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A vector error correction model of the Singapore stock market

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Abstract

This article examines the long-term equilibrium relationships between the Singapore stock index and selected macroeconomic variables, as well as among stock indices of Singapore, Japan, and the United States. Upon testing appropriate vector error-correction models, we detected that changes in two measures of real economic activities, industrial production and trade, are not integrated of the same order as changes in Singapore's stock market levels. However, changes in Singapore's stock market levels do form a cointegrating relationship with changes in price levels, money supply, short- and long-term interest rates, and exchange rates. While changes in interest and exchange rates contribute significantly to the cointegrating relationship, those in price levels and money supply do not. This suggests that the Singapore stock market is interest and exchanges rate sensitive. Additionally, the article concludes that the Singapore stock market is significantly and positively cointegrated with stock markets of Japan and the United States.

JEL classification: G15

Keywords: VECM; Cointegration; Vector error correction; Singapore stock market

1. Introduction and review of literature

The Stock Exchange of Singapore Ltd (SES) was incorporated on May 24, 1973, and began operation on June 4 of the same year after its split from the Stock Exchange of Malaysia, itself formed only after World War II. The SES was admitted to the International Federation of Stock Exchanges in October 1980. Aiming to generate brokerage fees and interest-income for the stock-broking firms, the stock market

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scene was originally dominated by a small cartel of brokerage firms that excessively financed their clients' purchases of equity through equity-linked leverage instruments, in particular forward contracts. Shares were grossly over-priced in relation to the underlying assets of the company because they had been overstated. It reached crisis level when private and institutional investors failed to meet their obligations on forward contracts on Pan Electric shares, and forced the three-day closure of the market and led to speedy amendments to the Securities Industry Act in 1986.

The new act gave the Monetary Authority of Singapore more regulatory clout over the stock-broking industry and required more disclosure and transparency from stock-broking firms. Furthermore, banks were allowed to form subsidiaries to engage in stock-broking, and investment in stocks, shares, unit trusts, and gold using the CPF account were allowed under the Central Provident Fund (CPF) Approved Investments Scheme. In 1987 and again in 1990, the ceiling on foreign ownership of local brokers was raised. Since September 1987, a system has been implemented whereby trades are settled within a week. Also in June 1990, the SES began its drive to convert to fully scripless trading, which by now is completely implemented. 1990 also saw the first listings of stockbrokers on the SES.

Although such legislation added substantial liquidity to the market, the Exchange did collapse temporarily in the footsteps of Wall Street's Black Monday: On October 20, 1987, the Straits Time Industrial Index fell 261.78 points, the largest one-day drop in the history of the SES. Another drastic drop in the Singapore stock market indices occurred during the Gulf War, again with the U.S. market leading that of Singapore. In all, however, the Stock Exchange of Singapore has enjoyed healthy growth along with the economy of the nation. Between January 1975 and January 1995, The Singapore All-Share Index grew from 78.1 to 509.1, yielding a 9.8% compounded annual rate of return excluding dividends.

The claim that macroeconomic variables drive the movement of stock prices is, by now, a widely accepted theory. However, only in the past decade or so have attempts been made to capture the effect of economic forces in a theoretical setting and to calibrate these effects empirically. Until recently, the most widely used framework in this regard was the Arbitrage Pricing Theory (APT) model developed by Ross (1976). Using this approach, Chen et al. (1986), for example, showed that economic variables do indeed have a systematic effect on stock market returns. Economic forces affect discount rates, the ability of firms to generate cash flows, and future dividend payouts. It is through this mechanism that macroeconomics variables become risk factors in equity markets. The APT approach essentially seeks to measure the risk premia attached to these various risk factors and attempts to assess whether they are significant and if they are "priced" into stock market returns.

The development of cointegration analysis has allowed for another approach to examine the relationships between economic variables and stock markets. Chen et al. (1986) provided the basis for the belief that a long-term equilibrium existed between stock prices and macroeconomic variables, and Granger (1986) proposed to verify this through cointegration analysis. A set of time-series variables are said to be cointegrated if they are integrated of the same order and a linear combination of them is stationary. Such linear combinations would then point to the existence of a long-term relationship among the variables (Johansen & Juselius, 1990).

An 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 may be examined. One goal of the current study is to use Johansen's vector error-correction model (VECM) to formulate both monthly stock market levels and monthly stock returns. This extends Mukherjee and Naka's (1995) study of the impact of economic forces on the Japanese stock market to the Singapore context.

Another goal of this article is to examine the dynamic relations between the Singapore stock market and the two well-developed stock markets of the U.S. and Japan. Using a variety of methodologies, the co-movement among the world stock markets has long been suggested. Ripley (1973) using factor analysis, Panton et al. (1976) using cluster analysis, Dwyer and Hafer (1988) applying unit root tests, and Eun and Shim (1989) with the aid of vector autoregression came to the conclusion that markets of various countries are indeed related. Jeon and Chiang (1991) suggested the existence of a common stochastic trend in the system of stock prices in the New York, London, Tokyo, and Frankfurt exchanges, based on univariate and multivariate approaches. They concluded, "A system of stock prices in the four largest stock markets in the world share one long-run equilibrium relationship" (p. 337).

Kasa (1992) corroborated this, but again for larger, more established stock markets—the U.S., Japan, England, Germany, and Canada—"There is a single common stochastic trend that lies behind the long-run co-movement of these equity markets" (p. 122). Moreover, he showed that this trend was most important in the Japanese market. This implies to investors with long holding periods that the gains from international diversification have probably been overstated in the literature. Arshanapalli and Doukas (1993) disagreed. They concluded that with the exception of the Nikkei index, France, Germany, and United Kingdom stock markets were not related to the U.S. stock market before the stock market crash of October 1997. For the post-crash period, however, they agreed that the three European markets are indeed strongly cointegrated with the U.S. stock market. Moreover, they found that while the U.S. has a strong impact on the French, German, and United Kingdom markets, the opposite is not true. They did not find any evidence of interdependence between the U.S. and Japanese markets. Additionally, their study concluded, "The Japanese stock market innovations are unrelated to the performance of the major European stock markets" (p. 207) Harvey (1991) also thought the Japanese stock market was not fully integrated with other world stock markets.

Chan et al. (1992) examined the relationship among 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 suggest that the stock prices in major Asian markets and the Unites States are weak-form efficient individually or collectively in the long run. Additionally, they imply that international diversification among the markets is effective, as had been previously suggested by Grubel (1968) and Levy and Sarnat (1970), since they found no evidence of cointegration. They postulate, "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 Unites States, Japan, Hong Kong, South Korea, Singapore and Taiwan are independent of each other" (p. 402).

Empirical studies that support the link between the well-developed stock markets and the Asian markets include Aggarwal and Rivoli (1989) and Cheung and Mak (1992), who observed the day-to-day co-movement of the U.S. market and various Asian markets. Using the vector error-correction model, this article investigates the long-run relationship of the U.S. and Japanese stock markets with the Singapore stock market levels. Following Eun and Resnick (1984), who pointed out that using monthly data would lead to more robust estimates than using daily data, we use monthly rather than daily time-series data. This decision is supported by other researchers as well (e.g., Maldanado & Saunders, 1981; Errunza & Rosenberg, 1982; Philippatos et al., 1983).

2. Macroeconomic variables and the Singapore stock market: hypothesized relations

Based on "simple and intuitive financial theory" (Mukherjee and Naka, 1995; Chen et al., 1986), we hypothesize a relationship between the Singapore stock market and several macroeconomic variables: exchange rate, short- and long-term interest rates, inflation, money supply, domestic exports, and industrial production.

Appreciation of the Singapore dollar leads to a relative increase in price of Singapore products in foreign markets, a decrease in demand for Singapore exports, and hence lower cash flows into the country. At the same time, stronger Singapore currency lowers the cost of imported goods, which constitute almost all of production inputs. The relationship between exchange rates and stock prices in the case of Singapore thus becomes an issue for empirical studies. The long-standing position of the MAS has been to prevent imported inflation through maintaining the Singapore dollar at a strong level, and an appreciating currency is generally accompanied by increases in reserves and money supply and a decline in interest rates (Pebbles & Wilson, 1996). As such, we hypothesize that stock prices are positively related to appreciating currency and increasing money supply and negatively related to falling interest rates.

The intuition behind the relationship between interest rates and stock prices is straightforward. An increase in the rate of interest raises the opportunity cost of holding cash and is likely to lead to a substitution effect between stocks and other interest bearing securities. Additionally, changes in both short-term and long-term rates are expected to affect the discount rate in the same direction via their effect on the nominal risk-free rate (Mukherjee & Naka, 1995). The effect of money supply on stock prices is also a matter of empirical proof. Since the rate of inflation is positively related to money growth rate (Fama, 1981), an increase in the money supply may lead to an increase in the discount rate and lower stock prices. However, this negative effect may be countered by the economic stimulus provided by money growth, which would likely increase cash flows and stock prices (Mukherjee & Naka, 1995).

An increase in expected inflation rate, under general circumstances, is likely to lead to economic tightening policies that would have a negative effect upon stock prices. The rise in the rate of inflation, additionally, increases the nominal risk-free rate and raises the discount rate in the valuation model. Since cash flows do not rise at the same rate as inflation (DeFina, 1991), the rise in discount rate leads to lower stock prices. Price stability, meanwhile, is a stated macroeconomic policy goal of the Singapore monetary authorities and an expected target in the mind of the public. Hence, the hypothesized relationship between stock prices and inflation is negative or insignificant in our opinion, because the public is aware of the credibility of the MAS in maintaining price stability.

And finally, the level of real economic activity, as proxied here by both industrial production and domestic exports (roughly 60% of total exports from Singapore, which includes re-exports of goods) is likely to have a positive relation with stock prices through its effect on expected future cash flows. Fama (1990) and Geske and Roll (1983) also suggested such a positive relationship between industrial production and stock prices.

3. Methodology and data selection

Using Johansen's vector error-correction model, this article examines the dynamic relations between macroeconomics variables and the Singapore stock market, as well as the association between the U.S. and Japanese stock markets and the Singapore stock exchange. Although Engle and Granger's (1987) two-step error-correction model may also be used in a multivariate context, the VECM yields more efficient estimators of cointegrating vectors. This is because the VECM is a full information maximum likelihood estimation model, which allows for testing for cointegration in a whole system of equations in one step and without requiring a specific variable to be normalized. This allows us to avoid carrying over the errors from the first step into the second, as would be the case if Engle-Granger's methodology is used. It also has the advantage of not requiring a priori assumptions of endogenity or exogenity of the variables. The VECM is of the form

$$\Delta \mathbf{Y}_t = \sum_{j=1}^{k-1} \Gamma_j \Delta \mathbf{Y}_{t-j} + \alpha\beta' \, \mathbf{Y}_{t-k} + \boldsymbol{\mu} + \epsilon_t \tag{1}$$

where $\sum_{j=1}^{k-1} \Gamma_j \Delta \mathbf{Y}_{t-j}$ and $\alpha\beta' \, \mathbf{Y}_{t-k}$ are the vector autoregressive (VAR) component in first differences and error-correction components, respectively, in levels of Eq. (1). $\mathbf{Y}_t$ is a $p \times 1$ vector of variables and is integrated of order one. $\boldsymbol{\mu}$ is a $p \times 1$ vector of constants. k is a lag structure, while ϵ_t is a $p \times 1$ vector of white noise error terms. Γ_j is a $p \times p$ matrix that represents short-term adjustments among variables across p equations at the jth lag. β' is a $p \times r$ matrix of cointegrating vectors, and Δ denotes first differences. α is a $p \times r$ matrix of speed of adjustment parameters representing the speed of error correction mechanism. A larger α suggests a faster convergence toward long-run equilibrium in cases of short-run deviations from this equilibrium.

In estimating the VECM, we first check for stationarity and unit roots through performing the augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) tests on the variables in levels and first differences. Only variables integrated of the same order may be cointegrated, and the unit root tests will help us determine which variables are integrated of order one, or I(1).[1]

The choice of lag lengths may be decided using Sim's likelihood ratio test. However, for simplicity, in this article we will use the multivariate forms of the Akaike information criterion (AIC) and Schwartz Bayesian criterion (SBC), where AIC = T ln(residual sum of squares) + $2n$ and SBC = T ln(residual sum of squares) + $n\ln(T)$. The AIC and SBC are model selection criteria developed for maximum likelihood estimation techniques. In minimizing the AIC and SBC, we minimize the natural logarithm of the residual sum of squares adjusted for sample size, T, and the number of parameters included, n.

The model is estimated by regressing the $\Delta\mathbf{Y}_t$ matrix against the lagged differences of $\Delta\mathbf{Y}_t$ and $\mathbf{Y}_{t-k}$ and determines the rank of $\pi = \alpha\beta'$. The eigenvectors in β' are estimated from the canonical correlation of the set of residuals from the regression equations. To determine the rank of π, which will give the order of cointegration, r, we calculate the characteristic roots or eigenvalues of π, $\hat{\lambda}_i$. Furthermore, we test for r using the λ_{trace} and $\lambda_{\max}$ test statistics, where $\lambda_{\text{trace}} = -\mathrm{T}\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_I)$ and $\lambda_{\max} = -\mathrm{T}\ln(1-\hat{\lambda}_{r+1})$. The choice of the number of maximum cointegrating relationships will be based on the λ_{trace} tests. The $\lambda_{\max}$ test is used to test specific alternative hypotheses.[2] We will reject models where π has a full rank since in such a situation $\mathbf{Y}_t$ is stationary and has no unit root, and so there would be no error-correction.

Having determined the order of cointegration, we select and analyze the relevant cointegrating vector and speed of adjustment coefficients. Assuming π does not have a full rank and there are multiple cointegrating vectors, we will choose the first eigenvector based on the largest eigenvalue, which is probably the most useful. Since we consider the natural logarithm of the All-Share Price Index, LSES, to be the dependent variable, we will normalize β' with respect to the coefficient for LSES.

Tests on the parameters of the cointegrating vector may be performed using the likelihood ratio test. This is crucial because we would like to test whether stock prices contribute to the cointegrating relation and also if the macroeconomic variables are significant in the cointegrating relationship. The null hypothesis in such a situation would be a linear restriction represented by H_0: $\beta = H\phi$, where β is a $(p+1) \times r$ cointegrating matrix, H is a $(p+1) \times s$ matrix with $(p+1-s)$ restrictions and ϕ is a $s \times r$ matrix for a case without a linear trend. The likelihood ratio is given by $\mathrm{LR} = T\sum_{i=1}^{r}\ln[(1-\hat{\lambda}_{\mathrm{H},i})/(1-\hat{\lambda}_I)]$ and follows a χ^2 distribution with $r(p+1-s)$ degrees of freedom. The $\hat{\lambda}_{\mathrm{H},i}$ are eigenvalues based on restricted eigenvectors; the $\hat{\lambda}_i$ are those based on unrestricted eigenvectors.

The macroeconomic variables selected for this study are presented in Table 1. The monthly time-series were taken from various sources: LSES_t, $\mathrm{LM2}_t$, LCPI_t, LIP_t, LTDE_t, LSTB_t, and LLTB_t were transformed from data available through the Public Access Time-Series system, an on-line service by the Singapore Department of Statistics; LER_t was obtained from International Financial Statistics (IFS) published by the International Monetary Fund; and LUS_t and LJPN_t were transformed from indices

Table 1
Definitions of variables and time-series transformations

Variables	Definitions of variables
$LSES_t$	Natural logarithm of the index of market-value weighted average of month-end closing prices for all shares listed on the Stock Exchange of Singapore.
LER_t	Natural logarithm of the month-end exchange rate of the Singapore SDRs (Special Drawing Rights) as defined in the International Statistics (IFS).
$LM2_t$	Natural logarithm of the month-end M2 money supply in Singapore.
$LCPI_t$	Natural logarithm of the month-end Consumer Price Index.
LIP_t	Natural logarithm of the month-end Industrial Production Index.
$LSTB_t$	Natural logarithm of the month-end 3-month Interbank Offer Rate.
$LLTB_t$	Natural logarithm of the month-end yield on 5-year government securities.
LUS_t	Natural logarithm of the month-end stock-price index of the United States.
$LJPN_t$	Natural logarithm of the month-end stock price index of Japan.
LTDE	Natural logarithm of the month-end Total Domestic Export from Singapore.
Transformation	**Definitions of Transformations**
$\Delta SES_t = LSES_t - LSES_{t-1}$	Monthly return on the Singapore stock market (ex-dividend).
$\Delta ER_t = LER_t - LER_{t-1}$	Monthly change in exchange rate.
$\Delta M2_t = LM2_t - LM2_{t-1}$	Monthly growth rate of money supply.
$\Delta CPI_t = LCPI_t - LCPI_{t-1}$	Monthly realized inflation rate.
$\Delta IP_t = LIP_t - LIP_{t-1}$	Growth rate of industrial production.
$\Delta STB_t = LSTB_t - LSTB_{t-1}$	Monthly return on 3-month interbank market (short term).
$\Delta LTB_t = LLTB_t - LLTB_{t-1}$	Monthly return on government bonds (long term).
$\Delta US_t = LUS_t - LUS_{t-1}$	Monthly return on the United States stock market (ex-dividend).
$\Delta JPN_t = LJPN_t - LJPN_{t-1}$	Monthly return on the Japanese stock market (ex-dividend).
$\Delta LTDE = LTDE_t - LTDE_{t-1}$	Monthly change in Singapore's total domestic exports

published in the Survey of Current Business by the Bureau of Labor Statistics, USA. To arrive at the stationary variables needed in the ECM, all variables are converted into natural logarithms, and their first differences are taken (Table 1). Table 2 provides the summary statistics for the variables in levels and in first differences.

The data are seasonally adjusted, month-end data for the period from January 1988 to January 1995. We concentrate on this seven-year period because the SES All-Share Price Index, which the article analyzes, was constructed only from 1984 onwards. The index is a value-weighted index of all the shares listed on the SES and as such is a broad measure of market levels. The other widely watched index, the Straits Times Industrial Index, is not value weighted. A more important reason for the selection of this period is that only in the few preceding years were the distortions created by the monopoly of stock-broking firms over stock market activities removed through the passage of various reformatory acts. The Singapore stock market during this period

Table 2
Descriptive statistics of variables

	Mean	Std Dev	Minimum	Maximum
Variables in levels				
$LSES_t$	5.982	0.223	5.560	6.410
LER_t	0.864	0.069	0.757	1.022
$LM2_t$	11.031	0.278	10.504	11.464
$LCPI_t$	4.695	0.059	4.599	4.799
LIP_t	4.610	0.154	4.143	4.941
$LSTB_t$	3.688	0.373	2.827	4.343
$LLTB_t$	3.779	0.214	3.288	4.043
LUS_t	5.997	0.191	5.608	6.243
$LJPN_t$	7.416	0.227	6.998	7.859
$LTDE_t$	16.716	0.207	16.281	17.123
Variables in first differences				
ΔSES_t	0.00772	0.0463	−0.1642	0.1588
ΔER_t	−0.00299	0.0126	−0.0361	0.0271
$\Delta M2_t$	0.01119	0.0181	−0.0684	0.1059
ΔCPI_t	0.00238	0.0032	−0.0068	0.0090
ΔIP_t	0.00538	0.1052	−0.2171	0.3006
ΔLTB_t	0.00024	0.1238	−0.3586	0.5085
ΔSTB_t	−0.00251	0.0340	−0.1097	0.0892
ΔUS_t	0.00737	0.0258	−0.0847	0.1070
ΔJPN_t	−0.00248	0.0505	−0.1450	0.1333
ΔTDE_t	0.00829	0.0871	−0.2269	0.2421

is therefore likely to be more efficient and better able to ingest and discount macroeconomics and financial news.

4. Results

4.1. Unit root tests

Cointegration requires the variables to be integrated of the same order. So, we test the variables for unit roots to verify their stationarity. We do this through the augmented Dickey-Fuller test and Phillips-Peron test with a truncated lag of 11. The results of the Phillips-Peron test are reported in Table 3.

$Z(\tilde{\alpha})$ and $t_{\tilde{\alpha}}$ are the Z and t statistics of the Phillips-Peron test, while ϕ_3 is the statistic used in testing the joint restriction of a unit root and no deterministic trend. We found that all the variables are integrated of order one and have no deterministic trend except for $LTDE_t$ and LIP_t. The Phillips-Peron test statistics for these two measures of real economic activity are significant at the 1% level, and we conclude that they have a unit root and are non-stationary. Given this, these two measures cannot be cointegrated with stock market levels and are excluded from the model.

All the variables in first differences are stationary at the 1% significance level. As

Table 3
Unit root tests

Variables	$Z(\tilde{\alpha})$	$t_{\tilde{\alpha}}$	ϕ_3
$LSES_t$	−9.621	−2.188	2.557
ΔSES_t	−42.419***	−6.046***	18.061***
LER_t	−14.607	−3.0379	4.842
ΔER	−69.504***	−11.307***	62.846***
$LM2_t$	−3.914	−1.425	1.361
$\Delta M2$	−124.66***	−12.904***	83.489***
$LCPI_t$	−20.909	−3.372	5.795
ΔCPI_t	−88.685***	−12.018***	72.006***
LIP_t	−65.367***	−7.286***	26.629***
ΔIP	−88.764***	−24.732***	304.00***
$LSTB_t$	−9.467	−2.510	3.497
ΔSTB	−72.673***	−8.093***	32.774***
ΔLTB_t	−7.329	−1.851	1.735
$LLTB_t$	−66.974***	−6.828***	23.429***
LUS_t	−9.490	−2.179	3.130
ΔUS	−54.739***	−7.995***	31.162***
$LJPN_t$	−10.221	−2.514	3.378
ΔJPN	−56.553***	−6.757***	22.801***
$LTDE_t$	−63.697***	−6.318***	20.115***
ΔTDE	−91.484***	−21.503***	228.09***

*** denotes significance at the 1% level.

such the final vectors of variables to be examined is given by $\mathbf{Y}_t$ = ($LSES_t$, $LCPI_t$, $LM2_t$, $LSTB_t$, $LLTB_t$, LER_t) and $\mathbf{Y}_t$ = ($LSES_t$, LUS_t, $LJPN_t$).

4.2. The impact of economic forces

In building the VECM that captures the impact of economic forces on the Singapore stock market, we construct VECMs with truncated lags of $k = 2$ to $k = 10$. Because of the small sample size, we were not able to extend the lag structure. The model with the lowest AIC and SBC was the one for $k = 2$, followed by the one for $k = 3$. We report the results for these two models as they best meet our model-selection criteria while having some differences with one another. The models for $k = 8$ to $k = 10$ are completely rejected because the λ_{trace} and λ_{max} tests indicate that π for these models have full rank at the 1% significance level, rendering the VECM an inappropriate model.

Table 4 reports the results and critical values (CV) of the λ_{trace} and λ_{max} tests for $k = 2$ and $k = 3$. In the case of $k = 2$, the λ_{trace} test indicates that there is no more than one cointegrating relation, while the λ_{max} test rejects $r = 0$ for the alternative that $r = 1$ at the 1% significance level. We conclude that there is one cointegrating vector, i.e., $r = 1$.

When $k = 3$, the λ_{trace} test indicates that no more than two cointegrating vectors exist, while the λ_{max} test rejects $r \leq 1$ in favor of $r = 2$ at the 1% level of significance.

Table 4
Results and critical values for the λ_{trace} and λ_{max} test

H_0	λ_{trace}	$CV_{(trace, 1\%)}$	$CV_{(trace, 5\%)}$	λ_{max}	$CV_{(max, 1\%)}$	$CV_{(max, 5\%)}$
			$k = 2$			
$r = 0$	147.671***	111.01	102.14	69.300***	46.82	40.30
$r \leq 1$	78.371**	84.45	76.07	28.750	39.79	34.40
$r \leq 2$	49.621	60.16	53.12	20.337	33.24	28.14
$r \leq 3$	29.284	41.07	34.91	12.004	26.81	22.00
$r \leq 4$	17.281	24.60	19.96	9.370	20.20	15.67
$r \leq 5$	7.911	12.97	9.24	7.911	12.97	9.24
			$k = 3$			
$r = 0$	163.238***	111.01	102.14	56.927***	46.82	40.30
$r \leq 1$	106.309***	84.45	76.07	50.820***	39.79	34.40
$r \leq 2$	55.488**	60.16	53.12	24.101	33.24	28.14
$r \leq 3$	31.387	41.07	34.91	14.437	26.81	22.00
$r \leq 4$	16.950	24.60	19.96	9.396	20.20	15.67
$r \leq 5$	7.554	12.97	9.24	7.554	12.97	9.24

*** denotes significance at the 1 % level and ** at the 5% level.

We conclude that there are two cointegrating vectors, or $r = 2$. As mentioned earlier, when there is more than one cointegrating vector, the first eigenvector, which is based on the largest eigenvalue, is regarded as the most useful. Table 5 presents the full set of adjustment coefficients in the VECM for the same values of k. When $k = 2$, small αs in all but the case of STB point to the lack of a speedy built-in adjustment mechanism to the long-run equilibrium. When $k = 3$, the magnitude of αs increase for all variables.

Table 5
Error-correction model

	ΔSES_t	ΔCPI_t	$\Delta M2_t$	ΔSTB_t	ΔLTB_t	ΔER_t
			$k = 2$			
α	0.0056	−0.0103***	−0.0676***	0.2413***	0.0027	0.0023
	(0.209)	(−5.258)	(−6.447)	(3.323)	(0.132)	(0.290)
$k = 1$	0.2901***	2.2700*	−0.0727	0.0727*	−0.2708*	−0.1790
	(2.747)	(1.859)	(−0.269)	(1.652)	(−1.778)	(−0.452)
			$k = 3$			
α	−0.0754	0.0069*	0.0871***	0.4519***	0.0985***	−0.0292***
	(−1.603)	(1.794)	(4.783)	(3.653)	(2.928)	(−2.181)
$k = 1$	0.3700***	1.9895	0.1638	0.0782*	−0.1340	−0.1214
	(3.153)	(1.308)	(0.588)	(1.678)	(−0.778)	(−0.300)
$k = 2$	0.0166	−1.5621	0.5065*	−0.0265	−0.0329	−0.0149
	(0.137)	(−1.086)	(1.770)	(−0.558)	(−0.195)	(−0.037)

t statistics are included in parentheses. In the case of $k = 2$, AIC = −6.190, SBC = −5.986, while AIC = −6.134, SBC = −5.753 when $k = 3$. The Box-Pierce-Ljung Q-test performed on the residuals indicates no autocorrelation in both models.

*** indicates significance at the 1 % level and * at the 10 % level.

Normalizing with respect to the coefficient for LSES, the cointegrating vector for $k = 2$ is given by $\beta_1' = (1.00, -0.319, 0.291, -0.559, 0.754, 3.714, 11.927)$. This yields the following cointegrating relationship:

$$\begin{aligned}\text{LSES}_t = {} & 0.319 \times \text{LCPI}_t - 0.291 \times \text{LM2}_t + 0.559 \times \text{LSTB}_t \\ & - 0.754 \times \text{LLTB}_t - 3.714 \times \text{LER}_t + 11.927\end{aligned} \tag{2}$$

Since a double logarithmic functional form is used here, the coefficients in β_1' can be interpreted as long-term elasticities.

In the case where $k = 3$, the cointegrating vector based on the largest eigenvalue is $\beta_1' = (1.00, 3.06, -0.916, -0.118, 0.352, 1.748, -12.559)$, and this results in the following long-term relation:

$$\begin{aligned}\text{LSES}_t = {} & -3.06 \times \text{LCPI}_t + 0.916 \times \text{LM2}_t + 0.118 \times \text{LSTB}_t \\ & - 0.352\ \text{LLTB}_t - 1.748\ \text{LER}_t + 12.559\end{aligned} \tag{3}$$

Through examining the comparative statics, we note that when $k = 2$, the coefficient for LCPI_t is positive and the coefficient for LM2_t is negative, while the opposite holds true in the case where $k = 3$. In the other lag structures where π did not have a full rank, the signs of the coefficients for LCPI_t and LM2_t are consistent with the findings in $k = 3$ rather than in $k = 2$. It is likely that LSES is negatively related to LCPI and positively with LM2. In both the models above, LSTB_t is positively related to LSES_t, while the relations between LLTB_t, LER_t, and LSES_t are negative. The intercept term is positive. The signs of the coefficients for LSTB_t, LLTB_t, and LER_t and the intercept are robust to changes in lag structure in all the accepted cases where π does not have full rank.

To test whether the coefficients in β' are significant, we use the test for linear restrictions, the LR test. Since our attempt is to determine whether economic forces have any impact on the stock market, the model would be valid only if LSES contributes significantly to the cointegrating relationship. We also test each of the economic factors individually for significance. The results show that both models are valid given that LSES contributes to the cointegrating relationship. Also, In both cointegrating relationships, LCPI and LM2 are not significant, but LSTB, LLTB, and LER are.[3]

The Singapore stock market's relationship with short-term interest rates is positive, while its relation with long-term rates is negative. This finding is consistent with Mukherjee and Naka's (1995) findings for Japan as well as Bulmash and Trivoli's (1991) findings for the U.S. Mukherjee and Naka (1995) explain this by noting that the long-term interest rate may serve as a better proxy for the nominal risk-free component of the discount rate in stock valuation models. Alternatively, Bulmash and Trivoli (1991) suggest that the long-term interest rate is a surrogate for expected inflation that is incorporated into the discount rate.

The association between exchange rates and stock prices provides the most striking contrast between Singapore and the larger economies of the U.S. and Japan. A stronger currency drives the Singapore market higher rather than lower, as is the case for Japan (Mukherjee & Naka, 1995) and the U.S. (Fang & Loo, 1994). In these two countries, an appreciation of the currency would make exports less competitive, thus lowering export earnings. However, this is not so for Singapore. As The and Shanmugaratnam (1992) and Yip (1996) pointed out, Singapore's economy has a high import and export content, and intermediate goods in particular form a significant portion of total expenditure. A strong Singapore dollar lowers the cost of imported inputs, thus allowing local producers to be more competitive internationally. Also, Singapore's small and open nature renders monetary or interest rate targeting as a relatively impotent anti-inflationary tool compared to exchange rate management. Yip (1996) further highlighted that a strong Singapore dollar limits imported inflation. Given these two reasons, it is likely that the appreciation of the Singapore dollar is received as favorable news by the Singapore stock market and hence generates positive returns.

The negative relationship between price levels and stock market levels is consistent with Mukherjee and Naka's (1995) findings for Japan as well as Fama and Schwert's (1977) and Chen et al.'s (1986) findings for the U.S. The relationship between stock returns and inflation has been the focus of many studies. The Fisherian relation between nominal interest rates or rates of return on assets and expected inflation lead us to expect that one of the reasons people hold various assets is to hedge against inflation. Therefore, stock returns should be positively correlated with inflation. Yet, Fama and Schwert (1977) found that while government bonds and real estate were hedges against inflation, stocks did not seem to serve that function. Fama (1981) proposed that the negative relation between stock returns and inflation could be traced to the fact that the more important determinant of stock returns was real activity. A negative relationship existed between inflation and real activity because the nominal quantity of money did not vary sufficiently with real activity. As such, the negative relation between stock returns and inflation is a spurious one. This is a plausible explanation in Singapore's case.

Money supply changes and stock returns in Singapore are positively related, and this is also consistent with the findings for the U.S. (Bulmash & Trivoli, 1991) and Japan (Mukherjee & Naka, 1995). There are a few possible explanations for this. One is that an increase in money supply has a direct positive liquidity effect on the stock market. Another possibility, suggested by Mukherjee and Naka (1995), is that injections of money supply have an expansionary effect that boost corporate earnings. The third explanation follows from Fama's (1981) comments on inflation: increases in real activity that drive stock returns also stimulate the demand for money via the simple quantity theory model, thus creating the positive relation between money supply and stock prices.

However, the LR tests indicate that inflation and money supply factors are not significant to the Singapore stock market. It appears that the Singapore stock market responds in a consistent way to the small and open nature of the country's economy. The important factors affecting Singapore are exchange rates and domestic interest rates, where the latter closely tracks world interest rates. The impacts of real domestic activity as measured by industrial production or trade seems to be irrelevant from the cointegration point of view, while money supply growth and its corollary, the rate of inflation, are statistically insignificant. Price stability as a macroeconomic objective

Table 6
Results and critical values for λ_{trace} and λ_{max} tests

H_0	λ_{trace}	$CV_{(trace, 1\%)}$	$CV_{(trace, 5\%)}$	λ_{max}	$CV_{(max, 1\%)}$	$CV_{(max, 5\%)}$
$r = 0$	46.222***	41.07	34.91	25.117**	26.81	22.00
$r \leq 1$	21.105**	24.60	19.96	17.114**	20.20	15.67
$r \leq 2$	3.991	12.97	9.24	3.991	12.97	9.24

*** denotes significance at the 1 % level and ** at the 5 % level.

of Singapore authorities could have contributed to the latter observation. The findings in this study seem to suggest that the Singapore stock market is quite different from those of large economies like the U.S. and Japan (Chen et al., 1986; Fama, 1990).

5. Interrelationship among stock markets

To ascertain the integrated relationship between the Singapore stock market and the U.S. and Japanese stock markets, we built pertinent models for $k = 6$–13. We found that models for $k \leq 7$ and $k = 10$ yielded no cointegrating relationships at the 1% level. The model with $k = 8$ had the lowest SBC, while $k = 9$ had the lowest AIC. In such a situation, we would choose the minimum SBC because there is a tendency for the AIC to favor models that are over-parametized. As such, our selected model is the VECM with $k = 8$.

Table 6 presents the results of the λ_{trace} and λ_{max} tests, and Table 7 reports the parameters of our VECM. Based on the above tests, we conclude that there are two cointegrating relationships at the 5% level.

Normalizing with respect to $LSES_t$, the cointegrating vector based on the largest eigenvalue is $\beta' = (1.000, -1.722, -0.674, 9.285)$, and this gives the cointegrating relation

$$LSES_t = 1.722 \times LUS_t + 0.674 \times LJPN_t - 9.285. \tag{4}$$

The signs of the coefficients of LUS_t and $LJPN_t$ are robust to changes in k. We may thus infer that the Singapore stock market has a positive long-term relation with the U.S. and Japanese markets. As in the previous models, we perform tests on linear restrictions. The validity of this model is supported by the significance of LSES in the cointegrating relation. We may also observe that the stock markets of the U.S. and Japan have a significant effect in the cointegrating relation.[4] Moreover, the fact that αs are small and insignificant in the cases of U.S. and Japan (Table 6) may further suggest that U.S. and Japan are exogenous to changes in SES. A large and significant α in the case of SES means that the Singapore stock market responds quickly to changes in the large U.S. and Japanese markets. In conclusion, the results of this experiment lead us to believe that the Singapore stock market tends to follow the directions taken by the U.S. and Japanese stock markets and that the impact of these two markets on Singapore is highly significant.

Table 7
Error-correction model

	ΔSES	ΔUS	ΔJPN
α	−0.2236***	0.0067	0.0785
	(−3.244)	(0.151)	(0.959)
$k = 1$	0.2069	0.2292	−0.0278
	(1.461)	(0.874)	(−0.221)
$k = 2$	−0.0121	−0.4513*	0.0950
	(−0.081)	(−1.716)	(0.072)
$k = 3$	−0.1501	0.0269	−0.0295
	(−0.983)	(0.102)	(−0.225)
$k = 4$	0.0815	−0.3796	0.1715
	(0.531)	(−1.415)	(1.305)
$k = 5$	0.0553	−0.4206	0.0484
	(0.364)	(−1.570)	(0.374)
$k = 6$	−0.0383	−0.1740	−0.0462
	(−0.261)	(−0.641)	(−0.375)
$k = 7$	−0.2803***	0.0239	0.1394
	(−2.059)	(0.092)	(1.163)

t statistics are included in parentheses. AIC = −6.114, SBC = −5.445. The Box-Pierce-Ljung *Q*-test performed on the residuals indicates no autocorrelation in both models. $LR_{k=2}$ follows a χ^2 distribution with one degree of freedom while $LR_{k=3}$ follows a χ^2 distribution with two degrees of freedom.

*** indicates significance at the 1 % level and * at the 10 % level.

Although the co-movement of the Singapore stock market with the U.S. and Japanese stock markets has been noted before, past studies have focused mainly on the day-to-day linkages among these markets. For example, Cheung and Mak (1992) found the U.S. market to lead the Singapore market with the lag relationship significant enough to indicate a causal relationship. Aggarwal and Rivoli (1989) found the Singapore market mimics even anomalous behavior of the U.S. market, such as the well-known Monday effect. Extending the analysis to monthly data, we find that the U.S. appears to have a longer-term structural effect on the Singapore stock market, and this is found to be true of the Japanese stock market as well.

These findings have important implications for international portfolio management. Solnik (1974), Eun and Resnick (1984), and Errunza (1983), for example, recommended that stock portfolios be diversified internationally to reduce systematic local risk, as did Chan et al. (1992), who thought international diversification of investment portfolios is justified and desirable because unsystematic risk across countries can be reduced. However, other studies, Maldanado and Saunders (1981) and Philippatos et al. (1983) for instance, found that co-movements do exist among the stock markets of certain industrialized countries. In light of Singapore's close positive relation with the U.S. and Japanese stock markets, as discovered in the current study and further supported by Aggarwal and Rivoli (1989) and Cheung and Mak (1992), the benefits of portfolio diversification within the U.S., Japan, and Singapore may be somewhat limited.

6. Conclusions and suggestions for further studies

Using Johansen's methodology for multivariate cointegration analysis and monthly time-series data, this article has identified several economic factors that have a long-run equilibrium effect on the Singapore stock market. We found that two measures of real domestic activities, industrial production and trade, were not integrated of the same order as changes in stock market levels. We noticed, on the other hand, that inflation, money supply growth, changes in short- and long-term interest rate, and variations in exchange rate do form a cointegrating relation with changes in Singapore's stock market levels. Based on tests of linear restrictions, we found that while inflation and money supply growth were not significant in the cointegrating relation, changes in interest and exchange rates were. In short, we detected that the Singapore market is sensitive to "external" factors. This is not surprising given Singapore's small and open economy. On the macroeconomic side, the significant factors are exchange rates and interest rates, which in Singapore's case closely follow world interest rates.

Moreover, having built a tri-variate model using the stock indices of Singapore, the U.S., and Japan, we found the three markets to be highly cointegrated. This suggests that changes in the U.S. and Japanese stock markets have a significant effect on the Singapore stock market. In particular, Singapore's stock market has a positive long-run equilibrium relation with the U.S. and Japanese markets, the largest two in the world. As such, there may be limits to the benefits of equity portfolio diversification within these three countries.

There is, however, no established theoretical explanation for these dynamic relations. The most common proposition put forward is that of global financial integration. The thrust of this argument is that with technological and financial innovation, the advancement of international trade and finance, and deliberate regional and global co-operation, the geographical divide among various national stock markets are less obvious. Jeon and Chiang (1991) cite deregulation and market liberalization measures, rapid developments in the communication technology and computerized trading systems, and increasing activities by multinational corporations as factors contribution to such integration. The harmonization of interest rates as documented by Bhoocha-oom and Stansell (1990) as well as references to a "world" interest rate in international finance texts are further evidence of this. However, the theoretical under-pinning of the integration of equity markets is not yet well understood. In particular, it is not clear why stock market shocks tend to be transmitted from larger to smaller stock markets.

New York and Tokyo stock markets are among the major world capital markets, and the U.S. and Japan are two of Singapore's major trading partners. They were ranked second and third, respectively, as of 1995 in total trade by country with Singapore—the largest importing nation for Singapore's domestic exports was the U.S., while Singapore imported mostly from Japan. As a small open economy with export demand as a main engine of economic growth, Singapore remains susceptible to external shocks, and the economic well being of its major trading partners, to some degree at least, is expected to affect its economy. This could in turn be observed as stock market shocks being transmitted from larger trading nations to smaller ones—the stock markets, after all, are said to be reflectors of economic health. It is not surprising then to observe the U.S. and Japanese stock markets have an impact on the Singapore stock market.

Two points are worth noting and may provide grounds for further research. First, since cointegration refers to long-run relationships between the variables appearing in the cointegrating vector(s), the close and positive long-term relationship between the U.S., Japan, and Singapore stock markets discovered in this article does not by itself prove similar relations exist in the short run. Second, Johansen's method is known to be sensitive to the choices of lags and the dimensions. Mukherjee and Naka (1995) used 20 years of data and 7 variables. Because of a more limited number of observations, we used five macro variables instead. Experimenting with various dimensions and time series data may, in itself, be a useful study.

Notes

1. For example, the ADF tests the null H_0: $\gamma = 0$ in $\Delta y_t = a_0 + a_2 t + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-1+i} + \epsilon_t$ to verify if a unit root exists in the presence of a drift and deterministic trend. The ADF test, however, assumes the asymptotic normality of the idiosyncratic error term. The Phillips-Peron test, while similar, allows for weaker statistical assumptions regarding ϵ_t.
2. The critical values for these tests are taken from Osterwald-Lenum (1992).
3. For H_0: LSES is insignificant in the cointegrating relationship, $LR_{k=2} = 6.574$** and $LR_{k=3} = 23.971$***. Similarly, for H_0: LCPI is insignificant in the cointegrating relationship, $LR_{k=2} = 0.018$ and $LR_{k=3} = 2.960$; H_0: LM2 is insignificant in the cointegrating relationship, $LR_{k=2} = 0.301$ and $LR_{k=3} = 4.570$; H_0: LSTB is insignificant in the cointegrating relationship, $LR_{k=2} = 10.848$*** and $LR_{k=3} = 10.989$***; H_0: LLTB is insignificant in the cointegrating relationship, $LR_{k=2} = 4.965$* and $LR_{k=3} = 8.752$**; and for H_0 : LER is insignificant in the cointegrating relationship, $LR_{k=2} = 6.509$** and $LR_{k=3} = 11.683$***, where ***, **, and * denote significance at the 1, 5, and 10% levels, respectively.
4. For H_0: LSES is insignificant in the cointegrating relationship, $LR_{k=8} = 15.139$. For H_0: LUS is insignificant in the cointegrating relationship, $LR_{k=8} = 19.625$; and for H_0: LJPN is insignificant in the cointegrating relationship, $LR_{k=8} = 18.343$. All statistics are significant at the 1% level and with $LR_{k=8}$ following a χ^2 distribution with two degrees of freedom.

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