Jurnal Pengurusan 23(2004) 33-52

Co-movement among Sectoral Stock Market Indices and Cointegration among Dually Listed Companies

Ramin Cooper Maysami
Loo Sze Wee
Koh Tat Koon

ABSTRACT

This paper analyzes the co-movement between sectoral stock indices of the US and Singapore, through examining whether the S&P 500 Electronics (Semiconductor) Price Index leads Stock Exchange of Singapore's Electronics Price Index. The article also examines price co-movement of stocks listed dually in Singapore and the US. Using Johansen's (1988) Vector Error Correction Model (VECM), the paper concludes the existence of long-run cointegrating relationship both between the US and Singapore electronic sectors in general, and more specifically among the three dually listed stocks under consideration. However, the results point to a short-term disequilibria in the prices of dually listed stocks, leading to the conclusion that short-run arbitrage opportunities may exist.

ABSTRAK

Kertas ini mengkaji pergerakan bersama (co-movement) antara indeks saham sektoral US dan Singapura dengan meneliti sama ada Indeks Harga Elektronik (Semikonduktor) S&P 500 mendahului Indeks Bursa Saham Elektronik Singapura. Kertas ini juga meneliti pergerakan bersama antara harga saham yang tersenarai serentak di Singapura dan US. Menggunakan Model Vektor Pembetulan Ralat (VECM) Johansen, kertas ini mendapati bahawa hubungan kointegrasi jangka panjang antara sektor elektronik di US dan Singapura wujud, khususnya di kalangan tiga saham yang tersenarai serentak yang terlibat dalam kajian ini. Bagaimanapun, keputusan kajian menunjukkan ketidakseimbangan jangka pendek harga-harga saham yang tersenarai serentak menyebabkan adanya peluang arbitraj jangka pendek.

INTRODUCTION

The co-movements of world stock market indices have long been debated and the consensus seems to be that larger markets, USA and Japan for example, lead the smaller stock markets such as those in Singapore, Hong Kong and Malaysia. An extension of such studies is whether specific groupings of stocks listed on a particular exchange show a cointegrating relationship with similar collection of stocks listed on another exchange. This, of course, is crucial information in determining the benefits of diversifying across an individual sector, say, electronic-related securities listed on two different exchanges.

It is, thus, the first goal of the current study to extend the existing literature through a sectoral analysis of the co-movement between single rather than aggregate stock indices of the U.S. and Singapore. Specifically, the objective is to examine whether electronics sectors in the U.S. stock markets lead similar sectors in the smaller Singapore stock exchange. The importance of the electronics sector to Singapore as an engine of growth was stated by Singapore's Prime Minister Goh Chok Tong at the Official Opening of Jurong Island on 14 October 2000. He said:

> Even as we go into new areas of growth such as IT and the Life Sciences, manufacturing, with its significant contribution to GDP, employment and foreign exchange earnings, will remain an integral part of our economy. Our sharp recovery from the recent regional economic slowdown underlines the importance of manufacturing to Singapore. After only two quarters of GDP contraction in 1998, our economy bounced back. This V-shape recovery was driven mainly by manufacturing *riding on the upturn in the global electronics cycle.* And as reported by the Straits Times, manufacturing, which accounts for nearly a quarter of the economy, is the twin-engine of growth for Singapore, along with financial and business services. Electronics production, which accounts for almost half of the manufacturing sector, grew 25.5% year-on-year last November.

This is the hint which resulted in selecting the electronic sector for the experiment in this study.

The second goal of the article is to test for price co-movement of dually-listed stocks. The suggestion here is that information lags between stock markets produce short-term disparities in the prices at which securities trade at different locations at any given time (Chowdhry & Nanda 1991). If there were a cointegrating relationship between prices of a stock listed in two different stock markets, movements in one market's price would be mirrored in the other market. Any disequilibrium in the movement of the stock prices quoted in the two exchanges presents an opportunity for arbitrage profits. The consequence of exploring the relationship between dually listed stocks raises the possibility of market and inter-market inefficiencies and presents opportunities to profit from such established relations.

Specifically, three electronics-related Singapore-based companies, which are listed on another stock exchange in addition to the Stock Exchange of Singapore, are examined. These include Creative Technology Ltd (CT), Chartered Semiconductor Manufacturing Ltd (CSM), and ST Assembly Test Services Ltd (STATS). The goal is to examine whether the stock prices quoted in the two exchanges are cointegrated.

Cointegration analysis is an appropriate method of choice to examine such relationships: "Cointegration methodology, in particular the Johansen's (1988) cointegration tests, assess the extent to which equity prices have tended to move similarly across countries and regions in the long run. The assessment as to whether national equity prices are cointegrated is equivalent to testing whether there are linear combinations of these indices, which will converge to stationary long run equilibrium relationship," (Cashin, Kumar & McDermott 1995). Another advantage of cointegration analysis is that through building an error-correction model (ECM), the dynamic co-movement among variables and the adjustment process toward long-term equilibrium can be examined.

The choice to analyze the SES Electronics sector is made considering Singapore's vision to be a world-class electronics hub, as well as the consistent contributions of the sector to the Singapore's economy. Yeo (2000) has highlighted the development and growth of the electronics sector in Singapore over the last couple of decades. Singapore has been successful in attracting major multinational companies to establish their manufacturing and regional headquarters here, and has encouraged local companies to venture into the supporting industries sector. Many of these local companies have now become significant international players.

The contribution of the electronic sector to Singapore's recovery during the Asian financial crisis further demonstrated the sector's importance to the nation's economy. As a matter of fact, Singapore's positive first quarter economic results for 1999, after two successive negative quarters, were due mainly to a recovering electronics sector (Mah 1999). The Monetary Authority of Singapore (MAS), in its annual report for 1999/2000, gave an even clearer picture of the electronic sector's contributions to recovery from the crisis:

> The Singapore economy recovered strongly in 1999, following growth of just 0.4% in 1998. GDP growth increased steadily from 0.8% in the first quarter of 1999 to 7.1% in the last quarter, with growth averaging 5.4% for 1999 as a whole. The recovery in the economy was led by the manufacturing sector, which rebounded strongly on the back of an upturn in the global electronics cycle. In particular, electronics output rose by 24%, led by the semiconductor, telecommunications equipment and computer and peripherals industries.

The conclusions drawn from the study will be beneficial in two ways: (1) whether diversification across the electronic sectors indices of the US and Singapore stock markets would lower the overall portfolio risk, and (2) whether there exists opportunities for profit from the inefficiencies of stock market mechanisms in the transfer of information between stock markets.

The benefits of diversification as suggested by Grubel (1968), Lessard (1973), Levy and Sarnat (1970) and Solnik (1974) form the backbone of the modern portfolio theory. The existence of long-run cointegrating relationship between two stock market indices, however, renders the benefits of *international* diversification negligible. The presence of a cointegrating relationship between stock prices of listed company in two markets means price movements in one market would be mirrored in the other market. Any disequilibrium in the movement of the stock prices quoted in the two exchanges, on the other hand, presents an opportunity for profits.

The remainder of this study is organized as follows: the next section is the review of relevant literature, followed by a detailed recount of our methodology and data selection. The results of the empirical study are then reported and discussed. The paper ends with a summary and concluding section.

LITERATURE REVIEW

Early studies by Ripley (1973) using factor analysis, Panton, Lessig and Joy (1976) employing cluster analysis, Dwyer and Hafer (1988) applying unit root tests, and Eun and Shim (1989) with the aid of vector autoregression concluded that the world major stock markets were cointegrated.

Jeon and Chiang's (1991) study of stock prices in the New York, London, Tokyo, and Frankfurt exchanges based on both univariate and multivariate approaches concluded, "the system of stock prices in the four largest stock markets in the world shared one long-run equilibrium relationship."

Kasa (1992) corroborated similarly, but again for large, established stock markets–the US, Japan, England, Germany, and Canada: "there is a single common stochastic trend that lies behind the long-run co-movement of these equity markets." Moreover, he showed that this trend was most important in the Japanese market. This suggests to investors with long holding periods that the gains from international diversification have probably been overstated.

Arshanapalli and Doukas (1993) somewhat disagreed. They concluded that with the exception of the Nikkei index, prior to the stock market crash of October 1997, France, Germany and UK stock markets were not related to the US stock market. For the post-crash period, however, they agreed that the three European markets were indeed strongly cointegrated with the American market. Moreover, they found that while the US had a strong impact on the French, German and UK markets, the opposite was not true. They did not find any evidence of interdependence between the US and Japanese markets. Additionally, their study concluded, "the Japanese stock market innovations are unrelated to the performance of the major European stock markets." Harvey (1991) also suggested that the Japanese stock market was not fully integrated with other world stock markets.

There is increasing consensus that smaller markets follow the direction of the larger markets with increased globalization of the financial markets. Philippatos, Christoti and Christoti (1983) applied both parametric and non-parametric tests along with the principal component analysis tests to the data for the period of 1959 to 1978 to conclude the existence of stable inter-temporal relationship between stock market indices of the industrialized world and Asian stock markets for the intermediate term investment horizon. Aggarwal and Rivoli (1989) examined the relationship between the U.S. stock market and those of Hong Kong, Singapore, Manila, and Bangkok. They concluded that the Asian markets followed the U.S. market movements on a day-to-day basis.

Cheung and Mak (1992) studied the linkage among the stock indices of Australia, Hong Kong, Korea, Malaysia, Philippines, Singapore, Taiwan and Thailand with the American stock market. Using the Box Jenkins methodology and univariate autoregression integrated moving average models, and employing weekly equities returns data for the period 1977 to 1988, they concluded that the U.S. market led most of Asia-Pacific markets in the 1978 to 1988. Taiwan, Korea and Thailand were not included in the list of affected stock markets, most likely due to the implementation of various types of capital controls.

Tai (1985) examined stock price behaviors in Tokyo, Australia, New Zealand, Hong Kong, Singapore, Seoul, Taipei, Manila and Bangkok, using daily prices of the indices of these countries over the period of January 1980 to March 1984. The relationship between exchanges varied significantly. Strong relationships existed between prices in Tokyo-New Zealand and Australia-New Zealand. The correlation coefficients were 0.84 and 0.74 respectively. For Bangkok-Australia and Taipei–Hong Kong, on the other hand, the correlation coefficients were 0.30 only.

Hui and Kwan (1988) conducted a similar study. They used weekly data and examined Hong Kong, Singapore, South Korea and Taiwan during the period 1975-83. The results were that the relationships between these markets were weak, suggesting possible improvement in the ratio of returns to risk by investing in these markets.

Another way to look at the possible existence of co-relationship between markets is to examine their correlation matrices with the requisite that such correlation matrices should remain stable over time. Cheung and Ho (1991) used the principle component method on a common factor for the Asian Emerging Markets vis-a-vis the U.S. and U.K. region. The conclusion was the existence of a stable intermediate investment horizon when longer time periods were used. However, when shorter time periods were used, the results were not consistent.

Chan, Gup and Pan (1992) disagreed. They examined the relationship among the stock markets in Hong Kong, South Korea, Singapore, Taiwan, Japan and the United States, individually and collectively, to test for international market efficiency. Their findings suggested that the stock prices in major Asian markets and the US were weak-form efficient individually or collectively in the long-run. Additionally, they implied that international diversification among the markets was indeed effective, as had been suggested much earlier by Grubel (1968) and Levy and Sarnat (1970) who had found "no evidence of cointegration." In short, Chan et al. (1992) postulated "neither the stock price of a single country nor that of a group of countries can be used to predict the future stock price of another country—stock prices in the US, Japan, Hong Kong, South Korea, Singapore and Taiwan are independent of each other."

CO-MOVEMENTS AMONG SECTORAL STOCK MARKET INDICES

The academic literature has generally concentrated on analyzing the linkage of different sectors within one country. For example, Sun and Brannman (1994) found a single long-run relationship among the SES All-S Equities Industrial & Commercial Index, Finance Index, Hotel Index, and Property Index from 1975 to 1992. Ta and Teo (1985) observed high correlation among six Singapore sector indices in the period 1975 to 1984 and the overall SES market return. Using daily data in examining the relationships, they concluded that sector returns were highly correlated to each other, although such correlations did not remain stable over time. Cashin et al. (1995) argued, "...it is well established that the greater the international integration of equity markets, the higher the degree of correlation among national equity prices."

DUALLY LISTED STOCKS

The literature focusing on dually listed stocks are varied in nature. Miller (1999), for example, studied market's reaction to announcement of dual listing, Karolyi (1998) focused on the motivations of dual listings, while Switzer (1986), Viswanathan (1995), as well as Foerster and Karolyi (1998) focused on market price behavior around the listing announcements.

There are a small number of studies investigating the market efficiency of dual listed stocks. Lau and Diltz (1994) used seven dual listed stocks to examine the transfer of pricing information between the New York Stock Exchange and the Tokyo Stock Exchange. Hauser, Tanchuma and Yarri (1998) investigated the transmission of pricing information for five stocks based in Israel that were listed on both Tel Aviv Stock Exchange and the NASDAQ. With the goal of identifying cross border efficiencies, they concluded that the foreign market reacts to domestic price changes more quickly than the domestic market reacts to foreign price changes. Chowdhry and Nanda's (1991) conclusion was that there were indeed information lags between stock markets leading to the possibilities of arbitrage profits through trading the same stock in two markets.

METHODOLOGY AND DATA SELECTION

A series containing *d* unit roots is said to be integrated of order d, denoted I(*d*), if it has to be differenced *d* times before it becomes stationary. Consider two time series, y_t and x_t, both I(*d*). The residuals obtained from regressing y_t on x_t would also be I(*d*). However if there exists a vector β such that the disturbance term from the regression ($\mu_t = y_t - \beta x_t$) is of lower integration order, I(*d-b*), where *b*>0, then y_t and x_t are said to be cointegrated of order (*d,b*).

The economic interpretation of cointegration is that if two or more series are linked to form an equilibrium relationship over the long-run, they would move closely together over time and the difference between them would be stable. This is the case even if the series themselves contain stochastic trends. Harris (1995) states "the concept of cointegration mimics the situation of a long-run equilibrium to which an economic system converges over time, and μ_t defined above can be interpreted as the disequilibrium error."

It is also of interest to consider the short-run evolution of the variables under consideration, especially since disequilibrium is usually the norm rather than the exception. The main reason that disequilibrium occurs is because economic agents often are not able to adjust to new information instantaneously, due to the substantial pecuniary and non-pecuniary costs of adjustments. As such, the current value of the dependent variable in the short-run (dynamic) model is being determined by both the current and past values of the explanatory variable, as well as the lag values of itself.

Johansen's (1988) vector error-correction model (VECM) incorporates both short- and long-run effects, and provides information on the speed of adjustment in response to disequilibrium. Furthermore, since all terms in the model would be stationary, standard regression techniques are valid.

THE VECM MODEL

Defining a vector of z_t of n potentially endogenous variables, it is possible to specify the model z_t as an unrestricted vector autoregression (VAR) involving up to k-lags of z_t.

$$z_t = A_1 z_{t-1} + \dots + A_k z_{t-k} + u_t, \tag{1}$$

where $\mathbf{z}_t$ is n x 1 and each of the A_i is an n x n matrix of parameters.

Equation (1) can be formulated into a vector error-correction (VECM) form:

$$\Delta z_t = \Gamma_1 \Delta z_{t-1} + \dots \dots + \Gamma_{k-1} \Delta z_{t-k-1} + \Pi z_{t-K} + u_t, \tag{2}$$

where $\Gamma_i = -(I - A_1 - \ldots - A_i)$, ($i = 1, \ldots, k-1$), and $\Pi = -(I - A_1 - \ldots - A_k)$. The estimates of Γ and Π provides information on short- and long-run adjustments to changes in z_t respectively.

If Π has reduced rank, that is, if the rank of matrix Π is equal to $r \leq (n-1)$, there exists a representation such that:

$$\Pi = \alpha\beta', \tag{3}$$

where α is the adjustment matrix representing the speed of adjustment to disequilibrium, and β is the cointegration matrix that has the property that $\beta' z_t \sim I(0)$, assuming $z_t \sim I(1)$. In this instance, there are r cointegrating vectors in β (i.e., r columns of β form r linearly independent combination of $\mathbf{z}_t$, each of which is stationary), together with n-r non-stationary vectors (i.e., $n-r$ columns of β form $I(1)$ common trends). Hence, testing for cointegration amounts to considering finding the number of r linearly independent columns in Π, which is the rank of Π.

THE PROCEDURE

Prior to running the cointegration tests, unit root tests on the time-series data of the variables involved must be conducted. This is essential in order to avoid the problem of spurious regression. If a variable contains a unit root, then it is non-stationary. Unless it combines with other non-stationary series to form a stationary cointegration relationship, the regressions involving the series can falsely imply the existence of a meaningful economic relationship.

The two most commonly used procedures, the Augmented Dicky-Fuller (ADF) test and the Phillips-Peron (PP) test, are employed in this study (Harris 1995; Maddala and Kim 1998). The ADF test involves adding an unknown number of lagged first differences of the dependent variable to capture autocorrelated omitted variables that would otherwise, by default, enter the error term, u_t. It is important to select the appropriate lag-length: too few lags may result in over-rejecting of the null when it is true, while too many lags may reduce the power of the test. Unlike the ADF test, which includes additional higher-order lagged terms, the PP test adopts a non-parametric correction to the t-test statistic to account for the autocorrelation that will be present.

Assuming the variables in the system have the same order of integration, we can proceed with the Johansen's approach. We use the following four-step procedure as outlined in Charemza and Deadman (1997):

1. Regress Δz_t on $\Delta z_{t-1}, \Delta z_{t-2}, \ldots, \Delta z_{t-k+1}$, then regress Δz_{t-k} on $\Delta z_{t-1}, \Delta z_{t-2}, \ldots, \Delta z_{t-k+1}$. Construct the n x 1 vector R_{0t} and R_{kt} from the residuals of the first and second regression respectively.
2. Compute the four n x n matrices S_{00}, S_{0k}, S_{k0}, S_{kk} from the second moments and crossproducts of R_{0t} and R_{kt} as:

$$S_{ij} = T^{-1} \sum_{t=1} R_{it} R'_{jt} , \tag{4}$$

where T is the sample size, and $i, j = 0, k$.

3. Solve the equation:

$$|\lambda S_{kk} - S_{k0} S_{00}^{-1} S_{0k}| = 0, \tag{5}$$

to find the eigenvalues of the polynomial equation in λ obtained from the determinant above. The solution yields the eigenvalues $\lambda_1 > \lambda_2 > \ldots > \lambda_n$ (ordered from the largest to the smallest) and associated eigenvectors v_i which may be arranged into the matrix $V = (v_1 \; v_2 \; \ldots \; v_n)$. The eigenvectors are normalized such that $V' S_{kk} V = I$.
If the cointegration matrix β is of (reduced) rank $r < n$, then the first r eigenvectors $v_1, v_2, \ldots, v_r$ are the cointegration vectors.

4. For each κ_i, compute the *LR* statistic:

$$LR = -T \sum_{i=r+1} \ln(1 - \lambda_i), \tag{6}$$

which, under the null hypothesis that there are at most r cointegrating vectors, has an asymptotic distribution whose quantiles are tabulated by Johansen (1988) and Osterwald-Lenum (1992). This LR statistic is commonly known as the trace statistic (λ_{trace}).

We begin by testing the null hypothesis that there are no cointegrating vectors (i.e., $r = 0$) in the VAR model. If this cannot be rejected, the procedure stops since no confirmation of the existence of cointegrating vectors has been found. If it is rejected, we will examine sequentially the hypotheses that $r \leq 1$, $r \leq 2$, and so on. If the null hypothesis for $r \leq r_0$ cannot be rejected, but that for $r \leq r_0 - 1$ has been rejected, the conclusion is that the number of cointegrating vectors, and therefore the rank of β, is r_0.

Another test of the significance of the largest β_r is the maximal eigenvalue statistic (λ_{max}):

$$\lambda_{max} = -T \log(1 - \lambda_{r+1}) \quad r = 0, 1, 2, \ldots, n-2, n-1. \tag{7}$$

This tests the hypothesis of existence of r cointegration vectors against the alternative that r+1 exist. Cheung and Lai (1993) showed that the trace test is more robust to both the skewness and excess kurtosis in the residuals than the maximal eigenvalue test. Hence, this paper will adopt the trace test in testing of cointegration.

Johansen (1988) showed that the first r estimated eigenvectors $v_1, v_2, \ldots, v_r$ are the maximum likelihood estimates of the columns of β, the cointegrating vectors. After normalization, the elements of the matrix β may be interpreted as long run parameters. Once the matrix β is known, the elements of α can be obtained as the first r columns in the matrix $S_{0k}V$. As mentioned above, the elements in α measure the speed of adjustment of the variables with respect to a disturbance in the equilibrium relation.

DATA SELECTION

To test sectoral cointegration, data is extracted from SES Equities Electronic Price Index (SESELE) and S&P 500 Electronics (Semiconductors) Price Index (SP500ELE). Eun and Resnick (1984) pointed out that more robust estimates could be achieved by using monthly rather than daily data. This study takes the suggestions and uses monthly time series data from November 1996 to November 2000.

For the company level analysis, 3 companies that are currently dual listed in Singapore and the U.S. will be examined–Creative Technology Ltd (CT), Chartered Semiconductor Manufacturing Ltd (CSM), and ST Assembly Test Services Ltd (STATS). CT was incorporated as a private limited company on 18 July 1983 to design, manufacture and distribute PC products. In 1989, it launched the Sound Blaster, making it the world's best selling sound platform for IBM-compatible PCs and the de facto industry standard. It was listed on Nasdaq in August 1992. CT is now a leading provider of multimedia hardware and software products for use with PCs.

CSM is one of the world's top three silicon foundries providing wafer fabrication services and process technologies that enable blue-chip companies to create and deliver innovative system-level solutions. Currently, it has more than 3,400 employees based at 11 locations around the world.

STATS, part of the Singapore Technologies Group, provides test and assembly services to semiconductor companies which do not have their own manufacturing facilities, vertically integrated semiconductor device manufacturers and independent semiconductor wafer foundries. The company has an assembly design centre in Milpitas, California and a test development centre in San Jose, California.

As CSM and STATS were listed in November 1999 and January 2000, respectively, they do provide sufficient monthly observations. For this reason, daily time-series data are used for the company level analysis. The first observation for CT, CSM, and STATS is on 15 June 1994, 1 November 1999, and 31 January 2000, respectively. The last observation for the three companies is on 31 November 2000.

Table 1 presents the variables selected for our studies, and Table 2 provides the summary statistics for the variables in level and first differences.

TABLE 1. Definitions of variables and time-series transformations

Variables	Definitions of Variables
$LSESELE_t$	Natural logarithm of the monthly SES Electronics Index
$LSP500ELE_t$	Natural logarithm of the monthly S&P 500 Electronics (Semiconductor) Index
$LCTSIN_t$	Natural logarithm of the daily Creative Technology Ltd (Singapore) Price
$LCTUS_t$	Natural logarithm of the daily Creative Technology Ltd (U.S.) Price
$LCSMSIN_t$	Natural logarithm of the daily Chartered Semiconductor Mfg Ltd (Singapore) Price
$LCSMUS_t$	Natural logarithm of the daily Chartered Semiconductor Mfg Ltd (U.S.) Price
$LSTATSSIN_t$	Natural logarithm of the daily ST Assembly Testing Service Ltd (Singapore) Price
$LSTATSUS_t$	Natural logarithm of the daily ST Assembly Testing Service Ltd (U.S.) Price

Transformation	Definitions of Transformations
$\Delta SESELE_t = LSESELE_t - LSESELE_{t-1}$	Monthly return on the SES Electronics Index
$\Delta SP500ELE_t = LSP500ELE_t - LSP500ELE_{t-1}$	Monthly return on the S&P 500 Electronics Index
$\Delta CTSIN_t = LCREATSIN_t - LCREATSIN_{t-1}$	Daily return on Creative Technology (Singapore)
$\Delta CTUS_t = LCREATUS_t - LCREATUS_{t-1}$	Daily return on Creative Technology (U.S.)
$\Delta CSMSIN_t = LCHARTSIN_t - LCHARTSIN_{t-1}$	Daily return on CSM (Singapore)
$\Delta CSMUS_t = LCHARTUS_t - LCHARTUS_{t-1}$	Daily return on CSM (U.S.)
$\Delta STATSSIN_t = LSTATSSIN_t - LSTATSSIN_{t-1}$	Daily return on STATS (Singapore)
$\Delta STATSUS_t = LSTATSUS_t - LSTATSUS_{t-1}$	Daily return on STATS (U.S.)

TABLE 2. Descriptive statistics of variables

Variables in Levels				
	Mean	Std Dev	Minimum	Maximum
$LSESELE_t$	4.808909	0.303853	4.234251	5.420933
$LSP500ELE_t$	6.839602	0.497699	6.157148	7.815268
$LCTSIN_t$	3.024650	0.504963	1.619388	4.158883
$LCTUS_t$	2.579705	0.452587	1.269761	3.637586
$LCSMSIN_t$	2.455619	0.299799	1.638997	2.917771
$LCSMUS_t$	4.212630	0.302990	3.442019	4.661078
$LSTATSSIN_t$	1.586127	0.376127	1.011601	2.360854
$LSTATSUS_t$	3.329910	0.381789	2.733068	4.095344
Variables in First Differences				
	Mean	Std Dev	Minimum	Maximum
$\Delta SESELE_t$	0.012864	0.122422	-0.326933	0.259004
$\Delta SP500ELE_t$	0.022699	0.12531	-0.320467	0.281398
$\Delta CTSIN_t$	-0.000161	0.039293	-0.307485	0.316037
$\Delta CTUS_t$	-0.000252	0.042482	-0.246430	0.330922
$\Delta CSMSIN_t$	0.000540	0.052421	-0.162519	0.234073
$\Delta CSMTUS_t$	3.49E-05	0.055989	-0.210408	0.251819
$\Delta STATSSIN_t$	-0.003989	0.040994	-0.218879	0.135545
$\Delta STATSUS_t$	-0.004173	0.049565	-0.323534	0.131028

RESULTS

UNIT ROOT TESTS

Each variable, in level as well as in first differences, are tested for unit roots using both the ADF and the PP tests. Table 3 reports the results of the PP tests conducted on the variables. All the variables in level fail to reject the hypothesis of a unit root at 5% significance level. In their first differences, all the variables reject the hypothesis of a unit root at 1% significance level. We therefore conclude that all variables are integrated of order one. Hence, the vectors of variables to be examined are:

Y_t = ($LSESELE_t$, $LSP500ELE_t$);
Y_t = ($LCTSIN_t$, $LCTUS_t$);
Y_t = ($LCSMSIN_t$, $LCSMUS_t$); and
Y_t = ($LSTATSSIN_t$, $LSTATSUS_t$).

COINTEGRATING RELATIONSHIP IN THE ELECTRONICS SECTOR

We constructed the VECM with lags of k = 3 to k = 10 for the electronics sector analysis. We find that the model with the lowest Schwartz Bayesian

TABLE 3. Phillips-Peron test

Variables	Truncated lags	Z(α)	tα	φ_3
LSESELE	3	0.563336	-1.707711	-1.873203
DSESELE	3	-5.58331**	-5.5659**	-5.487876**
LSP500ELE	3	1.116835	-1.25711	-1.998716
DSP500ELE	3	-6.105368**	-6.173625**	-6.129176**
LCTSIN	7	-0.444701	-1.744025	-2.275605
DCTSIN	7	-38.23453**	-38.22347**	-38.21513**
LCTUS	7	-0.584704	-2.012693	-2.316101
DCTUS	7	-38.72819**	-38.71720**	-38.70598**
LCSMSIN	5	-0.072507	-1.994060	-2.061536
DCSMSIN	5	-16.68873**	-16.65996**	-17.06931**
LCSMUS	5	-0.111299	-1.735653	-1.921905
DCSMUS	5	-13.35740**	-13.32999**	-13.59824**
LSTATSSIN	4	-1.436954	-0.465312	-3.086381
DSTATSSIN	4	-13.34327**	-13.43024**	-13.40821**
LSTATSUS	4	-1.322205	-0.488181	-3.565320
DSTATSUS	4	-13.85566**	-13.93896**	-13.91892**

** denotes significance at 1% level.

criterion (SBC) is that with k = 10. Table 4 presents the result of the λ_{trace} tests for this model. The λ_{trace} test rejects the hypothesis of no cointegrating equation at 1% significance level, but fails to reject the hypothesis that there is at most one cointegrating equation. Hence we conclude that there is one cointegrating equation.

TABLE 4. Results and critical values for the λ_{trace} test of the electronics sector

H_0	λ_{trace}	$CV_{(trace, 1\%)}$	$CV_{(trace, 5\%)}$
	k = 10		
r = 0	25.71998**	24.60	19.96
r ≤ 1	3.338642	12.97	9.24

** denotes significance at 1% level

The cointegration vector is β'_{ELE} = (1.000000, -0.317053, -2.569219), which results in the following long-run relation:

$$LSESELE_t = 0.317053 LSP500ELE_t + 2.569219 \quad (8)$$

Table 5 presents the error correction model (ECM) for the sectoral analysis. The α is negative and significant for DSESELE, while that for

TABLE 5. Error correction model for electronics sector analysis

	DSESELE	DSP500ELE
A	-0.546114**	-0.21907
	(-3.64080)	(-1.08703)
k = 1	0.418662	0.046604
	(-1.88005)	(-0.16927)
k = 2	0.329695	0.355707
	(-1.43386)	(-1.27008)
k = 3	-0.042825	-0.067219
	(-0.16791)	(-0.22262)
k = 4	0.355378	-0.255992
	(-1.44469)	(-0.90689)
k = 5	0.196456	0.052889
	(-0.79313)	(-0.18899)
k = 6	0.401744	0.396105
	(-1.55244)	(-1.22586)
k = 7	0.024355	-0.13166
	(-0.10564)	(-0.45811)
k = 8	0.406327	-0.439195
	(-1.68753)	(-1.55872)
k = 9	0.828171**	-0.070582
	(-2.66204)	(-0.17857)

Note 1. t statistics are included in the parentheses;
Note 2: AIC = -8.130051, SBC = -6.381179, Log Likelihood = 88.85879;
** indicates significance at the 5% level.

DSP500 is not significant. The implication is that the two series will converge in the long run, and that whereas SES Electronics Index responds quickly to changes in the S&P 500 Electronics (Semiconductor) Index, the S&P 500 Electronics (Semiconductor) Index may be exogenous to changes in the SES Electronics Index. This implies that the electronics sector in Singapore has the tendency to follow the direction of that in U.S.

COINTEGRATING RELATIONSHIP OF DUALLY LISTED STOCKS

In the case of company level analysis, we constructed VECM with lags of k = 2 to k = 14, and found that share prices for each company in the two stock markets in Singapore and U.S. do establish cointegrating relationships. Table 6, 7, and 8 present the results of the λ_{trace} tests for the models selected.

The cointegrating vectors are β'_{CT} = (1.000000, -1.050602, -0.000152, -0.184991),

β'_{CSM} = (1.000000, -0.977656, 1.662024), and

β'_{STATS} = (1.000000, -0.989318, 1.708085) for CT, CSM, and STATS respectively.

TABLE 6. Results and critical values for the λ_{trace} test of Creative Technology Ltd

H_0	λ_{trace}	CV $_{(trace,\ 1\%)}$	CV $_{(trace,\ 5\%)}$
	k =10		
r = 0	35.12323**	30.45	25.32
r ≤ 1	5.451065	16.26	12.25

** denotes significance at 1% level

TABLE 7 Results and critical values for the λ_{trace} test of Chartered Semiconductor Manufacturing Ltd

H_0	λ_{trace}	CV $_{(trace,\ 1\%)}$	CV $_{(trace,\ 5\%)}$
	K = 7		
r = 0	24.33396**	20.04	15.41
r ≤ 1	1.372977	6.65	3.76

** denotes significance at 1% level

TABLE 8. Results and critical values for the λ_{trace} test of ST Assembly Testing Services Ltd

H_0	λ_{trace}	CV $_{(trace,\ 1\%)}$	CV $_{(trace,\ 5\%)}$
	k = 6		
R = 0	28.77657**	24.60	19.96
R ≤ 1	2.583681	12.97	9.24

** denotes significance at 1% level

Thus the long-run relationships are:

$$\text{LCTSIN}_t = 1.050602\text{LCTUS}_t + 0.000152T + 0.184991, \quad (9)$$

where T in Equation 9 is the trend variable.

$$\text{LCSMSIN}_t = 0.977656\text{LCSMUS}_t - 1.662024 \quad (10)$$

$$\text{LSTATSSIN}_t = 0.989318\text{LSTATSUS}_t - 1.708085. \quad (11)$$

The normalized cointegrating vector is close to our predictions that the coefficients of the two variables in all three cases should be equal in magnitude and opposite in sign. After normalization with reference to the Singapore variables, the coefficients of LCREATUS, LCHARTUS, and LSTATSUS are 1.050602, 0.977656, and 0.989318 respectively. This implies that LCREATSIN, LCHARTUS, and LSTATSSIN will be very close to 1 times LCREATUS, LCHARTUS, and LSTATSUS respectively, ceteris paribus.

Table 9, 10, and 11 show the ECM for CT, CSM and STATS respectively. It is observed that the error correction terms in all three cases are negative and significant. This means that the time-series of the two variables in all the three cases will converge in the long-run. In addition, the error correction terms indicate the speed of adjustment towards long-run equilibrium. The larger the value of the error correction term, the faster the short-run disequilibrium is removed and long-run equilibrium is achieved. The speeds of adjustment are relatively faster for CSM and STATS, with the estimated error correction coefficients of 0.334 and 0.343 respectively. This implies that about 33.4% and 34.3% of the previous discrepancies between the actual and desired share price of CSM and STATS in Singapore, respectively, are corrected each day. The short-run dynamic adjustment for CT in Singapore is slower, with an estimated speed of adjustment of 4.4% in each day.

TABLE 9 Error correction model for Creative Technology Ltd

	ΔCTSIN	ΔCTUS
A	-0.044114**	0.040496**
	(-2.05700)	(-1.90419)
k = 1	0.011152	-0.387793 **
	(-0.28149)	(-9.68920)
k = 2	-0.086877	-0.318953 **
	(-1.93033)	(-7 41801)
k = 3	-0.086114	-0.285193**
	(-1.84039)	(-6.39298)
k = 4	-0.053829	-0.229172**
	(-1.12549)	(-5.02759)
k = 5	-0.037417	-0.135948**
	(-0.77633)	(-2.97372)
k = 6	-0.054952	-0.103479**
	(-1.15688)	(-2.31218)
k = 7	-0.025673	-0.100014**
	(-0.56036)	(-2.32901)
k = 8	-0.07155	-0.064128
	(-1.65022)	(-1.59537)
k = 9	-0.016712	-0.042668
	(-0.43141)	(-1.26700)
C	-0.000127	-0.000262
	(-0.13254)	(-0.27598)

Note 1. t statistics are included in the parentheses;
Note 2: AIC = -13.72127, SBC = -13.58218, Log Likelihood = 6789.168;
** indicates significance at the 5% level.

TABLE 10. Error correction model for Chartered Semiconductor Manufacturing Ltd

	ΔCSMSIN	ΔCSMTUS
A	-0.334271**	0.100876
	(-2.45651)	(-0.77857)
k = 1	0.223932	-0.34059**
	(-1.56711)	(-2.50834)
k = 2	0.406142**	-0.514228**
	(-2.83351)	(-3.94025)
k = 3	0.176756	-0.407615**
	(-1.27032)	(-3.27864)
k = 4	0.18669	-0.390552**
	(-1.42538)	(-3.38478)
k = 5	0.182589	-0.243084**
	(-1.48479)	(-2.31629)
k = 6	0.163991	-0.297967**
	(-1.60953)	(-3.49841)
C	-0.000195	-0.000916
	(-0.06270)	(-0.30990)

Note 1. *t* statistics are included in the parentheses;
Note 2: AIC = -12.70913, SBC = -12.31664, Log Likelihood = 1004.123;
** indicates significance at the 5% level.

TABLE 11. Error correction model for ST Assembly Testing Services Ltd

	ΔSTATSSIN	ΔSTATSUS
A	-0.343046**	0.287829
	(-2.09389)	(-1.71037)
k = 1	0.34029	-0.314535
	(-2.09603)**	(-1.90300)
k = 2	0.2616	-0.225901
	(-1.60518)	(-1.43824)
k = 3	0.197821	-0.333186**
	(-1.28364)	(-2.31344)
k = 4	0.332069	-0.276491**
	(-2.38808)**	(-2.15386)
k = 5	0.213509	-0.128591
	(-1.64989)	(-1.09539)
k = 6	-0.068226	0.002797
	(-0.61221)	(-0.03043)
C	-0.004511	-0.003523
	(-1.55521)	(-1.18259)

t statistics are included in the parentheses. AIC = -13.24263, SBC = -12.76764, Log Likelihood = 832.0884.
** indicates significance at the 5% level.

CONCLUSIONS

The results from the sectoral analysis indicate that there is a positive cointegrating relationship between the Singapore electronic sector (SESELE) and the US SP500 electronic index (SP500ELE). Furthermore, from the result of the error correction model we deduce that the SESELE is responsive to changes in SP500ELE and not vice versa. This implies that there is a tendency for the SP500ELE to lead the SESELE, and that the risks in investing in these two indices are correlated. The implication of the sectoral-level analysis is that there may be limited room for investors in reaping the benefits of diversification by investing into these two indices simultaneously.

The three individual shares in the company level analysis show positive cointegrating relationships between their share prices in Singapore and U.S. on a day-to-day basis–a reasonable finding given that dual listed stocks are issued by the same firm, any information affecting the firm or common market factors should be reflected in the prices quoted in both exchanges and the resulting extent of price movement should approximately be the same.

However, we found short-term disequilibria in share prices, and this presents the investors with arbitrage opportunities. The ECM shows a relatively slower speed of adjustment for CT as compared to CSM and STATS. This further implies that investors may find it more beneficial to focus on the arbitrage opportunities in the share prices of CT, as it takes longer for the equilibrium prices to be reached.

REFERENCES

Aggarwal, R. & Rivoli, P. 1989. The relationship between the U.S. and four Asian stock markets. *ASEAN Economic Bulletin* 6: 110-120.

Arshanapalli, B. & Doukas, J. 1993. International stock market linkages: Evidence from the pre- and post-October 1987 period. *Journal of Banking and Finance* 17· 193-208.

Cashin, P., Kumar M. S. & McDermott, C. J. 1995. International integration of equity markets and contagion effects. *International Monetary Fund Working Paper.*

Chan, C. K., Gup, B. E. & Pan, M. S. 1992. An empirical analysis of stock prices in major Asian markets and the US. *Financial Review* 27(2): 289-307

Charemza, W. W. & Deadman D. F. 1997 *New Directions in Econometric Practice*, (Second edition) UK. Edward Elgar Publishing Ltd.

Cheung, Y. E. & Lai, K. S. 1993. Finite-sample sizes of Johansen's likelihood ratio tests for cointegration. *Oxford Bulletin of Economics and Statistics* 55: 313-28.

Cheung, Y. L. & Mak, S. C. 1992. The international transmission of stock market fluctuation between the developed markets and the Asian-Pacific markets. *Applied Financial Economics* 2(1): 43-47

Cheung, Y. L. & Ho, Y. K. 1991. The inter-temporal stability of the relationships between Asian Emerging equity markets and the developed equity markets. *Journal of Business Finance and Accounting* 18: 235-253.

Chowdhry, B. & Nanda, V. 1991. Multimarket trading and market liquidity. *The Review of Financial Studies* 4: 483-511.

Dwyer, G. P. & Hafer, R. W. 1988. Are national stock markets linked? *Federal Reserve Bank of San Francisco Economic Review* Nov/Dec: 3-14.

Eun, C. & Resnick, B. 1984. Estimating the correlation structure of international share prices. *Journal of Finance* 39: 1311-1324.

Eun, C. & Shim, S. 1989. International transmission of stock market movements. *Journal of Financial and Quantitative Analysis* 24(2): 241-56.

Foerster, S. & Karolyi, G. 1998. The effects of market segmentation and illiquidity on asset prices: Evidence from foreign stocks listing in the US (August 1998). *Dice Center for Research in Financial Economics* Working Paper Series 96-6. http://ssrn.com/abstract=1006

Grubel, G. H. 1968. Internationally diversified portfolios: Welfare gains and capital flows. *American Economic Review* 58: 1299-1314.

Harris, R. 1995. *Using cointegration analysis in econometric modeling*. New York: Prentice Hall/ Harvester Wheatsheaf.

Harvey, C. R. 1991. The world price of covariance risk. *Journal of Finance* 46: 111-157

Hauser, S., Tanchuma Y. & Yarri, U. 1998. International transfer of pricing information between dually listed stocks. *Journal of Financial Research* 21. 139-157

Hui, T. K. & Kwan, K. C. 1998. Equity diversification among the Four Asian NICs. *Asia Pacific Journal of Management* 5: 132-138.

Jeon, B. N. & Chiang, T. C. 1991. A system of stock prices in world stock exchanges: Common stochastic trends for 1975-1990. *Journal of Economics and Business* 43: 329-338.

Johansen, S. 1988. Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control* 12: 231-254.

Johansen, S. & Juselius, K. 1990. Maximum likelihood estimation and inference on cointegration with application to the demand for money. *Oxford Bulletin of Economics and Statistics* 52: 169-210.

Karolyi, G. 1988. What happens to stocks that list shares abroad? A survey of the evidence and its managerial implications. *NYU Salomon Brothers Center Monograph 7*

Kasa, K. 1992. Common stochastic trends in international stock markets. *Journal of Monetary Economics* 29: 95-124.

Lau, S. T. & Diltz, J. D. 1994. Stock returns and the transfer of information between the New York and Tokyo stock exchanges. *Journal of International Money and Finance* 13: 211-222.

Lessard, D. R. 1973. International portfolio diversification: A multivariate analysis for a group of Latin American countries. *Journal of Finance* 28: 619-633.

Levy, H. & Sarnat, M. 1970. International diversification of investment portfolios. *American Economic Review* 60: 668-675.

Maddala, G. S. & Kim, I. 1998. *Unit roots, cointegration and structural change.* UK. Cambridge University Press.

Mah, B.T. 1999. Speech at the inaugural dinner of the Korean Business Association (Singapore). http://www.mnd.gov.sg/speeches_nd1999_080799.htm.

Miller, D. 1999. The market reaction to international cross listings: Evidence from depositary receipts. *Journal of Financial Economics* 51(1).

Monetary Authority of Singapore. 1999/2000. Annual Report. http://www.mas.gov.sg/annual9900/annual9900-content.html.

Osterwald-Lenum, M. 1992. A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics. *Oxford Bulletin of Economics and Statistics* 54: 461-472.

Panton, D., Lessig, P. & Joy, O. M. 1976. Comovement of International Equity Markets: A Taxonomic Approach. *Journal of Financial and Quantitative Analysis* 11. 415-432.

Philippatos, D.B., Christofi A. & Christofi, P. 1983. The inter-temporal stability of national stock market relationships: Another view. *Financial Management* 12: 63-69.

Ripley, D. 1973. Systematic elements in the linkage of national stock market indices. *The Review of Economics and Statistics* 15: 356-361.

Singapore Economic Development Board. 2000. Annual Report. http://www.sedb.com.sg/annual/an_2000_10.html.

Solnik, B. 1974. Why not diversify internationally rather than domestically? *Financial Analyst Journal* 30: 48-54.

Sun, Q. & Brannman, L.E. 1994. Cointegration and co-movement of SES sector prices Indices. *Nanyang Technological University Working Paper Series* 12-94.

Switzer, L. 1986. The benefits and costs of listing Canadian stocks in U.S. markets. In *Corporate Structure, Finance and Operations*, ed. L. Sarna, 241-254. Toronto: Carswell Co.

Ta, H. P. & Teo, C. L. 1985. Portfolio diversification across industry sectors. *Securities Industry Review* 11(2): 33-39.

Tai, L. S. T. 1985. The relationships among stock indices on Asian Pacific exchanges. *Asian Pacific Journal of Management* 3: 42-43.

Teo, M. K. 2001. EDB Chairman's Year-in-Review Press Conference. http://www.sedb.com.sg/cf-bin/CheckTemplate.cfm?ID=5&ArticleID=2450.

Viswanathan, S. 1995. A Multiple signaling model of corporate financial policy. *Research in Finance* 12:1-35.

Yeo, C. T. 2000. Speech at the opening of Globaltronics 2000. http://www.mcit.gov.sg/s_00_09_12.html.

Ramin Cooper Maysami
University of North Carolina at Pembroke
One University Drive, P.O. Box 1510
Pembroke, NC 28314
USA

Loo Sze Wee
Koh Tat Koon
Nanyang Business School
Nanyang Technological University
Nanyang Avenue
Singapore 639798