy being executed out of a 13-year set of potential trading days.

[13] The dollar profits are expressed in US dollars (using an exchange rate of AUD$1 = USD$0.50) and use the dollar value per index point in the 2001 contract specifications. These values have changed over time due to contract redenomination and hence the dollar figures are indicative only.

variability in the gains. Hence, an investor would have to have exercised a deal of patience over a long horizon to have realised these potential profits.

Of note, the average gains are negatively associated with the dollar value per index point. As the filter increases, so the number of days on which the trading rule is invoked decreases. However, there is a simultaneous rise in the average gain. There is a monotonic rise in the dollar gain per contract as the filter is increased. Using a 1% filter, there appear to be potentially large gains to be realised. Again, to put these in perspective, the gains translate to a dollar value per contract of $880 in Australia and $240 in the USA. But recall that the reported numbers are averages and are not realised on every occasion Moreover, there are very few instances when the trading rule is invoked. In the case of Australia, the trading rule is exercised using the 1% filter just 12 times in 13 years. The occasions when the trading rules are executed tend to be clustered, especially for the higher filters. For example, again using the case of Australia with a 1% filter, out of the 12 times the trading rule is executed, 7 of these dates are clustered in October 1987 and 4 of these dates are clustered in June 1990. Again, our summary is that while positive returns appear to be present, a very long investment horizon would have been required to realise them.

7. Summary

There is considerable evidence that information from one market spills over into other markets, especially in relation to developed markets. However, this evidence is generally limited to spot markets. This paper extends the literature by investigating spillovers in derivative instruments across international markets. Moreover, the paper focuses on whether there is information in a mispricing series from a domestic index futures contract that is relevant to a mispricing series in another market. In theory, even if the underlying markets are correlated, there is no a priori reason as to why mispricing series should also be related. To investigate this question, three well-known index futures contracts are examined in the Australian, UK and USA markets.

The study first constructs a mispricing series for each market using daily data. Then, after allowing for time-zone differences, the study examines correlation across the three mispricing series. The findings first reveal that each mispricing series has strong autocorrelation properties, consistent with prior literature. Second, using a VAR framework, evidence is found of bi-directional spillovers between the three mispricing series. These results suggest that a mispricing series in one market is predictable. In order to examine whether the statistical significant results translate into economically significant profits, a trading rule is tested that uses conditional information from markets over the previous day. We find that the trading rule generates a large number of small profitable trades, however these profits quickly disappear when a filter is applied that proxies for transactions costs. In summary, the results show that some profits are possible but that a long horizon, probably beyond the scope of most traders, is required to exploit the spillover information.

TABLE 1

Descriptive Statistics of Mispricing Series Across Markets

The data are drawn from index futures on the Australian SPI contract, UK FTSE100 contract and the US S&P500 contract. The sample covers January 1986 to December 1998. The mispricing series is calculated from the cost-of-carry model as in (2) using daily closing values. The number of observations is 2,996.

	Mean	**Median**	**Std Dev**	**Min**	**Max**
AUSTRALIA					
Mispricing	-3.660	-0.390	20.340	-249.614	76.855
Scaled Mispricing by S_t	-0.00314	-0.00020	0.01315	-0.16112	0.03728
UK					
Mispricing	-0.405	0.256	13.881	-118.525	63.200
Scaled Mispricing by S_t	-0.00031	0.00008	0.00548	-0.05775	0.02199
USA					
Mispricing	0.964	0.378	2.585	-24.777	14.769
Scaled Mispricing by S_t	0.00165	0.00089	0.00515	-0.11013	0.02810

TABLE 2

Cointegration Tests Across Markets

The data are drawn from index futures on the Australian SPI contract, UK FTSE100 contract and the US S&P500 contract. The sample covers January 1986 to December 1998. The number of observations is 2,996. The null hypothesis of the ADF test is H_0: I(1) or unit root and is based on the following regressions:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \varepsilon_t \qquad \text{...(4)}$$

$$? \, e_t = a_1 e_{t-1} + \sum_{j=1}^{p} ?_j ? \, e_{t-j} + u_t \qquad \text{…(5)}$$

with null hypothesis that α_1=0. ADF tests are run with time-trend included with lag order determined by AIC.

	AUS_t/UK_{t-1}	UK_t/US_{t-1}	US_{t-1}/AUS_t
Futures	-3.77*	-2.78	-3.38*
Spot	-3.54*	-3.03	-3.35*
Futures/ Spot	-5.70*	-2.76	-5.68*
Mispricing	-5.81*	-3.13*	-5.68*

* Significant at 10% (critical value is –3.12)

TABLE 3

Analysis of Mispricing Series and Cross-Market Relations

The data are drawn from index futures on the Australian SPI contract, UK FTSE100 contract and the US S&P500 contract. The sample covers January 1986 to December 1998. The mispricing series is calculated from the cost-of-carry model as in (2) using daily closing values and scaled using spot values. The number of observations is 2,996. The table reports on the following regressions. Standard errors have been adjusted for heteroscedasticity and autocorrelation using the Newey-West procedure. T-statistics are presented in parentheses.

$$MP_{AU,t} = a_{AU} + \beta_1^{AU} MP_{AU,t-1} + ?_1^{AU} MP_{UK,t-1} + ?_1^{AU} MP_{US,t-1} + e_{AU,t}$$

$$MP_{UK,t} = a_{UK} + ?_1^{UK} MP_{UK,t-1} + \beta_1^{UK} MP_{AU,t} + ?_1^{UK} MP_{US,t-1} + e_{UK,t}$$

$$MP_{US,t} = a_{US} + \lambda_1^{US} MP_{US,t-1} + \beta_1^{US} MP_{AU,t} + \gamma_1^{US} MP_{UK,t} + e_{US,t}$$

	$MP_{AU,t}$	$MP_{UK,t}$	$MP_{US,t}$
Constant	-0.00107**	-0.00002	0.00065**
	(-3.42)	(-0.25)	(4.52)
$MP_{AU,t}$		0.02920**	0.01266*
		(2.80)	(1.77)
$MP_{AU,t-1}$	0.80884**		
	(31.07)		
$MP_{UK,t}$			0.07912
			(1.21)
$MP_{UK,t-1}$	0.06450	0.70176**	
	(1.21)	(34.07)	
$MP_{US,t}$			
$MP_{US,t-1}$	0.27746*	0.00404	0.64413**
	(1.84)	(0.12)	(8.99)
Adjusted R^2	0.720	0.524	0.455

* Significant at 10%

** Significant at 5%

TABLE 4

VAR Analysis of Cross-Market Relations in Mispricing

The data are drawn from index futures on the Australian SPI contract, UK FTSE100 contract and the US S&P500 contract. The sample covers January 1986 to December 1998. The mispricing series is calculated from the cost-of-carry model as in (2) using daily closing values and scaled using spot values. The number of observations is 2,996. The table reports on the following regressions. Standard errors have been adjusted for heteroscedasticity and autocorrelation using the Newey-West procedure. T-statistics are presented in parentheses. The F-test is for the joint significance of the mispricing coefficients for each market in each regression under the null hypothesis that the coefficients are jointly equal to zero. P-values for the F-test are presented in square brackets.

$$MP_{AU,t} = a_{AU} + \sum_{i=1}^{n} ß_i^{AU} MP_{AU,t-i} + \sum_{i=1}^{n} ?_i^{AU} MP_{UK,t-i} + \sum_{i=1}^{n} ?_i^{AU} MP_{US,t-i} + e_{AU,t} \quad \ldots(3a)$$

$$MP_{UK,t} = a_{UK} + \sum_{i=0}^{n-1} ß_i^{UK} MP_{AU,t-i} + \sum_{i=1}^{n} ?_i^{UK} MP_{UK,t-i} + \sum_{i=1}^{n} ?_i^{UK} MP_{US,t-i} + e_{UK,t} \quad \ldots(3b)$$

$$MP_{US,t} = a_{US} + \sum_{i=0}^{n-1} ß_i^{US} MP_{AU,t-i} + \sum_{i=0}^{n-1} ?_i^{US} MP_{UK,t-i} + \sum_{i=1}^{n} ?_i^{US} MP_{US,t-i} + e_{US,t} \quad \ldots(3c)$$

	$MP_{AUS,t}$	$MP_{UK,t}$	$MP_{US,t}$
Constant	-0.001**	-0.000	0.000**
	(-4.02)	(-0.81)	(4.73)
$MP_{AUS,t}$		0.074**	0.042**
		(7.59)	(4.06)
$MP_{AUS,t-1}$	0.607**	-0.038**	-0.089**
	(32.46)	(-3.28)	(-7.37)
$MP_{AUS,t-2}$	0.110**	-0.007	0.039**
	(5.04)	(-0.58)	(3.17)
$MP_{AUS,t-3}$	0.050**	0.007	0.012
	(2.26)	(0.59)	(0.97)
$MP_{AUS,t-4}$	0.148**	-0.009	-0.008
	(6.72)	(-0.74)	(-0.64)
$MP_{AUS,t-5}$	-0.018	-0.021**	0.007
	(-1.01)	(-2.17)	(0.66)
F-test	1411.50 [0.000]	10.78 [0.000]	9.29 [0.000]
$MP_{UK,t}$			0.156**
			(8.22)

$MP_{UK,t-1}$	0.221**	0.415**	0.014
	(6.32)	(22.13)	(0.68)
$MP_{UK,t-2}$	-0.204**	0.178**	-0.097**
	(-5.42)	(8.85)	(-4.61)
$MP_{UK,t-3}$	-0.041	0.125**	-0.056**
	(-1.08)	(6.19)	(-2.66)
$MP_{UK,t-4}$	-0.023	0.041**	-0.022
	(-0.60)	(2.03)	(-1.04)
$MP_{UK,t-5}$	0.060*	0.096**	0.009
	(1.74)	(5.16)	(0.47)
F-test	10.88 [0.000]	751.53 [0.000]	15.81 [0.000]
$MP_{US,t}$			
$MP_{US,t-1}$	0.464**	0.025	0.535**
	(13.89)	(1.34)	(28.09)
$MP_{US,t-2}$	-0.171**	-0.048**	0.014
	(-4.41)	(-2.31)	(0.65)
$MP_{US,t-3}$	0.118**	0.111**	0.155**
	(3.04)	(5.40)	(7.23)
$MP_{US,t-4}$	-0.064*	-0.013	0.029
	(-1.65)	(-0.60)	(1.36)
$MP_{US,t-5}$	-0.209**	-0.061**	0.054**
	(-6.17)	(-3.33)	(2.88)
F-test	49.22 [0.000]	8.39 [0.000]	483.48 [0.000]
Adjusted R^2	0.751	0.593	0.505

* Significant at 10%

** Significant at 5%

TABLE 5

Comparison of Trading Strategies Using Conditioned Mispricing Information

This table reports on a trading strategy that assumes taking an arbitrage position in each market if the most recent mispricing from the two foreign markets are both positive (negative). Each market is analysed separately using conditional information from the two foreign markets. The naïve strategy assumes independence between the mispricing series across markets but uses the sample means and standard deviations to estimate the number and proportion of trades, whereas the actual strategy uses the observed correlations between the mispricing series. The data are drawn from index futures on the Australian SPI contract, UK FTSE100 contract and the US S&P500 contract. The sample covers January 1986 to December 1998. The mispricing series is calculated from the cost-of-carry model as in (2) using daily closing values and scaled using spot values. The z-test is a test of the null hypothesis that there is no difference between the actual and naïve proportions, calculated as

$$Z = \frac{p' - p}{\sqrt{\frac{p\,q}{n}}}$$

Panel A - Australian Mispricing Conditioned on US and UK			
Filter	Description	Naïve	Actual
0%	# Trades	1427	1693
	Proportion	0.4763	0.5651
	Z-test	9.73**	
0.1%	# Trades	1077	965
	Proportion	0.3596	0.3221
	Z-test	-4.28**	
0.25%	# Trades	613	348
	Proportion	0.2045	0.1162
	Z-test	-11.98**	
0.5%	# Trades	186	86
	Proportion	0.0621	0.0287
	Z-test	-7.58**	
1.0%	# Trades	48	12
	Proportion	0.0163	0.0004
	Z-test	-6.87**	

Panel B - UK Mispricing Conditioned on Australia and UK			
Filter	Description	Naïve	Actual
0%	# Trades	1481	1779

	Proportion	0.4943	0.5938
	Z-test	10.89**	
0.1%	# Trades	1133	1129
	Proportion	0.3785	0.3768
	Z-test	-0.19	
0.25%	# Trades	762	575
	Proportion	0.2543	0.1919
	Z-test	-7.84**	
0.5%	# Trades	337	210
	Proportion	0.1127	0.070
	Z-test	-7.39**	
1.0%	# Trades	6	20
	Proportion	0.0020	0.0007
	Z-test	-1.59	

Panel C - USA Mispricing Conditioned on UK and Australia

Filter	Description	Naïve	Actual
0%	# Trades	1511	1814
	Proportion	0.5043	0.6055
	Z-test	11.08**	
0.1%	# Trades	1218	1351
	Proportion	0.4067	0.4509
	Z-test	4.93**	
0.25%	# Trades	841	843
	Proportion	0.2806	0.2814
	Z-test	0.10	
0.5%	# Trades	394	370
	Proportion	0.1316	0.1235
	Z-test	-1.31	
1.0%	# Trades	36	90
	Proportion	0.0119	0.0300
	Z-test	9.14**	

** Significant at 5%

TABLE 6

Returns from a Trading Strategies Using Conditioned Mispricing Information

This table reports on a trading strategy that assumes taking an arbitrage position in each market if the most recent mispricing from the two foreign markets are both positive (negative). Each market is analysed separately using conditional information from the two foreign markets. The table reports on the average gain per trade in index points. The number of times the trading strategy is executed is presented in parentheses. The data are drawn from index futures on the Australian SPI contract, UK FTSE100 contract and the US S&P500 contract. The sample covers January 1986 to December 1998. The mispricing series is calculated from the cost-of-carry model as in (2) using daily closing values and scaled using spot values.

Filter	**Australia**	**UK**	**USA**
0%	4.96 (1693)	2.87 (1779)	0.29 (1814)
0.1%	6.39 (965)	3.68 (1129)	0.37 (1351)
0.25%	10.04 (388)	4.95 (566)	0.35 (843)
0.5%	17.30 (86)	5.84 (210)	0.42 (370)
1.0%	70.36 (12)	22.79 (20)	0.96 (90)

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