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Stock Market Equilibrium and Macroeconomic Fundamentals

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Abstract

This paper examines the efficiency of the Stock Exchange of Singapore and the relationship between the stock market and the overall economy. Using a wide range of methods for testing market efficiency, the paper establishes that the Singapore stock market is both "weakly" and "semi-strongly" efficient in asset-pricing terms but not "strongly" efficient. Granger causality tests based on the efficiency test results indicate that developments in the stock market appear to be systematically related to the overall economy in Singapore and can thus serve as a leading indicator of its intertemporal behavior.

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SUMMARY

A resurgence in interest about the role played by stock markets in economic development has stimulated a burgeoning literature of research on emerging markets. This paper examines the efficiency characteristics of the Stock Exchange of Singapore, one of the few developed stock markets in South East Asia.

The paper employs a wide range of methods for testing stock market efficiency. It analyzes the "weak" form of efficiency tests, the "semi-strong" form of stock market efficiency tests, as well as the excess volatility test or the variance-bound tests. By and large, the econometric results in this paper establish that the Singapore stock market is both "weakly" and "semi-strongly" efficient in asset-pricing terms, although evidence suggests that the market may not be "strongly efficient."

Granger causality tests based on the efficiency tests indicate that developments in the Singapore stock market appear to be systematically related to the overall economy and can thus serve as a leading indicator of its intertemporal behavior.

I. Introduction

Recently, there has been a resurgence of research interest in the role played by stock markets in developing countries. The International Finance Corporation (IFC) in Washington has set up the Emerging Markets Study Group particularly devoted to the understanding of the relationship between the development of stock markets and the functioning of financial intermediaries and its overall effect on growth. This paper examines the efficiency characteristics of the Stock Exchange of Singapore (SES) and its role in the economy.

In principle, a well-functioning stock market may help the development process in an economy through the following means, inter alia: (i) growth of savings; (ii) efficient allocation of investment resources and (iii) better utilization of the existing resources. The stock market is supposed to encourage savings by providing households with an additional instrument which may better meet their risk preferences and liquidity needs. In a well-developed capital market, share ownership provides individuals with a relatively liquid means of sharing risk in investment projects. There is also considerable evidence on the extent to which these markets are playing a role in allocating capital to the corporate sector and the beneficial effects for the rest of the economy. Although the structure of corporate finance varies widely among the developing countries the use of equity finance by the corporate sector has been significant. During the 1980s, as a share of net investment expenditures, equity funds exceeded debt finance, or internally generated funds, in countries like Korea, Mexico, Thailand, and Turkey (Singh and Hamid (1992)). As Mayer (1987) shows this contrasts sharply with the corporate finance pattern in industrial countries, which in general rely much more on internally generated funds. The evidence from advanced countries indicates that the stock market does not perform this savings function at all well. Mayer's (1987) analysis of the flows-of-funds data for several industrial countries on a comparable basis over the period 1970 to 1985 shows that the equity market's net contribution to the investment needs of the nonfinancial corporate sectors both in the United States and the United Kingdom, was negative over this period, and this undermines the savings function of the stock market. From a theoretical standpoint, these results are not very surprising since they are broadly in accord with the pecking-order theory of corporate finance (Singh (1992)).

Thus, more recent research on the role of the stock market in an economy has argued from a different angle. The emphasis there is that having a "developed" stock market enhances the efficiency of investment. A well-functioning stock market can perform its allocative functions through the pricing of its shares. An efficient pricing process will reward the well-managed and profitable firms by valuing their shares more highly than those of successful and unprofitable firms. This mechanism lowers the cost of capital to the former and hence ensures a greater allocation of new investment resources to such firms at the expense of the latter group of firms, which correspondingly face a higher cost of capital. Keane (1983) has made a useful distinction between the two concepts of efficiency of share prices: the "fundamental valuation" and the "information arbitrage" efficiency. The latter refers to how quickly all available information is disseminated throughout the market and incorporated in share prices. The former concept refers to the notion of efficiency that posits that aggregate share prices generally reflect the true fundamentals of an economy. There is a large body of evidence from advanced country stock markets that indicate that share prices in these markets are generally efficient in the "information" sense: that is, all new information is reflected in share prices (Keane (1983)). The efficiency of the domestic market is further increased through contacts with foreign financial institutions and the importation of sophisticated financial technology. Moreover, better developed stock markets allow individuals to effectively price and hedge risk. The use of derivative instruments in many emerging stock markets has allowed foreign investors the possibility of hedging risks. The evidence suggesting that actual prices prevailing in London or New York stock exchanges are "efficient" from the point of view of fundamental valuation, that is, that relative share prices of corporations always reflect their true long-term expected earnings is far less conclusive however. The excess volatility tests by Shiller (1981b) and tests of efficiency based on the fundamental valuation view by Poterba and Summers (1984,1987) and others suggest the existence of myopia and fads in stock market pricing. There is also some systematic evidence of a correlation between cumulative equity returns and economic fundamentals. For instance, Mullin (1993) finds a statistically significant cross-country relationship between equity returns and export growth rates and between equity returns and growth rates of dividends per share, for a large number of developing countries over the period 1976-91. 1/ This finding is not inconsistent with the possibility of speculative bubbles. In fact, it is not only the actual efficiency of the stock market that has captured research interest, but also to what level it is efficient.

In spite of the progress achieved in equity markets of Newly Industrialized Economies (NIE), the link between stock markets and the overall economy remains a relatively unexplored area of research for these countries. In this paper, we shall investigate the efficiency of the Singapore stock market using a wide range of tests in order to establish to what level it is efficient if it is at all. The analysis begins in Section II with a brief overview of the evolution and structure of the Stock Exchange of Singapore (SES) and the key aggregate stock market indicators. Efficiency results using the "weak" form of test, the "semi-strong" form of test are presented in Section III. Section IV examines an alternative test for stock market efficiency namely, the excess market volatility paradigm pioneered by Shiller (1981b). We apply Shiller's method but develop it further using recent advances on ARCH (autoregressive conditional heteroscedasticity) GARCH and EGARCH variance modeling techniques along the lines reported by Engle (1982) and its extensions, GARCH and IGARCH. Section V looks at a related test on the relationship between the stock market and the economy based on the Blanchard (1981) model. Section VI concludes the paper. Appendix I presents an estimated dynamic error-correction model (ECM) of real stock returns in Singapore. Appendix II provides a formal description of the variance models and their application in the applied financial time series literature and the data sources and description.

1/ This result is based on an analysis of a group of major developing countries composed of Argentina, Brazil, Chile, India, Korea, Malaysia, Mexico, Taiwan Province of China, and Thailand, using panel data (breaking each country's export growth performance and equity returns over 1976-91 into four-year periods).

II. An Overview of the Structure of the Stock Exchange of Singapore and Aggregate Stock Market Indicators

Up to 1973, Singapore and Malaysia shared a joint stock exchange. The decision by the Singapore and Malaysian governments to terminate the interchangeability of currencies between the two countries in May 1973 brought about the split of the joint Stock Exchange of Malaysia and Singapore. This necessitated the incorporation of the SES on the May 24, 1973; its full operation as a separate exchange was effected on June 4, 1973. Under the trading system introduced on January 1, 1975, the SES's official list was divided into two sections, the First Trading Section and the Second Trading Section. Shares assigned to the first section may be traded on ready delivery basis and settlement contracts, whereas shares in the second section may be traded on a ready delivery basis only. Two over-the-counter markets, the Stock Exchange of Singapore Dealing and Automated Quotations System (SESDAQ) and the CLOB International Market were added later. The SESDAQ market was established in February 1987, with the aim of making it easy for small and medium-sized enterprises with growth potential to raise funds. The criteria for listing on this market are, comparatively, not as strict as for the first and second sections of the SES and small and medium-sized companies with growth potential can be easily registered. Following the termination of double listings in the SES and the Kuala Lumpur Stock Exchange (KLSE) in January 1990, the CLOB International Market was set up as a venue for transactions in shares of Malaysian companies delisted in Singapore, for the convenience of investors operating on the SES.

Shares traded on the SES are classified into six groups: industrial and commercial, finance, properties, hotels, plantations, and mining, and the Straits Times Index (STI) represents the All-Share Index. The selected aggregate stock market indicators the STI and the dividend and earnings yield, the stock market capitalization and its ratio to GNP, and the value traded on the SES are shown in Charts 1, 2, and 3, respectively. In 1983, the ratio of market capitalization of traded equities to real GDP was 89.2 percent and by 1992 this rose to 106.0 percent (IFC Emerging Markets Database 1993). Corresponding figures for Japan were 47.6 percent and 65.4 percent respectively, indicating that Singapore's securities markets have developed well and form an important component of the economy. At the end of December 1989 there were 333 companies listed on the first and second sections of the SES, the market capitalization of listed Stocks being US$139.1 billion. Over the years, the total market capitalization has increased enormousl. During the period under review, the SES experienced four significant drops - - the crash in 1981 which lasted for 16 months; a lesser crash in 1985 coinciding with the recession of 1985; the local Pan Electric crisis 1/ in November 1985; the worldwide market crash in October 1987. The fourth temporary crash occurred in January 1990, following the abolition of the dual listing of many Malaysian companies on the two exchanges (SES and KLSE). The sharp drops in the STI in 1987 and 1990 reflect these events.

1/ This collapse triggered a major crisis in the stock market. The solvency of several stockbroking firms was threatened as a result of overtrading and overextending their loans Trading on the SES was suspended on December 2, 1985 for three days so that remedial arrangements could be made to restore confidence.

Chart 1. Straits Times Index (Share Price Index) of the SES and Earnings and Dividend Yields- (1975q1 - 1991q2)

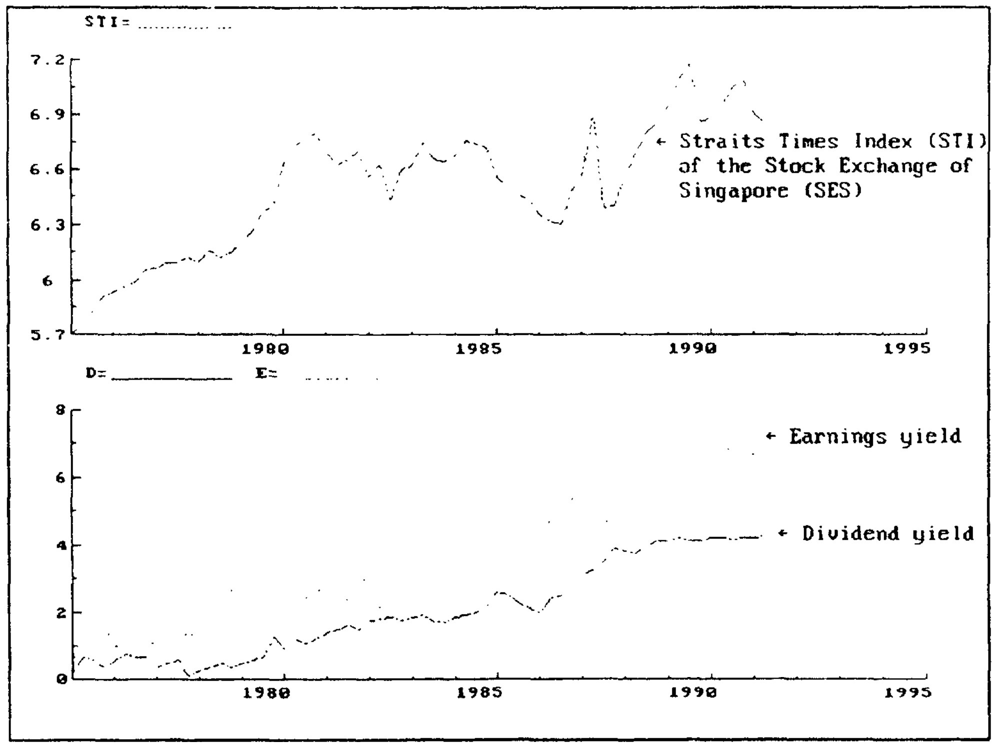


Chart 2. Stock Market Capitalization of the SES and its Ratio to Nominal GNP (1975q1 - 1991q2).

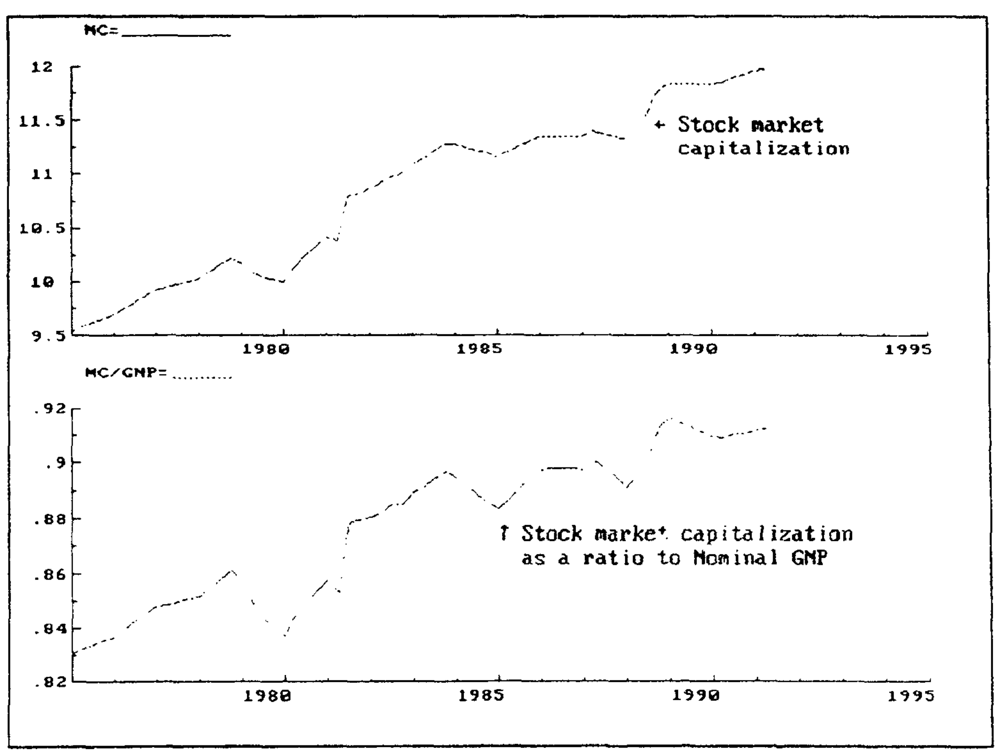


Chart 3. Value of Traded Stocks and Shares (Turnover) at the SES (1975q1 - 1991q2)

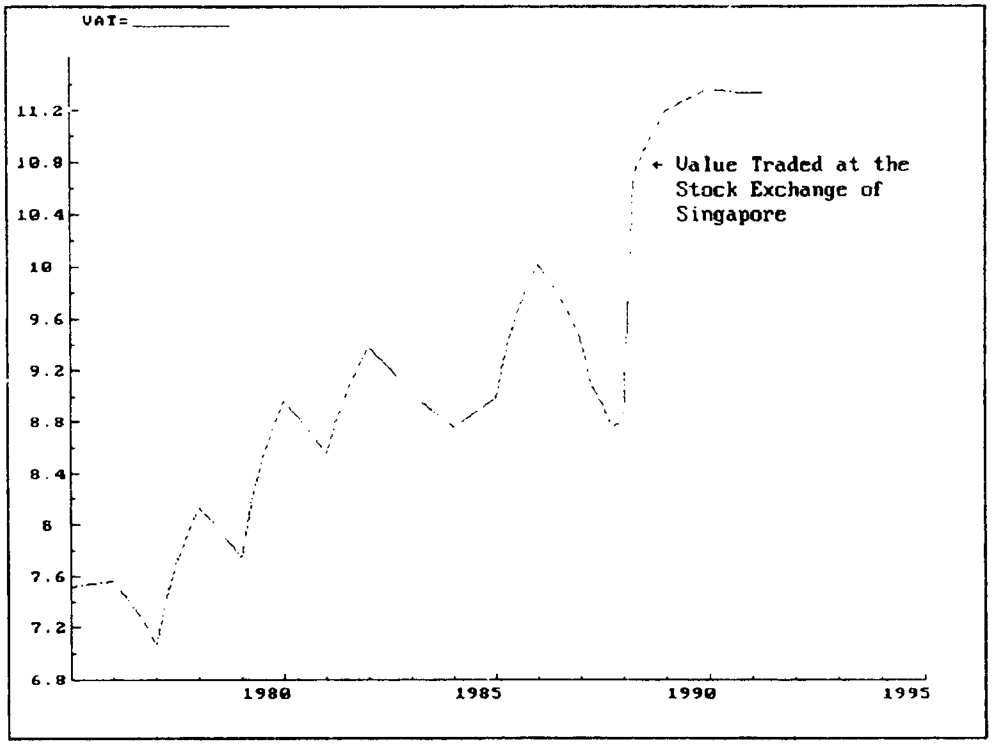
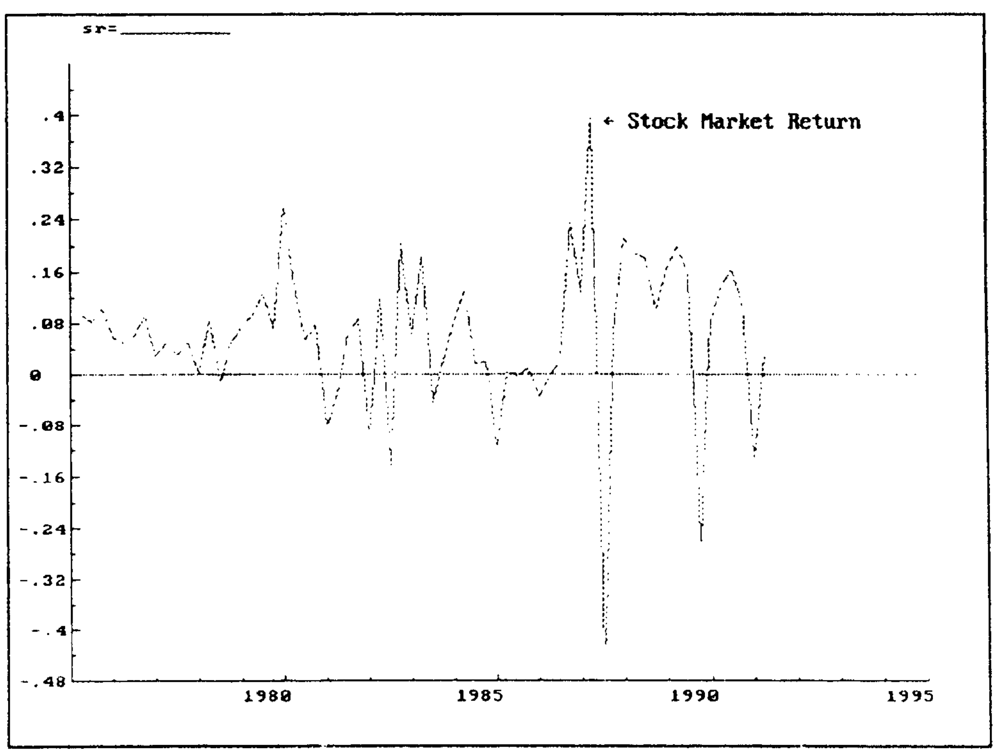


Chart 4. Total Stock Market Return (1975q1 - 1991q2)



III. Efficiency of the Singapore Stock Market

1. The "weak" form of the efficiency test

A capital market is said to be efficient if it fully and correctly reflects all relevant information in determining share prices. Three levels of efficiency have been used in the literature: the "weak" form, the "semi-strong" form and the "strong" form. The efficient Market Hypothesis (EMH) which asserts that prices should reflect the information contained in the historical sequence of prices. Thus, investors cannot devise an investment strategy to yield abnormal profits on the basis of past price patterns. Thus in this sense, if successive changes in prices are independent, they should follow a random walk model. To define the total return in the stock market, let p_t denote the price per share of a stock at time period t and d_t the dividend paid at time t. The (one-period) nominal return on a stock can be defined as follows: $sr_t = (p_{t-1} - p_t + d_t)/p_t$. It is equivalent to the total capital gains $(p_{t-1} - p_t)$ plus dividend earned d_t as a proportion of the initial investment (p_t). The graph of the stock return defined in this manner is shown in Chart 4 above.

The stock return defined above is tax unadjusted. Admittedly, in a more general context this is an important missing link. For instance, in her case study of the U.S. stock market, Beltratti (1989) argued that the Efficient Market Hypothesis could be rejected because of the forecastability of the tax component of before-tax stock market returns. Moreover, as Summers (1981) noted, the interaction of taxes and inflation, can have real effects on the valuation of capital if firms use nominal and not real accounting statements, which increases the real burden of taxation. Furthermore, Poterba and Summers (1984) show that temporary dividend tax changes can have real effects because of potential dividend-smoothing behavior on the part of firms. Hence current and expected future tax rates should be used by investors to assess the long-run productive potential of the economy, and as such should be included in the share price-dividend equation. These arguments notwithstanding, the models in this paper follow the "tax irrelevance view" of Miller and Scholes (1982). Using evidence from panel data, Bond et al. (1994) found that contrary to previous evidence there is little effect of taxes on dividend payments in the United Kingdom. In fact, for the case of Singapore, investors (domestic and foreign) are effectively untaxed on both dividends and other forms of capital gains and thus on total returns on equity investment (Huat (1990)). We shall also look at excess returns on a stock. In order to define the excess returns on stocks, we should define a yield for an alternative financial asset. Following Fama and French (1987b), we use the treasury bill rate (r_d) as the yield on the alternative asset. In the rest of the analysis, excess return is therefore defined as $(sr - r_d)_t$. The tables on the next page report the unit-roots test results for stock prices, stock returns, and excess stock returns. 1/

1/ The sample period used in this paper is from 1975Q1-1991Q2. Our vector autoregression (VAR) analysis has employed stock market varibales, aggregate demand and aggregate supply variables. Reliable data series on both the physical capital stock and human capital stocks ends in 1990 and this has constrained the econometric analysis to this sample period. To maintain uniformity across the three VARs, the paper has reported the results for the same sample period. Future extensions will extend the sample period and test the robustness of the results with most recent data

Table 1. Unit-Roots Tests of the Variables, Augmented Dickey-Fuller (ADF) and Cointegrating Regression Durbin-Watson Statistics (CRDW)- (1975q1 - 1991q2)

Variable	ADF coefficient	T-Statistic	Longest Lag	CRDW
p	-0.0932	-1.712	4	0.228
Δp	-0.6360	-4.308**	3	1.545**
sr	-0.1388	-4.279**	3	0.706**
Δsr	-0.8227	-6.165**	6	0.991**
$(sr - r_d)$	-0.1060	-3.238*	5	0.811**
$\Delta(sr - r_d)$	-0.7825	-5.441**	2	1.053**

Table 2. Phillips and Perron (1988) Z_α and $Z(t)_\alpha$ Statistics- (1975q1 - 1991q2)

Variable	$Z(\alpha)$	$Z(t_\alpha)$
p	-1.652	-0.707
Δp	-18.33*	-10.24*
sr	-17.02*	-9.662*
Δsr	-38.71**	-27.09**
$(sr - r_d)$	-15.11*	-7.002*
$\Delta(sr - r_d)$	-39.23**	-25.46**

Note: (i) A further test for the "weak" form of efficiency was carried out via the following Augmented Dickey-Fuller (1981) (ADF) equation,

$$\Delta(sr)_t = \alpha_0 + (\alpha_1 - 1)sr_{t-1} + \alpha_2 \Delta sr_{t-i} + \epsilon_t,$$

in which market efficiency was tested for by imposing the following joint restriction on (i): $\alpha_1 = 1$, $\alpha_2 = 0$. This joint restriction follows a $\chi^2(2)$ distribution and is rejected by the data on both stock returns (Δsr) and excess stock returns $\Delta(sr-r_d)$. This test result provides evidence against the nonstationarity of both stock returns and excess stock returns.

(ii) A deterministic trend is included in all the ADF regressions and found to be insignificant for all the data variables above. In computing the Z statistics, four auto-covariances are used as in Phillips and Perron (1988). In both tables, * and ** denote significance at the 5 percent and 1 percent levels respectively.

Chart 5. Recursively Computed ADF *t-statistics for the* Straits Times Index (STI) p_{-1} in the ADF Regression

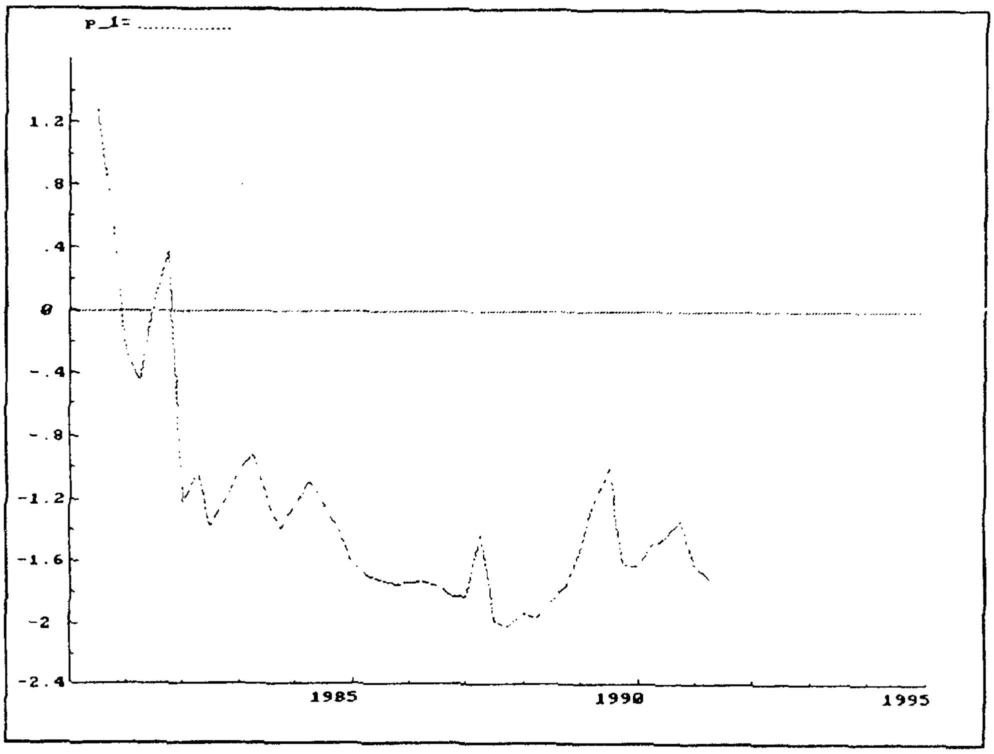
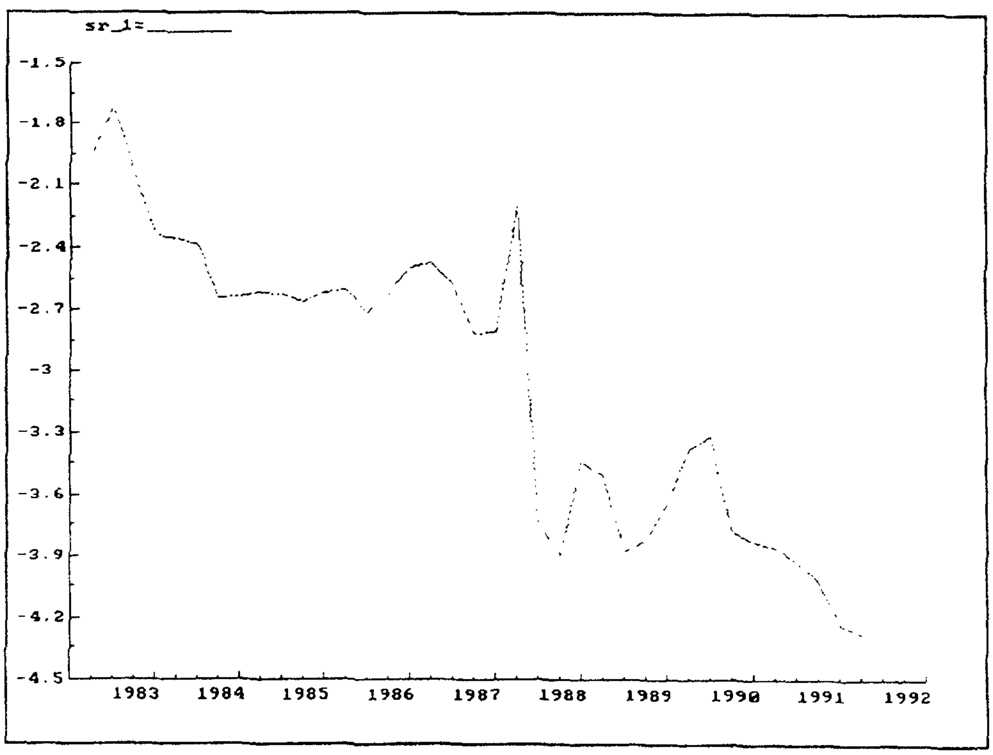


Chart 6. Recursively Computed ADF t-satistics for the Total Returns on Stocks sr_{-1} in the ADF Regression



The three unit-roots tests are conclusive on the nonstationarity of the stock price index (p), an I(1) variable, and the stationarity of both total return on stocks (sr) and excess returns on stocks (sr - r_d), (that is, I(0)). Further analysis of the stationarity properties of the variables through the recursively computed ADF t-statistics (Dickey & Fuller (1981)) shown in Charts 5 and 6, reveals that, though these are highly variable, the p_t and sr_t variables are for the most part of the sample period clearly I(1) and I(0) variables, respectively. These results suggest that stock returns are stationary and therefore the market is efficient in the weak sense, in that successive changes in prices are independent and unpredictable.

The weak form of the test of market efficiency is relatively less robust in that it does not establish that financial markets are efficient in terms of rationally reflecting fundamentals. Summers (1986) and Poterba and Summers (1987) have shown that this testing methodology lacks the power to reject the hypothesis of market efficiency, even though market valuations frequently differ significantly from the rational expectation of the present value of future cash flows. Furthermore, Shiller (1984) and Poterba and Summers (1987) have established that unpredictability in the short-horizon returns is compatible with predictability in the long-horizon returns. In other words, it is quite possible that stock prices are non-stationary over short periods of time, but have a tendency to mean reversion over longer periods. Conversely, predictability of share and stock prices in the long-run horizon as documented in Poterba and Summers (1987) does not even imply irrationality, Fama and French (1988a). Consequently, we tentatively accept the result from the weak form of the test that the Singapore stock market is efficient and move on to the semi-strong form of the test.

2. The "semi-strong" form of efficiency test

The "semi-strong" form of the EMH asserts that current stock prices not only reflect historical price information, but also all publicly available information relevant to a company's securities (Fama (1970)). Thus in this sense efficiency implies that income statements, announcements of dividend changes, or any other public information about a company will not yield abnormal economic profits. The "strong" form of the EMH asserts that all information that is known to any market participant about a company is fully reflected in markets. Hence, not even those with privileged information can make use of it to secure superior investment results. There is thus perfect revelation of all private information in market prices.

To conduct this test of stock market efficiency, we shall examine the relationship between the real stock market return and macroeconomic fundamentals of the Singapore economy in a vector autoregression (VAR). The advantage of employing the VAR within this context is that market efficiency can be tested for both the short and long run. In particular, cointegration techniques may be used in order to test for stock market efficiency. For instance, Granger and Escribano (1986) argue that two prices generated by an efficient market, by definition, cannot be cointegrated, as that implies that one variable can be used to forecast another.

Campbell and Shiller (1987) used this testing methodology, which is potentially able to deal with the nonstationarity of dividends issue that was in response to Shiller's (1981a) earlier work by employing a stationary linear combinations of nonstationary series. Using a VAR framework, that explicitly models the mechanism according to which expectations are formed, they tested the rational expectations present value model implied by the EMH by putting restrictions on the matrix of estimated coefficients in the VAR. Although relatively less conclusive, their results generally confirm Shiller's (1981b) original findings of excess market volatility and therefore stock market inefficiency. Recently, Cerchi and Havenner (1988) have established that prices of five different stocks over the period 1972-79 are cointegrated. While this also seems to contradict the EMH, the point made by Campbell and Shiller (1988) in the context of the dividend/price relationship may be of relevance here. The presence of noise in stock markets may be due to fads in which case we have a near rational expectations model in which ex post there seem to be profitable opportunities, but ex ante the observed relationship may be merely a statistical illusion.

In this subsection, we shall employ the Campbell and Shiller (1987) cointegration methodology of testing market efficiency to the SES. Under the semi-strong hypothesis of stock market efficiency, none of the fundamental macroeconomic variables in Singapore should be useful to forecast stock returns, since if the null hypothesis is true, then all the relevant information should have been already incorporated in the stock return model. The Campbell and Shiller (1987) model is however a bivariate VAR. Developing their techniques further in a semi-strong context, we have expanded the information set by including other relevant macroeconomic variables. Within this framework, the efficient market test is based on a number of extra macroeconomic variables that determine the fundamental growth path of the Singapore economy. 1/ These results allow us to test for the semi-strong form of market efficiency in three VAR systems in which our respective expanded information sets consist of aggregate demand and aggregate supply monetary macroeconomic variables.

The three VAR systems framework will enable us to test much more rigorously the EMH in a semi-strong context but with a richer set of macroeconomic variables compared with those of Campbell and Shiller (1987) and Beltratti (1989). Equations 1, 2, and 3 describe the three respective VARs systems.

1/ Leigh (1995) has developed endogenous growth econometric models using aggregate demand and aggregate supply variables.

$$\begin{bmatrix} (sr-\pi)_t \\ c_t \\ i_t \\ x_t \\ rer_t \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} & a_{46} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & a_{56} \end{bmatrix} \begin{bmatrix} (sr-\pi)_{t-1} \\ c_{t-1} \\ i_{t-1} \\ x_{t-1} \\ rer_{t-1} \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} (sr-\pi)_t \\ k_t \\ l_t \\ fdc_t \\ hc_t \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} & b_{16} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} & b_{26} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} & b_{36} \\ b_{41} & b_{12} & b_{43} & b_{44} & b_{45} & b_{46} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} & b_{56} \end{bmatrix} \begin{bmatrix} (sr-\pi)_{t-1} \\ k_{t-1} \\ l_{t-1} \\ fdc_{t-1} \\ hc_{t-1} \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} (sr-\pi)_t \\ (m2-p)_t \\ y_t \\ (r_d-\pi)_t \\ (r_f-\pi)_t \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} & c_{15} & c_{16} \\ c_{21} & c_{22} & c_{23} & c_{24} & c_{25} & c_{26} \\ c_{31} & c_{32} & c_{33} & c_{34} & c_{35} & c_{36} \\ c_{41} & c_{42} & c_{43} & c_{44} & c_{45} & c_{46} \\ c_{51} & c_{52} & c_{53} & c_{54} & c_{55} & c_{56} \end{bmatrix} \begin{bmatrix} (sr-\pi)_{t-1} \\ (m2-p)_{t-1} \\ y_{t-1} \\ (r_d-\pi)_{t-1} \\ (r_f-\pi)_{t-1} \end{bmatrix} \tag{3}$$

If the vector of macroeconomic variables is represented by Z_t, then the three VARs can be simply described by $Z_{1t} = AZ_{1t-i} + \epsilon_{1t}$, $Z_{2t} = BZ_{2t-i} + \epsilon_{2t}$ and $Z_t = CZ_{3t-i} + \epsilon_{3t}$, and it is these relations that describe the mechanism that agents use to forecast variables in the sense that, $E_t\epsilon_t = 0$ and $E_tZ_{1t-i} = A'Z_{1t}$, $E_tZ_{2t-i} = B'Z_{2t}$ and $E_tZ_{3t-i} = C'Z_{3t}$. The semi-strong form of the EMH can be tested for by restricting the elements of the companion matrices of A, B, and C. This is because under the null hypothesis of stock market efficiency or no effect of bubbles or fads in the stock market the extra macroeconomic variables should not be significant in the VAR. 1/

The three VARs are each based on a different system. The VAR in equation 1 is based on a variant of the aggregate demand system with consumption (c), investment (i) and exports (x) all expressed in real terms together with the real exchange rate (rer) and the real stock market return ($sr - \pi$). Thus the analysis in the aggregate demand VAR follows studies by Fama and French (1989) and Barro (1989) in which they show that there exists a significant relationship between stock market returns, consumption, and investment. The VAR in equation 2 has a real stock market return dynamic equation embedded in an augmented aggregate production function. The vector elements of the augmented production function VAR are the capital stock (k), labor variable (l), financial development variable (fdc) and human capital (hc). 2/ Finally, in equation 3 the efficient market hypothesis is tested in a money demand VAR. This system consists of real stock market returns ($sr - \pi$), real money balances ($m - p$), real income (y), real domestic interest rate ($r_d - \pi$) and real foreign rate of return ($r_f - \pi$). Fama (1981) and Fama and Gibbons (1982) found significant relationship between stock market returns, inflation, money and real variables. The VARs enable us to ignore the terminal conditions of the types described by Shiller (1981b) where the last sample stock price and dividend is used to calculate backward the perfect foresight price.

1/ This form of testing for market efficiency is thus analogous to tests described in the recent literature as "event studies". Event studies examine the speed at which stock prices react to firm-specific event announcements such as earnings. Quick adjustment to such announcements is consistent with market efficiency.

2/ The labor variable is proxied by employment per total hours worked. The financial development variable is proxied by the credit to GDP ratio and the human capital variable is defined by the weighted average of the rate of schooling of the labor force. Detailed descriptions of this are available from Leigh (1995).

Table 3. The Johansen Procedure: Equation 1 VAR with Five Lags, and a Constant for sr - π (Sample is 1976Q3 - 1991Q2)

The test statistics: 1/ 2/
(Testing the number of cointegrating vectors)

Test	$\rho=0$	$\rho\leq1$	$\rho\leq2$	$\rho\leq3$	$\rho\leq4$
μ_i	0.317	0.267	0.232	0.085	0.009
Trace	63.17	40.33	21.66	5.846	0.546
5%CV	68.5	47.2	29.7	15.4	3.8
μmax	22.84	18.68	15.81	5.3	0.546
5%CV	33.5	27.1	21.0	14.1	3.8

The eigenmatrix, β′

β′	*sr-π*	*c*	*i*	*x*	*rer*
1	1.00	-4.601	-8.381	2.837	5.692
2	0.01	1.00	0.94	-0.705	-0.42
3	-0.247	0.037	1.00	0.37	-1.547
4	0.240	-1.156	3.15	1.00	-2.95
5	-0.74	-0.167	-0.48	-0.207	1.00

1/ Trace is equivalent to $-T\sum\log(1-\mu_i)$.
2/ μmax is equivalent to $-T\log(1-\mu_i)$.

Table 4. The Johansen Procedure: Equation 2 VAR with Four Lags, a Constant, and Trend for sr - π (Sample is 1976q2 - 1991q2)

The test statistics:
(Testing the number of cointegrating vectors)

Test	ρ=0	ρ≤1	ρ≤2	ρ≤3	ρ≤4
μ_i	0.467	0.306	0.219	0.123	0.079
Trace	85.88	48.74	27.21	12.64	4.883
5%*CV*	87.3	63.0	42.4	25.3	12.2
μmax	37.15	21.53	14.57	7.754	4.883
5%*CV*	37.5	31.5	25.5	19.0	12.2

The eigenmatrix, β′

β′	*sr-π*	*k*	*l*	*fdc*	*hc*	*Trend*
1	1.00	-3.504	4.301	4.896	2.240	-0.009
2	-0.004	1.00	0.201	-1.45	-0.09	0.001
3	-1.988	-5.374	1.00	-5.672	9.209	0.034
4	0.013	-0.464	0.05	1.00	-0.167	0.019
5	-1.039	2.663	0.036	-4.34	1.00	0.006

Table 5. The Johansen Procedure: Equation 3 VAR with Six Lags, a Constant, and Seasonal Dummies 1/ for sr-π (Sample is 1976q4 - 1991q2)

The test statistics:
(Testing the number of cointegrating vectors)

Test	ρ=0	ρ≤1	ρ≤2	ρ≤3	ρ≤4
μ_i	0.645	0.532	0.191	0.153	0.003
Trace	128.4**	67.31**	22.5	9.989	0.185
5%*CV*	68.5	47.2	29.7	15.4	3.8
μmax	61.09**	44.82**	12.51	9.81	0.185
5%*CV*	33.5	27.1	21.00	14.1	3.8

The eigenmatrix, β′

β′	*sr*−π	*m2*−*p*	*y*	$r_d-\pi$	$r_f-\pi$
1	1.00	43.08	177.2	102.1	130.5
2	0.002	1.00	-0.991	4.73	5.286
3	1.167	-0.86	1.00	2.478	1.145
4	0.1172	-0.082	0.116	1.00	0.009
5	-0.073	-0.587	0.339	1.824	1.00

1/ Note that PC-FIML version (7.01) does not report the coefficients of seasonal dummies in the estimated eigenmatrix β′ of the VAR.

Tables 3, 4, and 5 report the cointegration analysis of the VARs described in equations 1, 2, and 3, respectively. Tables 3 and 4 report the estimated cointegration results for the aggregate demand and aggregate production VAR, respectively. As is evident from the two tables, the null hypothesis of no cointegrating vectors between real stock market return (sr - π) and the macroeconomic variables cannot be rejected in both systems. This suggests that long-run semi-strong efficiency holds in the Singapore stock market.

Table 5 presents the cointegration results for the VAR in equation 1. This analyzes the long-run relationship between real stock market return and money demand variables. According to the test statistics for cointegration, there are two significant cointegrating relationships between real stock returns and money demand variables. Prima facie, this suggests that the long-run real stock market return (sr - π) is predictable from a linear combination of real money balances (m - p), real income (y), real domestic interest rate (r_d - π), and real foreign rate of return (r_f - π), which rejects the null hypothesis of semi-strong efficiency. However, the first cointegrating vector normalized on real stock returns (sr - π) and corresponding to β' 1 in the eigenmatrix is difficult to interpret. More importantly, the implausiblity of the huge long-run elasticities with respect to real stock market return (sr - π) is a significant feature and warrants some caution. Moreover, although the second cointegrating vector in the eigenmatrix β' 2 normalized on (m - p) and summarized on the next page is an economically meaningful relationship, it mimics a money demand equation in which the real stock return is not a significant determinant of real money holdings. On the basis of this, we do not regard this cointegrating vector (β' 2),

$$\begin{pmatrix} sr-\pi & m-p & y & r_d & r_f \\ \\ 0.002 & 1.00 & -0.991 & 4.73 & 5.286 \end{pmatrix}$$

as evidence for semi-strong inefficiency in the SES. Rather, we can interpret this cointegrating vector as a long-run money demand equation. However, the analysis of the cointegrating results shown above can only be regarded as a partial test for long-run semi-strong efficiency. In order to implement a full systems test, we must conduct a likelihood ratio test (L.R) and impose restrictions on the estimated eigenmatrix β', in which the null hypothesis is semi-strong stock market efficiency. To test the validity of this hypothesis in the three systems being analyzed here, we can impose a restriction of the form,

$$H_o\colon \beta = C\phi$$

where C is a p $\times$ s matrix of constraints and ϕ the corresponding s $\times$ v matrix of unrestricted parameters. The likelihood ratio test of the significance of this restriction is,

$$-2\ln(Q{:}H) \quad = \quad T\sum \ln \left(\frac{(1 - \mu *_i)}{(1 - \mu_i)} \right) \tag{4}$$

which is distributed as χ^2 with v(p-s) degrees of freedom (Johansen and Juselius (1990)).

Table 6 reports the details of the various asymptotic test statistics and the efficiency implications thereof. In the aggregate demand and aggregate supply VARs there was clearly no cointegration but we can assume cointegration thus imposing the null hypothesis of semi-strong inefficiency. In both systems this null is rejected by the L.R test which thus negates semi-strong inefficiency. In the money demand VAR the null hypothesis is that of semi-strong efficiency. This is accepted by the likelihood ratio (L.R) test.

The rejection of the null hypothesis of stock market inefficiency and the acceptance of the alternative in both the aggregate demand and aggregate production function system is a significant result. Since the variables in the two systems are the fundamental determinants that govern the growth path of the Singapore economy (Leigh (1995)), the results not only corroborate the earlier evidence that there is no contemporaneous cointegrating equilibrium relationship between the real stock market return and the macroeconomic fundamentals, but also suggest that the stock market of Singapore is robustly semi-strong efficient. The results of the likelihood ratio test using excess real stock market returns are qualitatively analogous to the results for total real stock market returns.

Table 6 Likelihood Ratio (L.R) Test Results for Semi-Strong Efficiency 1/

Restriction	L.R Critical Value $\chi^2_{0.05}(v(p-s))$	Calculated L.R $\chi^2_{0.05}(v(p-s))$	Semi-Strong Efficient?
$\begin{pmatrix} 1.0 & 0 & 0 & 0 \\ -4.6 & 0 & 0 & 0 \\ -8.4 & 1 & 0 & 0 \\ 2.8 & 0 & 1 & 0 \\ 5.7 & 0 & 0 & 1 \end{pmatrix}$	$\chi^2(4) = 8.19$	$\chi^2(4) = 15.24$	*Yes*
$\begin{pmatrix} 1.0 & 0 & 0 & 0 & 0 \\ -3.5 & 0 & 0 & 0 & 0 \\ 4.3 & 1 & 0 & 0 & 0 \\ 4.9 & 0 & 1 & 0 & 0 \\ 2.2 & 0 & 0 & 1 & 0 \\ -0.0 & 0 & 0 & 0 & 1 \end{pmatrix}$	$\chi^2(5) = 10.2$	$\chi^2(5) = 21.03$	*Yes*
$\begin{pmatrix} 0.0 & 0 & 0 & 0 \\ 1.0 & 0 & 0 & 0 \\ -1.0 & 1 & 0 & 0 \\ 4.7 & 0 & 1 & 0 \\ 5.3 & 0 & 0 & 1 \end{pmatrix}$	$\chi^2(4) = 7.73$	$\chi^2(4) = 4.56$	*Yes*

1 The restriction matrices are imposed on the estimated eigenmatrices β' of the aggregate demand, the aggregate production function, and the money demand VAR systems described in equations 1, 2, and 3, respectively. The presence of an extra variable in the second VAR eigenmatrix denotes the significance of the trend term in the estimated aggregate production function VAR reported in Table 4.

IV Efficiency of the Singapore Stock Market: Stock Price Volatility (Variance-Bound Test)

1 Motivation and formalization

Shiller (1981b) and LeRoy and Porter (1981) pioneered the test of market efficiency that focuses on the stock price variance. Shiller's work at the beginning of the 1980s (1981b, 1981c, 1984) disputed the assertion of the EMH that stock prices reflect fundamental valuations. In Shiller (1981b), he compared the actual Standard and Poor's (S & P) composite price index and the "rational expectations perfect foresight" price, defined by the sum of discounted future dividends. The latter is assumed to be the fundamental price that would have prevailed had investors correctly forecast the stream of future dividends. He found that stock prices are far too volatile relative to dividends, yielding the conclusion that stock price movements cannot just be justified by subsequent changes in dividends. 1/ Shiller used a deterministic detrending method which implies that all the variables are stationary around a deterministic trend. Under this assumption, the sample variances of the detrended series converge to the corresponding population variances. The sample variances are thus used to conduct the variance-bound test.

This methodology has been disputed on several grounds. In particular, Nelson and Kang (1983) illustrated the general problem that arises from deterministically detrending a time series that is actually stationary around a stochastic trend. Moreover, Mankiw and Shapiro (1986) noted the importance of this bias in testing the rational expectations model. More significantly, Marsh and Merton (1986) pointed out that dividends may be non-stationary because of decisions by managers to smooth the return obtained by stockholders and consequently Shiller's deterministic detrending procedure could not be valid. They show that under a plausible dividend pay-out rule which makes dividends a random walk, the standard volatility test finds excess volatility in every sample even though the efficient markets model is correct. Flavin (1983) examined the small sample properties of the volatility test and show that they are extremely biased toward finding excess volatility.

1/ Shiller's (1981b) model of the variance-bound test can be summarized as follows: let p'_t be the ex post price of an asset, that is, the price that an asset would have had at the time t if future dividends had been known with perfect foresight at time t This ex post price is therefore given by.

$$p'_t = \sum_{i=0}^{\infty} a^{i-1} d_{t-i}$$

where $a = 1/(1 + r)$ is the discount factor and r is the interest rate. From the definition of p'_t, it follows that $p'_t = p_t + \epsilon_t$, where p_t is the actual price, $E(\epsilon_t | p_t) = 0$ and E denotes the mathematical expectations operator. This is the key rational expectations insight that forms the basis of the Shiller variance-bound test. The difference between the ex post price and the actual price should be uncorrelated with the current price. Assuming that the variances of p'_t and p_t exist and taking variances in the last equation, we obtain $\sigma^2(p') = \sigma^2(p) + \sigma^2(\epsilon)$, which implies that $\sigma^2(p') \geq \sigma^2(p)$, and it is this inequality that Shiller tested.

Campbell and Shiller (1987) and West (1988b) subsequently tried to address some of the problems inherent in the Shiller (1981b) approach The theoretical underpinnings of the variance-bound test outlined by Campbell and Shiller (1987) are formalized below. According to the rational expectations present value model for a stock price-dividend relationship,

$$P_t = \theta(1 - \delta)\sum\nolimits^{\infty}_{i=0}\delta^i E_t d_{t-i} + c, \qquad (5)$$

where P_t is the stock price, d_t is dividends, c is a constant, θ the coefficient of proportionality, and δ the discount factor. The stock-price dividend "actual" innovation with respect to the full market information set I_t is given by,

$$\xi_t = P_t - [1/\delta)(P_{t-1} - \theta(1 - \delta)d_{t-1}]. \qquad (6)$$

Defining a new variable $S_t = P_t - \theta d_t$ where S_t is called the "actual" spread, Campbell and Shiller showed that the "theoretical" spread is related to the "actual spread" and thus,

$$S'_t - S_t = \sum\nolimits^{\infty}_{i=1}\delta^i E(\xi_{t+i}|I_t). \qquad (7)$$

In the context of the stock price-dividend relationship, the spread variable here represents the difference between the stock price and a multiple of dividends. The stock price-dividend "theoretical" innovation is given by,

$$\xi'_t = (1 - \delta)P_t + [(\delta - 1)/(\delta)]P_{t-1} + [\theta(\delta - 1)^2/\delta]d_{t-1} - [\theta/\delta(1 - \delta)]d_{t-2} \qquad (8)$$ 1/

Under the present value model $\xi_t = \xi'_t$, that is, the "actual" stock price-dividend innovation is equal to the "theoretical" innovation since

$S_t = S'_t$, 2/ that is, the "actual" spread is equal to the "theoretical" spread. The variance-bound test is conducted by computing the variance ratio $\sigma^2(\xi)_t/\sigma^2(\xi')_t$ because under the null hypothesis

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1/ As in Campbell and Shiller (1987), this can be seen by defining the "theoretical" innovation variable as,

$$\xi'_t = \theta\sum\nolimits^{\infty}_{i=0}\delta^i E[(\Delta d_{t-i}|I_t) - E(\Delta d_{t-i}|I_t)]$$

$$= S'_t - (1/\delta)(S'_{t-1}) + \theta\Delta d_t. \qquad (i)$$

2/ Proof. Substituting S_t as defined by Campbell and Shiller (1987) into (i) as in footnote 1 of the previous page, collecting terms and simplifying yield,

$$\xi'_t = P_t - (1/\delta)P_{t-1} + (\theta/\delta)d_{t-1} - \theta d_{t-1} \qquad (ii)$$

Thus $\xi_t = \xi'_t$ Q.E.D.

of market efficiency this ratio should be 1, while a value beyond 1 implies excess market volatility and therefore market inefficiency. The "theoretical" innovation variance $\sigma^2(\xi')_t$ thus provides the upper bound to the "actual" innovation variance $\sigma^2(\xi)_t$.

While the focus of previous studies has been on improving the specification of the innovation equations used to conduct the variance-bound tests, less attention has been given to the appropriate measure of the innovation variances. Empirical researchers typically measure $\sigma^2(\xi)_t$ by taking the standard error of the stock price-dividend equation (see Shiller (1981b,c)). Campbell and Shiller (1987) used the estimated variance-covariance matrix of the stock price-dividend VAR to compute the innovation variance ratio, without modeling the true process that generates the variances of these innovations (see West (1988b) for a similar method). That ARCH effects are prevalent in equity markets is well established in the financial time series literature. For example, highly significant test statistics for ARCH have been reported for individual stock returns by Engle and Chowdhury (1992). Below we follow the efficient market theoretical schema as in Campbell and Shiller (1987) and West (1988b) but conduct a second-generation variance-bound test based on the appropriate modeling of variances of the stock price-dividend innovations.

2. Modeling the variance structures of the actual $(\xi)_t$ and the theoretical $(\xi')_t$ innovations

In this subsection we shall compute the innovations ξ_t and ξ'_t via equations (6) and (8), respectively. In order to obtain the innovation terms (ξ_t and ξ'_t) we need to estimate the constant parameter terms in the innovation equations. Following Campbell and Shiller (1987), we shall use the estimated cointegrating relationship between stockprice and dividend to compute the constant parameters values of θ and δ.

The rational expectations present value model of the EMH constrains $\theta = \delta/(1 - \delta)$. The discount factor δ is not known a priori but can be inferred by estimating the stock price-dividend cointegrating vector. For Singapore, the estimated stock price-dividend (p, d, c) cointegrating vector including a constant c is, 1/

$$\begin{pmatrix} p & d & c \\ 1.00 & -17.24 & 3.69 \end{pmatrix}$$

The estimate of θ from the cointegrating vector above is thus 17.24, from which the implied discount factor δ is equivalent to 0.945 with a constant term c equal to 3.69. This analysis yields an estimated discount rate of 5.8 percent. As Campbell and Shiller (1987) noted,

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1/ Campbell and Shiller (1987) employed the Engle-Granger (1987) two-step OLS procedure for estimating the cointegrating relationship between stock price and dividends and thus θ and δ. In contrast, in this paper we employ the Johansen-Juselius (1990) multivariate VAR cointegration approach.

a second consistent estimate for the discount rate is also provided by the sample mean return on stocks. The mean stock return in the SES is equal to 5.99 percent for our sample period which therefore corroborates the estimate of θ from the above cointegration analysis.

These estimates of θ and δ together with the stock price-dividend data, are then employed in equations (6) and (8) in order to generate time-series values of the "actual" innovation (ξ_t) and the "theoretical" innovation (ξ'_t). The presence of ARCH effects in ξ_t and ξ'_t innovations are then tested for using various lag structures, and Table 7 below reports the test statistics. We present two sets of diagnostics: the ARCH test along the lines of Engle (1982) and White's (1980) test for general heteroscedasticity. 1/ The Engle (1982) ARCH test reports the test statistics for both first order and fourth order lags. A detailed description of the basic formal intuition behind the ARCH, GARCH and IGARCH models of finance is provided in Appendix II.

Table 7. Tests for Heteroscedasticity in ξ_t and ξ'_t Innovation Residuals by ARCH Tests in Engle (1982) and White (1980)

Innovation Variable	ARCH $\chi^2(1)$	ARCH $\chi^2(4)$	X_iX_j $\chi^2(2)$
ξ_t	35.356**	31.332**	7.901*
ξ'_t	15.863**	12.114**	6.060*

As is evident from the table both tests reject the hypothesis of independent and identically distributed (i.i.d) innovation errors: there are significant ARCH effects in both innovation residuals. On the basis of the tests results above, the "actual" innovation $(\xi)_t$ and the "theoretical" innovation $(\xi')_t$ residuals are not white noise. The variance structures $(\sigma^2)_t$ are then modeled assuming that error disturbances follow a particular ARCH process. As in Engle (1982) our variance models are assumed to be two-parameter models largely because it seemed unlikely that numerical optimization of the more general model would be successful in light of the restriction that all αs must be positive to ensure positive variances. Following Engle (1982) but with some modifications to serve our purpose here, it is assumed that the weights declined linearly according to the following model,

1/ The Engle (1982) ARCH diagnostic statistic in our context here, is obtained by running a regression of ξ^2_t on a constant and ξ^2_{t-1} to ξ^2_{t-r}. White's (1980) test involves a regression of ξ^2_t on the regressors ξ_{t-1} and all their squares ξ^2_{t-r} and the null is unconditional homoscedasticity. The test statistics in both cases are asymptotically distributed as $\chi^2(r)$ and these are reported here. Equivalent F-forms exist, though.

$$\sigma^2(\xi)_t = \alpha_0 + \alpha\Sigma^4_{j=1}(4 - j)\xi^2_{t-j}/16. \qquad (9)$$

A similar assumption is made in modeling $\sigma^2(\xi')_t$. Alternative assumptions were explored for both $\sigma^2(\xi)_t$ and $\sigma^2(\xi')_t$ but these did not yield any significant changes in the estimated variance models. Table 8 below reports the ARCH and GARCH dynamic models for innovation variances ($\sigma^2(\xi)_t$ and $\sigma^2(\xi')$.

Table 8. ARCH and GARCH Models for Innovation Variances $\sigma^2(\xi)_t$ and $\sigma^2(\xi')_t$ 1/

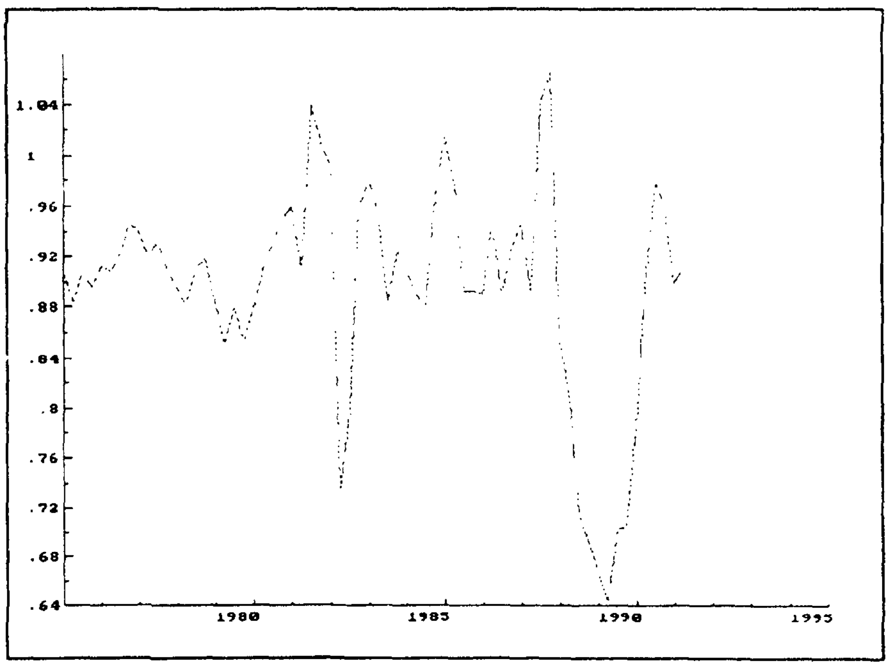
	ARCH	GARCH
$\sigma^2(\xi)_t$	$0.0005 + 0.49\xi^2_{t-2} + 0.23\xi^2_{t-3}$	$0.0001 + 0.32\xi^2_{t-2} + 0.16\xi^2_{t-3} + 0.4\sigma^2(\xi)_{t-1}$
$\sigma^2(\xi')_t$	$0.0008 + 0.57\xi'^2_{t-1} + 0.28\xi'^2_{t-2}$	$0.0003 + 0.5\xi'^2_{t-1} + 0.2\xi'^2_{t-2} + 0.6\sigma^2(\xi')_{t-1}$

Having established ARCH models for the actual innovation variance $\sigma^2(\xi)_t$ and theoretical $\sigma^2(\xi')_t$ innovation variance complemented by their corresponding GARCH models, we now conduc the Shiller (1981b) variance-bound tests of stock market volatility for the SES. The innovation here which is in contrast to Shiller (1981b,c), Campbell and Shiller (1987), and West (1988b), is to employ the time-varying estimates of $\sigma^2(\xi)_t$ and $\sigma^2(\xi')_t$ from the estimated ARCH models, in order to conduct the variance-bound test recursively. The time series values for the ARCH estimates of the ratio of the two innovation variances $\sigma^2(\xi)_t/\sigma^2(\xi')_t$, are plotted in Chart 7; as the graph indicates, the null hypothesis of excess volatility is rejected for a large part of the sample period. The time series of the GARCH innovation variance ratios, though not reported here, is qualitatively analogous to the broad pattern depicted for the variance ratio $\sigma^2(\xi)_t/\sigma^2(\xi')_t$ in Chart 7. In both ARCH and GARCH graphs for the variance ratio, slight excess volatility occurred in 1981 and 1987 and during the economy-wide recession in 1985, while high fluctuations in the ratio occurred during the years 1989-90. As discussed in Section II, these periods coincided with various crashes in the SES. Consequently, taking these as outliers in our

1/ The tests for heteroscedasticity in ξ_t and ξ'_t innovation residuals were conducted in PC-GIVE while the variance models -- $\sigma^2(\xi)_t$ and $\sigma^2(\xi')_t$ --were estimated by STAMP.

sample, the evidence that emerged from the ARCH and GARCH variance-bound tests indicates that the Singapore stock market is on average efficient in asset-pricing terms. This corroborates the earlier results from the "weak" and "semi-strong" forms of stock market efficiency tests reported in Section III.

Chart 7. Recursively Computed Estimates of Innovation Variance Ratios $\sigma^2(\xi)_t / \sigma^2(\xi')_t$



3. Caveat

This analysis has employed a wide range of methods for testing stock market efficiency We find no significant evidence for inefficiency in the Singapore Stock Exchange. However, further econometric analysis indicates that although meaningful cointegration could not be achieved in the individual systems analyzed in subsection (ii) above, real stock return is found to cointegrate with a broader combination of macroeconomic variables from the three-VAR system. This enables us to accept the Engle-Granger Representation theorem (1987) and use the derived cointegrated solution to estimate an ECM model of real stock returns in Singapore. Appendix I reports the parsimonious ECM model in which real stock returns (sr - π) are determined by output (y), consumption (c), domestic interest rate (r_d), real exchange rate or "competitiveness" (rer), broad money balances (m2 - p), stock market wealth (smw), and the capital stock (k), all expressed in real terms. The difficulty experienced in identifying and establishing the ECM model of real stock returns is reflected in the complexity of the dynamics of the model as well as the lag structures of the significant variables. This difficulty notwithstanding, the diagnostic tests of the estimated real stock return model are good. More significantly, the one step-ahead forecasts of real stock returns for the last ten quarters of the sample period indicate good forecasting performance of the ECM model.

The implication of this in the context of the key theme being addressed in the paper is that even though the stock market in Singapore is reasonably efficient, it may not "strongly" efficient. While this does not weaken the role played by financial markets in Singapore, the forecastability of real stock returns by an estimated parsimonious dynamic ECM model here does provide a caveat to the efficiency results established by this paper for the Singapore stock market.

V. Granger Causality Test Between Stock Market Values and the Growth of the Singapore Economy

From the evidence presented above, it would appear that the stock market in Singapore is both "weakly" and "semi-strongly" efficient: current share prices not only capture information contained in past prices but also reflect fundamental macroeconomic variables that determine growth in Singapore. If share prices in the SES are efficient, then according to Blanchard's (1981) model the market would anticipate the future direction of the Singapore economy. The implication of this is that there should be a relationship between past growth in stock market values and current growth in output, but not conversely. In order to establish this, one needs to conduct causality tests. These tests are not concerned with policy analysis or prediction, nor are they testing for a causal link based on structural restrictions from the theoretical model in Blanchard (1981). Rather, we are interested in the implications of that model, that is, whether past growth in the value of the stock market helps to explain current growth in output that has not been explained by past growth in output already.

The Granger causality test involves the following regression:

$$\Delta y_t = a_0 + a_1 \Delta y_{t-1} + \ldots + a_m \Delta y_{t-m} + b_1 \Delta x_{t-1} + \ldots + b_n \Delta x_{t-n} + \epsilon_t, \qquad (10)$$

where y is level of real output (GNP), x is the stock market value (proxied here by stock market capitalization of the SES), and ϵ_t follows a white-noise path. The null hypothesis is that past values of Δx do not significantly explain Δy, that is,

$$H_0\ (\Delta y, \Delta x):\ b_1 = b_2 = . = b_n = 0.$$

A test for the direction of the causality would then involve running a second regression:

$$\Delta x_t = c_0 + c_1 \Delta x_{t-1} + \ldots + c_m \Delta x_{t-m} + d_1 \Delta y_{t-1} + \ldots + d_n \Delta y_{t-n} + \epsilon_t, \tag{11}$$

and testing the null hypothesis,

$$H_0\ (\Delta x, \Delta y):\ d_1 = d_2 = . = d_n = 0.$$

A rejection of H_0 $(\Delta y,\Delta x)$ and a failure to reject H_0 $(\Delta x,\Delta y)$ would imply that causality runs one way, from Δx to Δy. In conducting the tests, we focus on real rather than nominal variables since the stock market is thought to be a good hedge against inflation and a causal relationship between nominal variables might in fact be due to general prices. Estimating equations (10) and (11) using data on Δy and Δx yields the following regression equations,

$$\begin{aligned} \Delta y_t = \ & \underset{[0.904]}{0.076} + \underset{[5.643]}{1.123\Delta y_{t-1}} + \underset{[1.816]}{0.052\Delta y_{t-2}} - \underset{[-0.253]}{0.226\Delta y_{t-3}} \\ & + \underset{[3.301]}{0.676\Delta x_{t-1}} - \underset{[-2.923]}{0.531\Delta x_{t-2}} - \underset{[-2.014]}{0.389\Delta x_{t-3}} \end{aligned}$$

$$T = 1975(4) - 1991(2)\ \textit{less}\ 10\ \textit{forecasts},$$

$$R^2 = 0.598,\ \sigma = 0.0154,\ DW = 1.85,$$

$$\textit{Chow}\ F(10,46) = 0.77,\ \textit{Forecast}\ \chi^2(10)/10 = 0.936,$$

$$\textit{Normality}\ \chi^2(2) = 0.30,\ AR\ 1\text{-}4\ F(4,60) = 1.312,$$

$$ARCH\ F(4,38) = 0.164,\ X_iX_j\ F(12,33) = 1.17,\ RESET\ F(1,45) = 0.5$$

(12)

$$\Delta x_t = \underset{[1.340]}{0.053} + \underset{[8.525]}{1.092\Delta x_{t-1}} + \underset{[0.435]}{0.097\Delta x_{t-2}} - \underset{[-2.509]}{0.383\Delta x_{t-3}}$$

$$- \underset{[-1.016]}{0.069\Delta y_{t-1}} + \underset{[0.798]}{0.185\Delta y_{t-2}} - \underset{[-1.273]}{0.075\Delta y_{t-3}}$$

$$T = 1975(4) - 1991(2) \textit{ less } 10 \textit{ forecasts},$$

$$R^2 = 0.575, \quad \sigma = 0.0165, \quad DW = 2.06,$$

$$\textit{Chow } F(10,46) = 0.43, \quad \textit{Forecast } \chi^2(10)/10 = 0.8127,$$

$$\textit{Normality } \chi^2(2) = 1.13, \quad AR\ 1\text{-}4\ F(4,42) = 0.752,$$

$$ARCH\ F(4,38) = 0.16, \quad X_iX_j\ F(12,33) = 0.96, \quad RESET\ F(1,45) = 0.1 \tag{13}$$

The estimated equation (12) suggests that past growth in real stock market value (Δx) can help explain current growth in real output (Δy) up to three quarters ahead with variables Δx_{t-1} and Δx_{t-2} significant at both the 5 percent and the 1 percent levels. However, equation (13) indicates that past growth in real output (Δy) does not appear to explain current growth in real stock market value (Δx) even at the 10 percent significance level. The joint test that all the coefficients of lagged Δxs are zero in regression (12), that is, H_0 ($\Delta y,\Delta x$): $b_1 = b_2 = b_3 = 0$, yielded $\chi^2_{0.05}(3) = 12.42$ compared with the critical value of $\chi^2_{0.05}(3) = 7.81$ which thus rejects the null hypothesis. Conversely, the joint test that all the coefficients of lagged Δys are zero in regression (13), that is, H_0 ($\Delta x,\Delta y$): $d_1 = d_2 = d_3 = 0$, yielded $\chi^2_{0.05}(3) = 4.63$, which implies that the null hypothesis cannot be rejected. Thus causality runs only from Δx to Δy.

These results conform to the implications of the Blanchard (1981) model and suggest that current growth in the value of the Stock Exchange of Singapore is a reasonable indicator of future growth in real output in Singapore. The regression results are consistent irrespective of the combination of variables that is employed. Sensitivity analysis using an expanded "information set" which includes other macroeconomic variables that determine growth in Singapore did not radically alter the above-noted conclusion. Thus developments in the SES appear to be systematically related to the Singapore economy. In principle this should imply that the stock market can serve as a leading indicator of the intertemporal behavior of the Singapore economy.

VI. Conclusions

This paper has examined the efficiency characteristics of the Stock Exchange of Singapore and the relationship between the Singapore stock market and the overall economy. We have tested for stock market efficiency using three standard methods reported in the literature. By and large, the evidence indicates that the stock market in Singapore is efficient in asset-pricing terms.

The "weak" form of market efficiency test establishes that stock prices in Singapore follow a random walk and that both stock returns and excess returns on stocks are stationary and thus unpredictable. The "semi-strong" tests examine the relationship between real stock returns and macroeconomic fundamentals in the Singapore economy. Using information sets that are broader than those typically used in the literature in a three-VAR system - - an aggregate demand system, an aggregate production function system, and a money demand system - - we find no contemporaneous equilibrium relationship between stock returns and macroeconomic fundamentals. This suggests that the Singapore stock market is semi-strongly efficient. Excess market volatility tests through robust methods of variance modeling namely, ARCH and GARCH models of finance - - indicate no significant evidence of asset-pricing inefficiency in the Stock Exchange of Singapore. Nevertheless, the good forecasting performance of the estimated parsimonious dynamic error-correction model (ECM) for real stock returns does provide a caveat to these results and suggests that the Singapore stock market may not be "strongly" efficient.

Granger causality tests based on our efficiency results indicate that the Singapore stock market can indeed predict the future directions of the economy but the causality does not run in the reverse direction. Developments in the stock market appear to be systematically related to the overall economy in Singapore and can thus serve as a leading indicator of its intertemporal behavior.

APPENDIX I

A Dynamic Error-Correction Model (ECM) of Real Stock Returns $(sr - \pi)_t$ in Singapore

$$\Delta(sr - \pi)_t = \underset{[0.699]}{0.0364} + \underset{[3.717]}{0.1436\Delta^2 y_{t-1}} - \underset{[-2.673]}{0.2785\Delta c_{t-2}}$$

$$+ \underset{[2.501]}{0.071\Delta(r_d - \pi)_{(t-1)}} - \underset{[-1.998]}{0.10\Delta^2\Delta_4 rer_{t-2}} - \underset{[-2.219]}{0.05\Delta(m2-p)_{t-1}}$$

$$+ \underset{[3.305]}{0.093\Delta_1\Delta_4 smw_{t-3}} + \underset{[2.162]}{0.427\Delta^2 k_{t-2}} - \underset{[-4.791]}{0.188 ECM_{t-1}}$$

$$ECM_t = (sr-\pi)_t - 1.1y_t - 3.8c_t + 5.4(r-\pi)_{dt} + 6.2rer_t + 1.15(m2-p)_t + 7.9smw_t + 2.36k_t$$

$$T = 1976(1) - 1991(2) \ \textit{less} \ 10 \ \textit{forecasts},$$

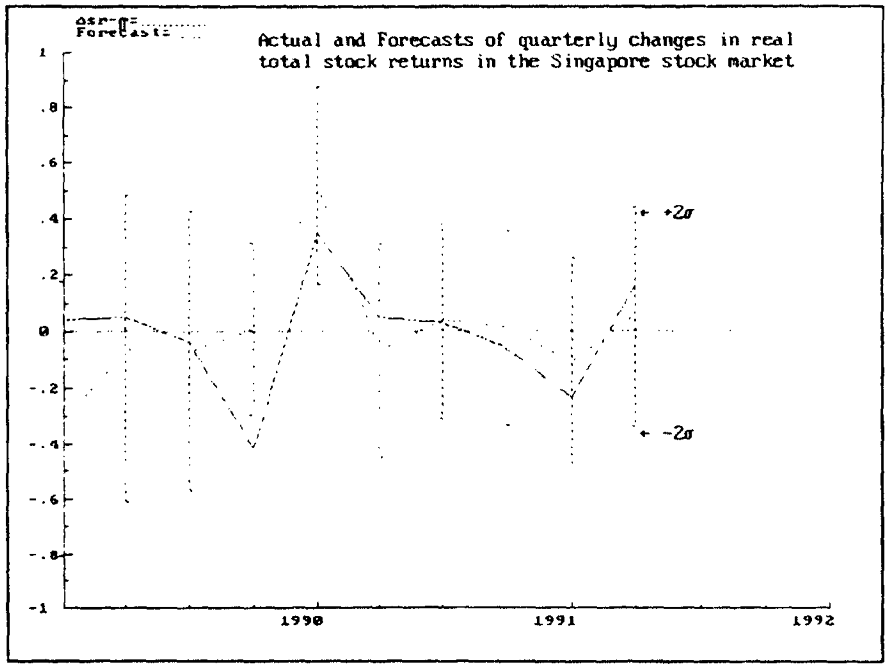
$$R^2 = 0.397, \ \sigma = 0.1021, \ DW = 2.06,$$

$$\textit{Chow} \ F(10,44) = 1.18, \ \textit{Forecast} \ \chi^2(10)/10 = 1.3185,$$

$$\textit{Normality} \ \chi^2(2) = 1.582, \ AR \ 1\text{-}4 \ F(4,40) = 1.52,$$

$$ARCH \ F(4,36) = 0.78, \ X_iX_j \ F(13,30) = 0.59, \ RESET \ F(1,43) = 2.7*$$

Chart 8. Actual and Forecasts of Quarterly Changes in Real Stock Returns Based on the Estimated Model Equation $\Delta(sr - \pi)_t$ Above and Forecast over the Period 1989q1 - 1991q2



APPENDIX II

I. **ARCH and GARCH Models of Finance**

Since the introduction of the ARCH (autoregressive conditional heteroscedasticity) model by Engle (1982), several papers applying this modeling strategy to financial time series data have already appeared. We start with the basic intuition behind the model. It allows the variance of a regression to change over time. The variance in one period is allowed to depend upon variables known from previous periods including the disturbances. The model explicitly recognizes the difference between the conditional and unconditional variance; the conditional variance may depend upon random variables in the conditioning set such as past disturbances, while the unconditional variance would be constant as traditionally assumed. Thus the ARCH framework becomes a more robust natural tool for testing market efficiency through the variance-bound test.

Following Engle (1982), the linear ARCH model can be formulated in terms of an information set ψ_t that includes all the information through time. Letting y_t be the independent variable and x'_t be a vector of explanatory variables included in ψ_{t-1}, the pth order linear ARCH regression model can be formulated as;

$$y \mid \psi_{t-1} \sim N(x'_t\beta, \sigma^2_t)$$
$$\sigma^2_t = \alpha_0 + \alpha_1\epsilon^2_{t-1} + \alpha_2\epsilon^2_{t-2} + \ldots + \alpha_p\epsilon^2_{t-p}$$
$$\epsilon_t = y_t - x'_t\beta \tag{14}$$

Although the conditional distribution of y_t is normal the ys are not jointly or marginally normal. The joint density is given by the product of all the conditional densities and under the assumption of normality and ARCH errors, the log-likelihood function can be expressed as follows;

$$L = -T/2\log(2\pi) - 1/2 \sum^T_{t=1} \log(\sigma^2_t) - 1/2 \sum^T_{t=1}\epsilon^2_t|\sigma^2_t, \tag{15}$$ 1/

where σ^2_t is the conditional variance function of ϵ_t. Maximizing equation (15) with respect to the vector of parameters α, λ and μ and a time trend coefficient generates the ARCH-corrected estimates. With financial time series data, this model captures the tendency for volatility clustering, that is, for large (small) price changes to be followed by other large (small) price changes but of unpredictable sign.

The implementation of ARCH estimation is accomplished in two steps. First, using the residuals obtained from equation (14), a Lagrange multiplier or ARCH test is applied to check for the presence of ARCH residuals and to determine the appropriate linear specification for σ^2_t. Second, once a suitable ARCH model has been selected, σ^2_t in equation (14) is estimated. In order to reduce the number of parameters and ensure a monotonic declining effect of more distant shocks, an ad hoc linearly declining lag structure is often imposed in the model (Engle (1982, 1983)), that is, restrictions on the αs.

The ARCH model can be extended to the generalized ARCH (GARCH) by allowing the current conditional variance to be a function of past conditional variances. The GARCH model provides a more flexible lag structure and formally it defines the variance structure as follows;

$$\sigma^2_t = \alpha_0 + \alpha(L)\epsilon^2_t + \beta(L)\sigma^2_t \tag{16}$$

To ensure a well-defined process all the parameters in the infinite-order AR representation must be non-negative, where it is assumed that the roots of the polynomial $\beta(\lambda) = 1$ lie outside the unit circle. For a GARCH (1,1) process, this amounts to ensuring that both α_1 and β_1 are non-negative. An IGARCH model is an extension of the GARCH model and refers to an integrated (nonstationary) GARCH model. In view of the fact that there is no evidence of nonstationary integrated variances for both $\sigma^2(\xi)_t$ and $\sigma^2(\xi')_t$, the IGARCH model has not been pursued here

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1/ Procedures for maximizing this likelihood can be found in Engle (1982).

II. Data Sources and Description

1 The Straits Times Index (STI)

Source: Stock Exchange of Singapore (SES) Factbooks.

2. Stock Market Capitalization

Source: Stock Exchange of Singapore (SES) Factbooks and The Emerging Markets Factbooks.

3. Value Traded at the SES

Source: Stock Exchange of Singapore (SES) Factbooks and The Emerging Markets Factbooks.

4. Dividend and Earnings Yield

Source: Stock Exchange of Singapore (SES) Factbooks.

5 GNP Expenditure based

Source: The South East Asia Division of the Bank of England.

6. Physical capital, labour and human capital data variables

Source: Leigh (1995) Ph. D Thesis Database.

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