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Share-price-changes-volume relation on the Singapore equity market

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A critical review of the literature on security-price-changes–volume research suggests that the published studies in the United States and one each in Hong Kong and Japan have largely ignored the impacts on the results from autocorrelation, non-normality of distributions, heteroscedasticity and non-linear functional forms. Therefore, the reported findings are not robust. In testing for this relation from a small sample of continuously traded shares in the Singapore share market, we find that consistent results may not be obtained because of violations of basic test conditions. A task that remains is an application of alternative test models with data transformation using a larger sample.

I. OBJECTIVES

This paper reports the preliminary findings on the relation between absolute share price changes and traded volume. First, published reports of the relation between the two variables are reviewed. Then we examine the distributional characteristics of the two variables in order to address the basic question as to whether robust results can in fact be obtained given the share price distributional characteristics reported in the literature. It is found that the variables violate normality, serial correlations and parameter stability assumptions quite seriously so that the robust and reliable results cannot be obtained with a simple linear specification and without data transformation. The preliminary findings reported here from a small sample suggest that any fruitful investigation of the price-changes–volume relation in the Singapore or any other market should start from a different direction, for which we suggest general approaches including the application of a random coefficient model.

Section II summarizes relevant literature from the perspective of this research. Section III outlines the data, test models and research design while Section IV presents the results of the investigation on the price-changes–volume relation. Finally, Section V is concerned with the justification and specification of different approaches to this research topic.[1]

II. PRICE CHANGES AND TRADED VOLUME

Share price and volume research

Share price change behaviour research has taken several directions and it is worthwhile to explain briefly the different research directions before proceeding with the job at hand, which is to review the price-changes–volume research. The earlier work on share price behaviour developed from the information effect studies. As a result, there is now an established tradition of research relating share price changes to arrival of information in the literature on information effects (research issue one). Good news leads to downward revisions of such prices, as documented in several studies (in developed and developing securities markets) following the now well-known studies by Ball and Brown (1968) and Fama *et al.* (1969), recently reviewed in Fama (1991). As a result, information efficiency theory has become well entrenched in financial economics paradigm[2] despite anomalous results reported. The price-changes–volume relation is predicted by these findings to be contemporaneous since a

[1]It will be documented later in this paper that almost all the reported research ignores the issue of distributional characteristics of the two variables. The researchers do not provide test statistics to show that normality and serial independence assumptions are valid. Consistently, none of the reports provides evidence of the strength of the relationship: we find that the correlation coefficient is around 5%, too low a degree of dependence to be acceptable.

[2]The efficient market hypothesis, along with the ideas of (a) equilibrium pricing of financial assets and (b) valuation theories, occupies a central place in the financial economics literature.

lagged relation between traded volume and price changes could be used to predict price changes, which is contrary to information efficiency theory.

Osborne (1964) suggested a positive relation between arrival of information and absolute share price changes: this has subsequently led to research on the share-price-changes–volume relationship (issue two). Conventional demand and supply economic theory also predicts a positive but contemporaneous relation between price changes and traded volume whenever demand shifts occur; supply shifts will produce a negative relation. Since then, a substantial body of empirical evidence has emerged, leading to general findings of a positive relation between absolute share price changes and traded volume in Hong Kong (Lam *et al.*, 1991), Japan (Tse, 1991) and the United States (several references in Karpoff, 1987). Hence, it appears that the relation is one of demand shifts in share markets: this makes sense as the supply of available shares is fixed at a point in time. Theoretical work by Copeland (1976) and Jennings *et al.* (1981), among others, suggests that the price-changes–volume relation is nothing but the adjustment of security prices to the arrival of new information, which shifts the demand for shares. New information is postulated as being dependent on a number of market microstructure factors such as number of traders, shares outstanding, intensity of information and the proportion (in the market) of optimists to pessimists.

All this work taken together is a continuation of a much earlier line of research on the distributional characteristics and price predictability of share prices (issue three) (e.g. Kon, 1984; Hall *et al.*, 1989; Tse, 1991). The conclusion reached about the statistical distribution is that the share price or return distribution is a mixture of normal distribution (MND) rather than a normal or Student's *t*-distribution as suggested in earlier work.[3] Another line of research – not as extensive as the latter – is the inquiry on the distribution of volume of sharing trading (issue four). Two notable works are those of Clark (1973) and Tauchen and Pitts (1983), which reach the conclusion that volume is a subordinated stochastic process and departures from normality are significant for data sets other than monthly volume data sets.

Despite the theoretical prediction of a contemporaneous effect between the two variables, some scholars[4] set out to discover causality between volume and price changes: Karpoff (1987, p. 124) reviews these works and concludes: 'The relationship was almost entirely contemporaneous, as most leading and lagging relations were statistically insignificant.' Examining the causality relation, therefore, appears to be the fifth research issue pursued by researchers.

Finally, there is a growing body of literature concerned with the question of how share (and other) markets are affected by the microstructure of the markets: an example of research on this sixth issue is that by Woods and McInnish (1992). Since our study is concerned more with the price-changes–volume relation than with pricing issues, a review of the work available under the titles of anomalous return behaviour, also known as periodicity anomalies, e.g. day-of-the-week effect,[5] is not provided.

Distributional characteristics of variables and price predictability

There is a substantial body of literature on the distributional characteristics of price changes (and therefore return series) and traded volume. We would like to trace the major findings of this line of research and then apply them to address the vexing question of the reliability of the tests conducted on price-changes–volume relations. Some of the major and generally well-accepted finance theories are founded on the assumption that the returns (logarithm of price changes) are normally distributed, despite evidence found lately that the distribution is more likely to be not from a family of normal distributions. Two major theories built on this assumption are the mean-variance portfolio and the options valuation theories of Markowitz (1958) and Black and Scholes (1973), respectively.[6]

Price changes have been found to be mean-reverting processes and conforming to random walk (Bachelier, 1900) or Brownian motion, and this has led to the establishment of a weak form (non-predictability) of share price markets. However, several important studies documented the general observation that individual security returns series are not normally distributed: this is despite the famous work of Fama (1976) documenting some evidence for the near normality of individual security returns using a sample of 30 stocks. Work done at about the same time (Mandelbrot, 1964) documented evidence to the effect that share returns in American markets have stable Paretian and Student's *t*-distributions. Further careful scrutiny of most of the same sources of data revealed that share price returns are random drawings from normal distribution leading to a mixed normal distribution (see Kon, 1984; Hall *et al.*, 1989; Agiray

[3]Earlier researchers were motivated to describe simply the distributional characteristics, but their findings are relevant and are now included in the review of literature on the price-changes–volume relation.

[4]A recent work on the Hong Kong market suggests that there is a weak causal relation (see Lam *et al.*, 1991).

[5]Readers are referred to a large body of literature under the topics of price-earnings anomalies, seasonality of returns and periodicity anomalies (see Ball and Bowers, 1988; Ariff and Johnson, 1990, Chapter 6).

[6]These theories were originally built on the assumption that the price (and therefore the return) series are normally distributed: return series in Markowitz's portfolio theory and price series in the Black–Scholes' option pricing theory (OPT). Later refinements in the case of OPT relaxed the assumption of normality. However, most theoretical ideas are still founded on the validity of this assumption.

and Lamoureux, 1989; Tse, 1991). There is a dearth of published work on the distributional characteristics of share price changes from non-American markets. Praetz (1972) and Beedles (1986) provide evidence to suggest that their studies of large samples (in one case 1335 share price series) lead to the conclusion that the price change distributions are not normal. Similar results of non-normality hold for a majority of share price series in the Singapore equity market (Ariff *et al.*, 1990).

While the normal distribution assumption for share price changes has been rejected in favour of a mixed normal distribution (MND), the distribution of traded volume is described by several researchers as being positively skewed and leptokurtic with no serial dependence (see Clark (1973) for an early work and Tauchen and Pitts (1983) for a later piece). In fact, the monthly volume series appear to be serially independent and approximately normally distributed despite being positively skewed, while weekly and daily series are more likely to be non-normally distributed.

Given the lack of normal distributions of the two variables used in research on the price changes and traded volume, several questions have been raised about the validity of most, if not all, of the research relating the two variables.[7] The specification of the two variables usually as a natural log of price changes and traded volume in a dependent relationship can be tested robustly only if normality is present. Further, it is also evident that daily and weekly data series are known to have (a) serial correlations and (b) heteroscedasticity. Hence, the price-changes–volume results cannot be robust as the tests carried out in these studies would not give the right rejection probabilities. In this study, we hope to report evidence on the important distributional characteristics. Next, the functional form of the price-changes–volume relation is suggested to be linear in all the reported studies. None of the researchers report verifying this assumption nor is there any reference to a theory for its basis. There are no reported results of non-linear specification except in Osborne (1964), which reported the non-linearity of the relation between price changes and volatility of price changes but not volume.

Price-changes–volume relation

Karpoff (1987) gives an excellent summary of research on the topic of price-changes–volume relations: interested readers are referred to this source. This discussion will, therefore, be brief. Salient features of the distributional characteristics of the two variables are also included in the research on price-changes–volume relations found in this source. Turning now to the nature of the relationship between the two variables, the following stylized facts have been documented largely in the American markets:

> Information arrives in random fashion leading to price changes which are then registered contemporaneously as volume changes. Traded volume is a proxy for information arrival. Absolute price changes and traded volume are positively correlated contemporaneously, i.e. there is no lag relationship.

Attempts to establish a causality relation revealed that the volume–price-change relation is contemporaneous, despite the studies in American and Hong Kong markets cited earlier showing a weak causal link in the direction of price changes leading the traded volume. Overwhelming evidence maintains that volume does not cause price changes and this is consistent with efficient market theory as well as demand shifts in response to information:

> Traded volume is higher when prices are increasing. When prices are declining, the traded volume is lower. This is the so-called asymmetric volume–price-change relationship.

These general findings have been reported entirely (except for one study each in Japan and Hong Kong) from the developed American markets using mostly individual security data over daily and weekly observations: there was at least one study that used hourly data. Most researchers examining the price–volume relations did not report on the distributional characteristics of the variables, $\ln \Delta p$ (natural logarithm of price changes) and V. Also, there were no data provided on the strength or correlation coefficient of the relationship, which is likely to be closer to zero.

From the foregoing discussion, the readers will note that (a) normality, (b) serial independence and (c) parameter stability are suspect in these reported studies. This is especially so with high-frequency (daily and weekly) price changes or return series. Violation of these usual assumptions in the model tested would mean that either the estimates are inconsistent or the test statistics are incorrect or both. More importantly, an alternative research model(s) should be devised in order to track correctly the relation between price changes and volume.

III. DATA, VARIABLES AND RESEARCH DESIGN

Data set

This study was carried out on the Stock Exchange of Singapore, which is a small bourse with about 339 listed stocks (in early 1993). It is a thinly traded equity market and the price-changes–volume relation for this market is examined because violations of the four relevant assumptions (serial independence, normality, linear functional forms and parameter stability) are more probable in such a market. The problem in using Singapore data is that one is not quite

[7] It is precisely this point that is puzzling as researchers have generally ignored this (among other issues, e.g. functional forms of relation) critical body of literature in formulating the recent inquiries into the price-changes–volume relation. This must therefore be remedied.

sure as to how many of the results are driven by thin-trading conditions: to alleviate this, only the continuously traded shares were selected and weekly interval data used.

The data set for this research was compiled from a personal collection of the authors from primary sources on the Stock Exchange of Singapore (SES) for the years 1975–89, i.e. over a test period of 15 years. Weekly capitalization-adjusted prices were used to set up a weekly data set out of the 344 shares that were traded on the SES anytime over the test period. Weekly interval data are appropriate for this study. The use of daily interval data would disqualify almost all firms, resulting in perhaps 10–15 firms traded continuously on a daily basis because of severe thin-trading conditions in that market in the earlier years (see Ariff and Johnson (1990), who established evidence of severe thin trading). Although we are unable to assess the bias in bid–asked spread in daily or weekly data in this market, as there is no report of bid or ask prices, weekly interval data are likely to suffer less bias because of 5 days of corrections of over- or under-reactions during the days in the week. Next, evidence available in market reports in this market suggests that volume peaks occur on Tuesdays and Thursdays, and trading on other days is within normal range. Using Friday closing prices as weekly prices will not therefore introduce systematic bias.

The dividends were added to capitalization-adjusted weekly prices of these firms; thus, the series is a fully adjusted price series. The second variable is measured as the number of shares traded during the interval. The shares were screened following the criteria that, for a share to be included in this study, it should have (a) traded prices on a weekly basis and (b) the firm should have been listed continually over the test period. About eight–nine firms satisfied these conditions.

Randomly picked 19 share price series (21% of the qualifying series) were included in this preliminary analysis to verify (a) the appropriateness of the functional forms of the price-changes–volume relation, (b) serial correlations, (c) normality and (d) parameter stability. The study is limited to continuously listed shares over the test period primarily to investigate thoroughly the critical questions relating to the robustness of current research methods before proceeding to investigate the price-changes–volume relation using a larger sample. The sample of 21% resulted in 11 regression runs using some of the more advanced econometric packages. The results are meant to be preliminary, i.e. only to pinpoint the general issues of robustness of research, and may not be fully generalizable until further work is done on a larger sample.

Test models and interpretation

The results obtained from relating the two variables Δp and V are reported in Section IV. The variables were tested under three specifications:

$$\text{P–V model: } \Delta p=\alpha_1+\beta_1(V)+\varepsilon_1, \quad t=1,2,\ldots,T \tag{1}$$

$$\text{V–P model: } V=\alpha_2+\beta_2(\Delta p)+\varepsilon_2 \tag{2}$$

$$\text{LV–P model: } \ln V=\alpha_3+\beta_3(\Delta p)+\varepsilon_3 \tag{3}$$

where α_1, α_2, α_3, β_1, β_2, β_3 are the parameters to be estimated, Δ is the change in variables over adjacent periods, ln is the natural logarithm operator, Δp, V are, respectively, price change and volume/total shares outstanding and ε_1, ε_2, ε_3 are white noise.

These test models were specified because these are the three that are normally applied to date by researchers investigating the relation between the two variables. The logarithmic specification (Equation 3) is often included in the hope that this will induce normality. In running these models with the weekly data, we tested if the variables satisfy the conditions required (i.e. tests (1)–(4) specified later) for consistent results. Violations of the conditions would suggest that the functional models given by Equations 1–3 are inappropriate: let us express Equations 1–3 in a general form as

$$y_t=\alpha+\beta X_t+\varepsilon_t \tag{4}$$

where all the terms are as defined in Equations 1–3.

Test statistics applied

The test statistics derived in this study are listed below.

(1) Residual serial correlation of order 1:
(a) The Durbin–Watson (DW) statistic is

$$\text{DW}=\frac{\sum_{t=2}^{T}(e_t-e_{t-1})^2}{\sum_{t=1}^{T}e_t^2} \tag{5}$$

where e_t are the OLS residuals.

(b) Godfrey's serial correlation test statistic is

$$\text{LM}=TR^2\sim\chi^2(1) \tag{6}$$

where R^2 is obtained from the regression of e_t, on a constant, χ^2 (chi-square) and e_{t-1} and the independent variables. LM is the Lagrangian multiplier and T represents the time period.

(2) Non-linearity:

Ramsey's RESET test of functional form is used. Our test statistic is given by

$$\text{LM}=TR^2\sim\chi^2(1) \tag{7}$$

where R^2 is obtained from the regression of y_t on a constant, x and $(\hat{\beta}x)^2$.

(3) Normality of the residuals:

The Jacque–Bera test is used for testing normality and is given by

$$JB = T\left[\frac{M_3^2}{6M_2^3} + \frac{1}{24}\left(\frac{M_4}{M_2^2} - 3\right)^2\right] \sim \chi^2(2) \qquad (8)$$

where

$$M_i = \sum_{t=1}^{T} \frac{e_t^i}{T}, \quad i = 0, 2, 3, 4$$

(4) Heteroscedasticity:

Consider

$$e_t^2 = \text{constant} + \alpha \hat{y}_t^2 \qquad (9)$$

and that the test statistic is given by $LM = TR^2 \sim \chi^2(1)$.

The violation of condition (4) will lead to incorrect interval estimates and that of conditions (1) and (2) will lead to inconsistent estimates of parameters. In all the three cases, the test statistics will be invalid and thus t-tests, F-tests, etc., will give incorrect rejection probabilities.

IV. RESULTS

The sample is split into two periods for the analysis 750613–820450 and 820507–890323. We attempt to do two things here. First, the β coefficients are estimated for the three different models using OLS regression. Second, misspecifications tests are conducted on the three models. While other variants of the above have been suggested, such as using Δp^2, $\ln|\Delta p|$, etc., Equations 1–3 are believed to be useful for a preliminary analysis before going on to detailed research.

The α and β coefficients were estimated using OLS and the results are reported in Appendix A. The summary results are presented in Tables 1 and 2. In theory, if the classical assumptions are satisfied, we can conduct specification tests on α and β, e.g. t- and F-tests, for the significance of the estimates. In practice, this may not be the best approach. If there are misspecifications of the models, the estimates may not be consistent and/or efficient. Unless some corrections or a further specification search is conducted, the estimates for the parameters of interest and the statistical inferences which follow give very misleading results.

In Table 1, we can see that, on average, 68% for period 1 and 48% for period 2 of all model runs indicate that the β coefficients are statistically significant at the 5% level. The F-statistics for joint significance of α and β coefficients indicate that, on average, more than half the models 'make sense'. However, the Durbin–Watson statistics indicate that a large proportion of the models are misspecified, i.e. there is serial correlation in the models. In other words, most of the models are misspecified and the presence of the serial correlations seems to indicate that one explanatory variable may not be enough, or that the explanatory variable is correlated with the error term. It is straightforward to correct for serial correlation. One can either include lagged variables or transform the original variables using the estimated autocorrelation coefficients.

Table 1. *Tests of the significance (at the 5% level) of β coefficients for two test periods using three functional specifications: 1975–89*

Functional forms	First period: June 75–April 82 weekly data			Second period: May 82–March 89 weekly data		
	Coefficients (%)	F-ratios (%)	Durbin–Watson tests (rejection of null hypothesis) (%)	Coefficients (%)	F-ratios (%)	Durbin–Watson tests (rejection of null hypothesis) (%)
Panel A: proportion						
P–V model (Equation 6)	74*	78	53	52	55	56
V–P model (Equation 7)	63	74	95	42	50	95
LV–P model (Equation 8)	70	82	100	47	56	100
All models tested	68 (38 out of 56)	76 (43 out of 56)	83 (46 out of 56)	51 (26 out of 55)	51 (28 out of 55)	84 (46 out of 55)

Panel B: number of regression runs	First period	Second period
1. Number of runs with no first-order autocorrelation	10 out of 56 or 18%	9 out of 55 or 16%
2. Number of runs with significant regression coefficients	38 out of 56 or 68%	26 out of 55 or 47%
3. Number of models statistically significant	43 out of 56 or 76%	28 out of 55 or 51%

* 74 means that 74% of the regression coefficients significantly different from 0 at critical value = 0.05 level.

Table 2. *Percentage tests suggesting acceptance of the null hypothesis on tests over two test periods using three functional specifications: 1975–89*

Functional forms	First period: June 75–April 82 weekly data				Second period: May 82–March 89 weekly data			
	Serially correlated (%)	Functional form incorrect (%)	Not normal (%)	Hetero-scedastic (%)	Serially correlated (%)	Functional form incorrect (%)	Not normal (%)	Hetero-scedastic (%)
P–V model (Equation 6)	58*	58	95	42	23	15	92	23
V–P model (Equation 7)	90	90	100	63	75	62	92	62
LV–P model (Equation 8)	100	84	47	44	92	62	31	54
All models	77	73	80	60	64	46	72	47

* 58 means that 58% of regression runs using the model specified led to rejection of the null hypothesis at the probability levels of $\alpha = 0.05$.

Durbin–Watson statistics is useful for detecting misspecification and, indeed, a range of misspecification tests is available as mentioned in Section III. Table 2 reports the misspecification test results or diagnostic test statistics for serial correlation, functional form, normality and heteroscedasticity. From Table 2, we can see that for the P–V and V–P models, normality is decisively rejected. The LV–P model is more consistent with the normality assumption. However, it is almost certain that there are still misspecifications even if normality is not rejected. Furthermore, linearity is rejected more than half the time, indicating that the linear functional form may not be appropriate. Heteroscedasticity is rejected less often but the assumption of constant β may be appropriate.

The conclusion from these misspecification tests is that we have not found a suitable model for investigating the price-changes–volume relation. When lagged dependent and independent variables are added to the models, the problems of non-linearity and non-normality do not go away. Of course, the normality assumption is less crucial for our case but the inconsistency of the estimates caused by misspecification of the functional form indicates that some transformation may help to alleviate the problem.

Preliminary analysis in this research using a small sample indicates that we are still far from the stage where we can conduct specification tests. What is needed first is to get results passing the misspecification tests. Without passing these misspecification tests, the specification tests have little to reveal about the price-changes–volume relation. However, a word of caution about the misspecification tests is appropriate here. Most of the tests are conducted under some auxiliary assumptions. In other words, there are maintained hypotheses that are not tested. This poses a major procedural problem because the tests are not robust to departures from the maintained hypotheses. Nevertheless, the message is still quite clear. If there are misspecifications of any form, the specification tests carry little weight. No meaningful conclusions can usually be drawn in cases like those encountered in this kind of research in any market.

V. FUTURE RESEARCH

From the evidence presented in Section IV and our exposition of the test models, we conclude that, if there is indeed a contemporaneous relation between price changes and volume, the present specifications are inadequate for modelling that relation. First, serial correlation is present, indicating some form of misspecification. The usual practice of including lag variables did not eliminate the problem completely: Tse (1991) describes some approaches to solve this problem. Second, violation of the homoscedasticity assumption suggests that the β coefficient is not constant over time. In most of the cases, misspecification is confirmed by including lags of dependent and independent variables, with no improvements in the test statistics. One approach may be the random coefficient model, but it seems that the state-space model, possibly with non-normal distribution, may have some advantage over the random coefficient model in terms of flexibility.

Third, violation of normality is another problem for hypothesis testing. The Jacque–Bera test is sensitive to outlier, and therefore cusum and cusumsu tests for misspecification may be used to test for normality. A solution is to apply non-parametric and semi-parametric tests. There is good evidence in the financial literature to suggest that price or return series from portfolios of securities are more likely to be normally distributed: this is an alternative preferred solution to normality issues. As for the normality of residuals, there seems to be no evidence to suggest that it is the case in this research. This is consistent with many other studies on the price/price change/return distribution characteristics. However, a transformation which gives an approximate normal distribution may be found, especially when the residuals are known to be skewed. Using Box–Cox or inverse hyperbolic sine is another solution. If this fails to induce normality, Lee's (1990) suggestion of using the method of moments may then be appropriate.

Fourth, theories do not suggest a functional form for the relation except that there is a relation, possibly a contemporaneous relation: Osborne (1964) found a non-linear relation between price changes and volatility. By taking the log of V, in most cases, the problem could not be eliminated. This suggests that more attention should be paid to the specification of the functional form. One direction is to use non-parametric regression. This is a well-developed area of research now as different research reports are available and the properties of the estimates are well known. Until the technical deficiencies of the existing reported research are addressed, it is not suggested that the large body of literature on the price-changes–volume relation is entirely unreliable. But rather, more attention should be paid to the misspecification of the problem. It is to this task of exploring the correct specification that more efforts need be directed in continuing research now that this preliminary investigation has pointed out the deficiencies of the existing approaches for studying the price-changes–volume relation.

APPENDIX A

Test results on three linear models of price changes and volume series over two test periods on the Stock Exchange of Singapore: 1975–89

Name of firm		First period β	First period R^2	First period F-ratio	First period Durbin–Watson	Second period β	Second period R^2	Second period F-ratio	Second period Durbin–Watson
B Raya	(P–V)[a]	7.227*	0.170	70.825*	2.041	56.547*	0.162	70.042*	1.942*
	(V–P)[a]	0.023*	0.170	70.825*	1.177	0.003*	0.164	70.042*	1.158
	(LV–P)[a]	—	NOT	RUN	—	5.707*	0.069	26.634*	0.916
C Dev	(P–V)	11.755	0.030	1.810	1.762	5.647*	0.030	1.123	1.702
	(V–P)	0.003	0.030	1.810	1.558	0.006	0.030	1.123	1.838
	(LV–P)	0.430	0.000	0.061	1.266	3.516	0.030	1.003	1.629
DBS	(P–V)	11.689*	0.031	11.253*	1.878	− 8.738*	0.023	8.498*	1.728
	(V–P)	0.003*	0.031	11.253*	1.008	− 0.003*	0.023	8.498*	1.036
	(LV–P)	4.976*	0.029	10.507*	0.984	1.326	0.003	1.147	0.978
DMI	(P–V)	0.879	0.000	0.080	2.919	27.901*	0.026	9.327*	2.016*
	(V–P)	0.000	0.000	0.000	2.003	0.000	0.026	9.327*	1.028
	(LV–P)	0.590	0.004	1.423	1.687	1.608	0.013	4.835	1.026
Esso	(P–V)	− 199.372*	0.0312	11.481*	2.688	62.686	0.006	2.200	2.079*
	(V–P)	0.000	0.031	11.481*	1.769	0.000	0.006	2.200	1.382
	(LV–P)	0.202	0.000	0.208	1.547	0.349	0.001	0.496	1.295
F&N	(P–V)	25.710*	0.070	26.884*	2.058	0.367	0.000	0.012	1.575
	(V–P)	0.003*	0.070	26.884*	1.289	0.000	0.000	0.012	1.469
	(LV–P)	5.287*	0.044	16.475*	1.184	3.138*	0.014	4.935*	1.484
Hawpar	(P–V)	2.312	0.014	5.034	1.892	3.504	0.000	0.261	2.936
	(V–P)	0.006	0.014	5.034*	1.029	0.000	0.001	0.261	1.147
	(LV–P)	1.907	0.017	4.972*	0.905	0.214	0.002	0.859	0.959
Inchape	(P–V)	18.498*	0.092	36.078*	1.737	7.592*	0.012	4.451*	1.565
	(V–P)	0.005*	0.092	36.077*	1.081	0.002	0.012	4.451	1.304
	(LV–P)	4.543*	0.048	17.821*	0.901	4.334*	0.035	12.960*	0.844
K-L-Kepong	(P–V)	22.264*	0.042	15.746*	2.228	5.109	0.003	1.016	1.713
	(V–P)	0.002	0.042	15.746	0.883	0.000	0.003	1.016	1.199
	(LV–P)	5.517*	0.031	11.495*	0.741	3.312*	0.022	8.030*	1.169
M Bank	(P–V)	8.074*	0.022	8.106*	1.913	− 4.167	0.005	1.639	1.733
	(V–P)	0.003	0.022	8.106	1.786	− 0.001	0.005	1.639	1.403
	(LV–P)	5.201*	0.031	11.472*	1.176	2.564	0.007	2.573	1.145
OCBC	(P–V)	22.553*	0.037	13.652*	1.897	2.366	0.001	0.367	1.875
	(V–P)	0.002*	0.037	13.652*	1.268	0.000	0.001	0.367	1.623
	(LV–P)	2.903	0.019	6.873	0.980	3.937	0.021	7.558	1.343
OUE	(P–V)	28.209*	0.128	52.262*	1.807	12.430*	0.038	13.968*	1.677
	(V–P)	0.005*	0.128	52.262*	1.642	0.003*	0.038	13.968*	1.401
	(LV–P)	6.031*	0.057	21.667*	1.040	4.445*	0.030	11.208*	0.894
PMC	(P–V)	10.168*	0.115	46.160*	2.244	16.762*	0.069	26.415*	1.919*
	(V–P)	0.011*	0.115	46.160*	1.147	0.004*	0.069	26.415*	1.164
	(LV–P)	5.207*	0.056	21.167*	0.794	2.810*	0.044	16.579*	0.769
Prima	(P–V)	23.581*	0.104	41.563*	2.073	6.593	0.011	3.825	1.952*
	(V–P)	0.004*	0.104	41.563*	1.418	0.002	0.011	3.825	1.545
	(LV–P)	7.417*	0.074	28.306*	1.344	3.156	0.012	4.492	1.532
Robinson	(P–V)	15.040*	0.096	37.971*	2.139	—	—	—	—
	(V–P)	0.006*	0.096	37.971*	1.177	—	—	—	—
	(LV–P)	6.061*	0.048	17.874*	1.204	—	—	—	—
S Land	(P–V)	10.759*	0.085	33.119*	1.739	12.372*	0.057	21.485*	1.755
	(V–P)	0.008*	0.085	33.119*	1.204	0.005*	0.057	21.485*	1.679
	(LV–P)	8.955*	0.095	37.498*	0.736	4.601*	0.046	17.073*	1.561
UOB	(P–V)	6.777	0.018	6.433	1.858	6.129	0.029	10.520*	1.841*
	(V–P)	0.003*	0.018	6.433	1.056	0.005*	0.029	10.520*	1.307
	(LV–P)	3.815*	0.025	9.300*	0.982	3.484*	0.021	7.676*	1.206
Boustead	(P–V)	3.043*	0.038	14.047*	1.947	0.011*	0.052	19.391*	2.188*
	(V–P)	0.012*	0.038	14.047*	1.722	4.700*	0.052	19.391*	1.196
	(LV–P)	5.255*	0.058	22.038*	0.977	—	—	—	—
Berjun	(P–V)	0.005	0.007	2.372	1.991	0.008*	0.029	10.648*	2.058*
	(V–P)	1.427	0.007	2.372	1.061	3.409*	0.029	10.648*	1.3028
	(LV–P)	—	—	—	—	—	—	—	—

[a] The three model runs are specified in Equations 1, 2 and 3, respectively. Some of the LV–P models are not run because V is a very small number. While a simple correction can be done, e.g.

$$LV = \log(V)\, I(V > 0.05) + \log(0.5)\, I(V \leqslant 0.05)$$

where I is the indicator function, we have decided not to do so.

* Null hypothesis is rejected at critical value = 0.05 level.

APPENDIX B

Test statistics on models tested over two test periods over 1975 on the Stock Exchange of Singapore

Name of firm		First period: Serial correlation	First period: Functional form	First period: Normality	First period: Heteroscedasticity	Second period: Serial correlation	Second period: Functional form	Second period: Normality	Second period: Heteroscedasticity
B Raya	(P–V)[a]	0.1496*	11.613	326.941	9.825	0.252*	0.0001*	2530.1	0.0089
	(V–P)[a]	61.236	36.604	5217.6	17.212	62.371	39.516	2597.9	64.166
	(LV–P)[a]	104.126	17.458	14.086	1.139*	—	NOT	RUN	—
C Dev	(P–V)	0.737*	4.017	1.591*	0.112*	0.261*	0.816*	0.914*	0.402*
	(V–P)	2.586*	15.342	194.156	5.729	0.198*	1.076*	57.589	0.0005
	(LV–P)	7.084	11.271	2.678*	1.109*	1.161*	2.983*	0.236*	0.0119*
DBS	(P–V)	1.243*	0.749*	255.57	24.007	6.635	65.711	13115.9	243.113
	(V–P)	88.188	40.974	1403.5	2.435	83.113	91.157	4738.1	61.929
	(LV–P)	91.797	19.123	3.221*	6.068	91.234	24.338	13.691	25.610
DMI	(P–V)	81.645	2.964*	80601.0	0.013*	0.022*	0.002*	134.353	0.042*
	(V–P)	0.0006*	0.0172*	1833188	0.002*	83.019	0.075*	15961	5.464
	(LV–P)	8.781	0.0262*	296.610	1.509*	83.593	0.548*	0.763*	0.096*
Esso	(P–V)	42.644	86.987	26880.8	95.948	0.758*	0.041*	223473	0.00387*
	(V–P)	4.932	42.981	5790.2	161.243	34.198	0.166*	5389.9	1.418*
	(LV–P)	18.211	2.669*	19.325	13.330	43.261	1.258*	1.395*	0.228*
F&N	(P–V)	0.306*	0.026*	5086.3	0.000*	17.053	23.604	17513	24.151
	(V–P)	45.279	32.142	20432	28.850	25.105	33.824	1938	8.489
	(LV–P)	59.741	23.203	3.481*	2.230*	23.516	24.108	27.542	22.590
Hawpar	(P–V)	1.046*	0.749*	249.399	1.219*	78.637	0.118*	381937	0.020*
	(V–P)	84.528	34.341	596.163	5.164	65.247	0.044*	54990	0.021*
	(LV–P)	80.725	27.169	0.982*	23.209	97.225	0.129*	2.013*	0.166*
Inchape	(P–V)	5.911	1.621*	82.523	0.050*	16.960	12.384	9.441	4.042
	(V–P)	75.957	27.226	774.0*	22.244	43.376	18.999	10774	0.728*
	(LV–P)	108.370	24.988	24.277	0.011*	119.411	24.703	9.144	23.186
K-L-Kepong	(P–V)	4.5895	1.103*	49.975	2.105*	7.453	15.210	13524	26.712
	(V–P)	111.927	25.202	3266	4.724	57.6859	43.390	3.365	1.224*
	(LV–P)	142.283	31.642	6.149	1.216*	61.061	27.211	3.143*	22.184
M Bank	(P–V)	0.673*	4.710	1529.6	0.000*	6.329	3.144	10934	22.052
	(V–P)	4.126	1.860*	579462	2.623*	32.004	42.527	42626	4.848
	(LV–P)	60.005	2.885*	0.382*	1.125*	65.591	21.057	7.472	14.393
OCBC	(P–V)	0.942	0.499	319.204	12.302	1.402*	41.327	2983	107.287
	(V–P)	48.049	48.639	796	5.649	12.561	86.869	4266	9.919
	(LV–P)	93.008	37.127	2.395*	0.160*	38.269	38.384	32.403	21.172
OUE	(P–V)	3.328	0.512*	254	25.017	9.152	0.686*	7755	0.056*
	(V–P)	11.519	79.506	20980	52.860	32.056	26.138	68707	12.198
	(LV–P)	82.674	29.428	5.326*	6.347	109.99	26.968	0.691*	18.304
PMC	(P–V)	5.398	0.701*	1335	0.728*	0.590*	1.478*	46530	0.002*
	(V–P)	65.342	19.764	5325	54.801	61.954	2.049*	38292	5.629
	(LV–P)	130.319	3.735	5.851*	7.927	134.593	2.666*	2.919*	0.930*
Prima	(P–V)	0.5097*	0.031*	989	0.379*	0.184*	0.713	11437	3.350*
	(V–P)	27.115	19.652	2002	26.173	18.624	23.656	1784	5.256
	(LV–P)	37.037	6.926	6.330	0.000*	19.625	18.122	1.534*	10.171
Robinson	(P–V)	1.780*	1.336*	908	0.146*	—	—	—	—
	(V–P)	60.983	26.210	155567	23.210	—	—	—	—
	(LV–P)	55.713	2.273	9.222	0.538*	—	—	—	—
S Land	(P–V)	6.088	16.157	127.762	23.211	5.387	0.634*	2190.7	0.000
	(V–P)	56.923	31.371	8652.7	1.546*	9.226	10.588	1062	8.579
	(LV–P)	143.715	36.430	1.071*	16.430	17.261	11.116	9.057	2.461*
UOB	(P–V)	1.592*	13.194	162.710	66.828	2.271*	2.151*	13021	61.495
	(V–P)	79.712	58.188	314.237	1.663*	42.996*	139.111	11397	63.454
	(LV–P)	92.477	43.117	1.113*	10.135	56.248*	43.781	4.259*	22.506
Boustead	(P–V)	0.249*	13.493	26596	0.302*	3.188*	5.976	2000	0.208*
	(V–P)	6.575	11.871	171743	1.681*	57.985	9.475	10.525	3.038*
	(LV–P)	94.179	7.103	4.405*	0.954*	—	—	—	—
Berjun	(P–V)	0.067*	0.180*	269584	0.579*	0.303*	3.432*	550.940	18.340
	(V–P)	79.434	6.085	90.043	0.031*	43.341	14.906	49.103	0.689*
	(LV–P)	—	NOT	RUN	—	—	—	—	—

[a] The three models run are specified in Equations 1, 2 and 3, respectively. Some of the LV–P models are not run because V is a very small number. While a simple correction can be done, e.g.

$$LV = \log(V)\, I(V > 0.05) + \log(0.5)\, I(V \leqslant 0.05)$$

where I is the indicator function, we have decided not to do so.

* Null hypothesis is not rejected at critical value = 0.05 level.

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