The Semi-Strong Efficiency of the Australian Share Market

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This paper tests the weak and semi-strong forms of the Efficient-Markets Hypothesis (EMH) using data on the Australian share market in the 1980s. The tests are based on aggregate share price indexes and the semi-strong efficiency tests use macroeconomic data. The weak-form tests examine the autocorrelation structure of share returns and test for unit roots in share prices. The data are found to be consistent with the EMH.

I Introduction

Efficient-Markets Hypothesis (EMH) has far-reaching implications for both the theory and practice of finance and, indeed, for the theory and practice of economics in general. It is not surprising, therefore, that it has been widely tested in a variety of ways—using data for different assets, different countries and different time periods. This paper contributes to the empirical literature on market-efficiency by testing the hypothesis in its semi-strong form using data for the Australian share market for the 1980s. The semi-strong EMH states that movements in share prices cannot be predicted on the basis of publicly available information. It is possible to distinguish two types of tests of semi-strong efficiency, one using macro data such as inflation, the money stock, exchange rates, and the other based on micro data such as company-specific announcements. The subject of this paper is confined to tests of the macro type.

Relatively few macro tests of the semi-strong EMH for the Australian share market have been reported. The results of existing studies by Sharpe (1983), Hogan, Sharpe and Volker (1982) and Saunders and Tress (1981) all lead to the rejection of the semi-strong form of the EMH.

Mishkin (1983) has pointed out that market-efficiency is a joint hypothesis combining the way in which equilibrium share prices are determined and rationality of market expectations. Thus two choices must be made in empirical work. The first is that of the variables affecting equilibrium share prices. This choice is generally made in an ad hoc way, determined as much by data availability as by theoretical considerations. The tests reported in this paper are based on a simple model of share prices derived from the work of Tobin (1969).

The second choice is the way in which (rational) expectations are to be modelled. The Australian papers cited above have resolved this problem in various ways. Sharpe (1983) and Hogan et al. (1982) use time-series methods, the latter univariate and the former multivariate, while Saunders and Tress (1981) model expected inflation by assuming it to be equal to actual inflation. The work reported below uses forecasting equations of the type used elsewhere in the empirical rational-expectations literature (see, e.g. Mishkin, 1983) to model the expected values of the macro variables.

The paper is set out as follows. The following section sets out a framework for testing the semi-strong hypothesis. Since weak efficiency is a necessary condition for semi-strong efficiency, it seems prudent to carry out preliminary tests for weak efficiency. Three tests were carried out—two examining the intertemporal structure of returns and the third being a test for a unit root in the price process. The results are reported in...
Section III. There is no evidence that the data are inconsistent with weak efficiency. In Section IV the results of the semi-strong tests are presented. The tests involved regressing returns on current and lagged changes in macroeconomic variables and testing for the joint significance of the lagged changes. The results support the semi-strong EMH. Conclusions are presented in the final section.

II The Model

The EMH claims that it is impossible to forecast asset returns (apart from their trend component) with currently available information. It is common to distinguish between weak, semi-strong and strong versions of the hypothesis depending on the contents of the phrase 'currently available information'. The weak EMH considers only past asset returns as the information set, the semi-strong EMH broadens this to include all publicly available information and the strong EMH also includes information which is not publicly available. Clearly, weak efficiency is a necessary condition for semi-strong efficiency which is, in turn, a necessary condition for strong efficiency.

While the focus of this paper is on tests of semi-strong efficiency using macro information, three types of preliminary tests of weak efficiency are also presented. The first is to regress the asset return on several past values of itself and test the null hypothesis that the coefficients of the lagged returns are jointly zero. An alternative approach is to examine the autocorrelation structure of the returns. A third approach is to test for a unit root since an implication commonly drawn from the weak EMH is that share prices follow a random walk.

Tests of the semi-strong EMH are based on the regression:

\[ R_t = E_t(R_t') = \sum_{s=0}^{n} \beta_s \Delta X_{t-s} - \Delta E_{t-s}(X_{t-s}) + e_t \]  

where \( R_t \) is the asset return, \( E_t(R_t') \) is the equilibrium conditional on information up to period \( t-1 \), \( X \) is a vector of variables which affect share prices and where \( e_t \) is a random error term, serially uncorrelated and uncorrelated with the expected errors. The null hypothesis is then \( H_0: \beta_s = 0, s = 1, 2, \ldots, n \).

This formulation of the model highlights three problems which must be solved before testing can be implemented. First, \( E_t(R_t') \) must be measured; second, the expected errors are measured; finally, the composition of the \( X \) vector must be specified. As to the first problem, the measurement of the expected equilibrium return, two commonly used alternatives were experimented with. The first was to assume \( E_t(R_t') \) to be a constant, \( \alpha \), and the second is to assume that \( E_t(R_t') \) is equal to the sum of a risk-free return, \( R_{RF} \), and a constant risk-premium. Then (1) becomes:

\[ R_t - R_{RF} = \alpha + \sum_{s=0}^{n} \beta_s \Delta X_{t-s} - \Delta E_{t-s}(X_{t-s}) + e_t \]  

with the first form obtained by setting \( R_{RF} = 0 \).

The second problem in the implementation of the testing procedure identified above, the generation of the expected errors, was resolved by using an approach relatively common in the macroeconomic rational-expectations literature, in which forecasting equations are estimated, the residuals from which are used to represent the expected errors. The forecasting equations are ad hoc with the only restrictions on them being that they contain only lagged variables and that the errors are not autocorrelated.

The final question concerns the choice of variables in the \( X \) vector. As indicated in the introductory section of this paper, in many empirical studies of share-market efficiency the choice of variables to be included in \( X \) is determined largely by data availability. In the present case some structure is imposed by using a simple model based on Tobin (1969) which determines six endogenous variables in terms of five exogenous variables. The endogenous variable of interest is the price of shares which is determined by the capital stock, the money supply, the level of government expenditure, the price level and the marginal efficiency of capital. We assume the first and last of these to be constant. Recalling that the dependent variable in (1) is the rate of change of share prices, we have \( X \) consisting of the rate of monetary growth, the inflation rate and the growth rate of government expenditure.

III Weak-Efficiency Tests

Four indexes of the prices of shares traded on the Australian Stock Exchange for the period 1980(1)–1988(6) were used—the All Ordinaries Index and the All Industries Index, each of which was used in both price and accumulation form. For examples of the first approach see Fama (1976), Sargent (1976) and Pesando (1979); for the second see Sharpe (1983).

2 See, e.g. Mishkin (1983).

4 The accumulation index is constructed so that its proportional change measures total return inclusive of dividends whereas the proportional change in the price index measures only capital gains. For sources of data, see the Data Appendix.
In all cases the return was calculated as the log-difference of the index.

The weak form of the Efficient-Markets Hypothesis implies that past returns cannot be used to predict current returns and therefore tests of weak efficiency are naturally based on an examination of the interrelationships between current and past returns. The most direct approach is to consider the autocorrelation structure of returns and test the joint significance of the autocorrelations using the Box-Ljung portmanteau statistic (Q) which is \( \chi^2 \) distributed under the null hypothesis that the first \( k \) autocorrelations are zero.\(^5\)

Table 1 contains the results of such a test in the \( Q(12) \) and \( Q(24) \) columns for \( k = 12, 24 \). The 5 per cent critical values are 21.0 and 36.4 respectively. The results indicate that there is no evidence of autocorrelation in share returns irrespective of which of the four measures is used. This was confirmed by the fact that in all cases none of the autocorrelations was individually significant.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>( Q(12) )</th>
<th>( Q(24) )</th>
<th>( F(12,0) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Ordinaries (AO)</td>
<td>4.70</td>
<td>7.45</td>
<td>0.42</td>
</tr>
<tr>
<td>All Industries (AI)</td>
<td>9.13</td>
<td>15.40</td>
<td>1.28</td>
</tr>
<tr>
<td>All Ordinaries Accumulation (AOA)</td>
<td>5.84</td>
<td>8.24</td>
<td>0.82</td>
</tr>
<tr>
<td>All Industries Accumulation (AIA)</td>
<td>8.69</td>
<td>14.44</td>
<td>1.35</td>
</tr>
</tbody>
</table>

5 per cent Critical Values: \( Q(12) = 21.0, Q(24) = 36.4, F(12,0) = 1.92 \)

An alternative but closely related approach is based on the use of either a likelihood-ratio (LR) or Lagrange-Multiplier (LM) test of the null hypothesis \( H_0: \beta_i = 0 (i = 1, 2, \ldots, k) \) in the equation\(^6\)

\[
R_t = \beta_0 + \sum_{i=1}^{k} \beta_i R_{t-i} + \varepsilon_t
\]

The \( F \) column in Table 1 reports the results of such a LR test for \( k = 12 \), the statistic being \( F \)-distributed under \( H_0 \) and Classical assumptions about the errors, \( \varepsilon_t \). The \( F \)-test results indicate that \( H_0 \) could not be rejected in any case although it should be reported that for all but the equation for AOA, individual lagged returns were on occasion significant. It is interesting to note that these individually significant lagged returns always occur at long lags (between 6 and 12 months) and therefore choosing a shorter maximum lag would tend to strengthen the conclusions of joint insignificance.

A third test of weak efficiency is based on the implication that share prices follow a random walk. Hence we test for a unit root in the (log) price process using the Phillips-Perron test which is based on regressions of the form

\[
\Delta \log P_t = \beta_0 + \beta_1 \log P_{t-1} + \beta_2 \Delta \log P_{t-1} + \sum_{j=1}^{k} \eta_j \Delta \log P_{t-j} + \varepsilon_t
\]

where \( P_t \) denotes the share price index. Two null hypotheses were considered. The first is simply \( H_0: \beta_1 = 0 \) so that under the null hypothesis the process has a unit root, drift and a trend. The second null hypothesis is \( H_2: \beta_1 = \beta_2 = 0 \) which reduces (3) to a random walk with drift (a 'difference-stationary' series).\(^7\) The values of the test statistics and the critical values were calculated using SHAZAM and are reported in Table 2. Various values of \( k \) were experimented with but the results were quite insensitive to variations in the lag length. The reported test statistics are based on \( k = 1 \). Clearly the null hypothesis of a unit root in the process generating the log of the share price cannot be rejected in any of the cases tested.

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\(^5\) See, e.g. Granger and Newbold (1986, p.100).

\(^6\) For a recent exposition of LR and LM tests see Maddala (1992), Chapter 3 Appendix. The Breusch-Godfrey test of residual autocorrelation used below in the semi-strong market-efficiency tests is essentially the LM equivalent of the LR test reported in Table 1. This test is, in turn, related to the Box-Ljung test; Johnson (1984, p. 319) states that the Breusch-Godfrey test 'is essentially a test of the joint significance of the first \( p \) autocorrelations of these residuals'.

\(^7\) An alternative to this strict distinction between trend- and difference-stationary processes, is to permit a combination of stationary and non-stationary processes and attempt to measure the importance of each. See, e.g. Cochrane (1988) and Christiano and Eichenbaum (1990) for applications to macroeconomic time series and Poterba and Summers (1988) for an application to share prices.

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This section has presented the results of three tests of weak efficiency of the Australian share market in the 1980s. None of the tests leads to the rejection of the weak EMH. Recalling that weak efficiency is a necessary condition for semi-strong efficiency, there is nothing in the results reported that precludes a progression to the semi-strong tests and we turn to these now.

**IV Semi-Strong-Efficiency Tests**

A common dilemma of tests using macroeconomic data concerns choice of data frequency. The greater the frequency the less severe are the degrees-of-freedom problems and the more discerning is the test in that efficiency over a smaller interval can be tested. The cost of higher frequency data is that many macroeconomic series are not available at monthly intervals. In this paper we report tests using monthly data with proxies being used for the price level and government expenditure, neither of which is available in monthly form. Results based on quarterly data are reported in Groenewold and Kuay (1992); they confirm those reported below.

(i) **Data**

The theoretical framework set out in Section II requires data on four variables: share prices (the dependent variable), the money supply, real government expenditure and the price level. All variables will be used in log-difference form.

The share-price data used have already been briefly discussed in the previous section. The money supply variable was used in three forms: M3, M0 (monetary base) and M6. Government expenditure data are unavailable on a monthly basis. No obvious monthly proxy for G was available and therefore a real economic activity variable was used instead. Ideally, broad measures of activity such as GDP are called for but these, too, are available only on a quarterly basis. Hence, alternative proxies were used: retail sales and employed persons both of which are available on a monthly basis. The price level was measured by the Index of Prices of Articles Produced by the Manufacturing Sector since broader and more satisfactory measures such as the CPI and GDP deflator are available only quarterly. Finally, the risk-free rate of return is required. Given the paucity of data available on returns to financial assets, it was decided to use the 90-day bank-accepted bill rate as a rate of return on a relatively riskless asset.

The sample period used was 1982(8)–1988(6), this relatively short period being necessary because of the limitations on the availability of the monetary aggregates and the need to include lagged residuals from the forecasting equations which themselves had lags.

(ii) **Forecasting Equations**

The regressions on which the tests of semi-strong efficiency are based require the unanticipated components of the variables in the vector X as regressors. These are generated as residuals from ad hoc forecasting equations which may include any available variables provided only lagged values are used. Degrees-of-freedom problems preclude all possible information being incorporated. Therefore, the number of lags was restricted to six. The regressors were restricted to lagged values of the three variables to be forecast. Insignificant regressors were eliminated systematically in reverse order of the absolute value of the t statistic. A LR test was used to test the joint exclusion of all eliminated variables.

Six different sets of forecasting equations were estimated corresponding to two different proxies for real economic activity and three different definitions of the money supply. Since the absence of residual autocorrelation is important for acceptable forecasting equations, all equations were tested for joint first- to fourth-order autocorrelation using a Breusch-Godfrey test. It was found impossible to obtain acceptable equations for retail sales since in all but one case there was evidence of strong residual autocorrelation. The retail-sales variable was therefore discarded as a real economic activity proxy. A Chow test for structural stability was used on the money forecasting equations at 1985:1, the date at which monetary targeting was abandoned after it had been used from the beginning of the 1980s. Only the M3 forecasting equations appeared to be affected and separate equations were estimated for each sub-sample. However, there was very strong evidence of residual autocorrelation in the forecasting equation for the second sub-sample. Results are reported, therefore, only for M0 and M6.

(iii) **Results**

Table 3 contains four sets of results, presented depending on whether M0 or M6 was used and whether the expected equilibrium return was proxied by a risk-free rate and a constant or a constant only.

\[ See, \text{ e.g. } Johnston (1984), \text{ Ch. 8.} \]
### Table 3

<table>
<thead>
<tr>
<th>Equation</th>
<th>Dependent Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$AO$</td>
</tr>
<tr>
<td>(a) $M-M0$, $E_s(R_i) = RRF_{s+1} + e$</td>
<td>0.454</td>
</tr>
<tr>
<td>(b) $M-M6$, $E_s(R_i) = RRF_{s+1} + e$</td>
<td>1.185</td>
</tr>
<tr>
<td>(c) $M-M0$, $E_s(R_i) = e$</td>
<td>0.454</td>
</tr>
<tr>
<td>(d) $M-M6$, $E_s(R_i) = e$</td>
<td>1.182</td>
</tr>
</tbody>
</table>

* $F_{(12,50,0.05)} = 1.85$

The body of the table contains the values of the $F$ statistic relevant to the test of the null hypothesis that the coefficients of all the lagged unanticipated terms are zero, i.e. $\beta_s = 0$ ($s = 1, 2, \ldots, n$) in equation (2). Given the 5 per cent critical value of 1.85, the null hypothesis cannot be rejected irrespective of the measure of share prices and the monetary aggregate and the expected equilibrium return. While joint significance can be rejected, there are some individually significant coefficients in the equations using $M-M6$; the change in $M6$ at a three-month lag and the change in employment at a six-month lag are usually significant. A Breusch-Godfrey test for the absence of first-to-twelfth-order autocorrelation indicated autocorrelation in only one equation, viz. (b) with $AO$ as the dependent variable. Hence, the data seem, on the whole, to be supportive of semi-strong efficiency although the lagged unexpected change in $M6$ and in employment appear to have some predictive power.

### V Conclusions

This paper has set out to test the semi-strong form of the EMH using monthly data for the Australian share market. Preliminary tests of weak efficiency were also reported. The results generally support market-efficiency in the sense that lagged returns or lagged values of the unexpected values of explanatory variables have no significant joint explanatory power in regressions for share returns although an occasional individual term was significant.

This conclusion is in contrast to those of the three previous Australian studies briefly described in the introductory section of this paper although quite consistent with recent overseas tests of semi-strong efficiency as reported in, e.g. Darrat (1988). Our analysis is most nearly comparable to that of Sharpe (1983) in terms both of the two-step estimation procedure and the tests used. A comparison of our results to his suggests various, not necessarily alternative, ways in which they might be reconciled. First, our sample period is more recent and it may be that markets have become more efficient since Sharpe's sample period of 1978-81. Second, he uses weekly data compared to our monthly so that it is possible that the inefficiencies he finds are too short term to be detected by our data. It is not clear, however, how our finding of some predictive power of $M6$ growth at three lags and of employment growth at six lags fits into this rationalization. Finally, Sharpe used different variables to ours and it is possible that, by and large, macro variables of the type used in the present study (output, money and inflation) have little predictive power for returns to shares but financial variables of the type used by Sharpe (such as foreign and domestic interest rates and exchange rates) are able to explain future share prices.

It is safe to conclude that the question of the semi-strong efficiency of Australian share markets in the 1980s is not a settled issue and that more work with recent data needs to be carried out before even the major issues are satisfactorily resolved.

### Data Appendix

The data and sources are as follows:

   - $M0$ = money base.
   - $M3$ = currency plus bank deposits of the private non-bank sector.
   - $M6$ = $M3$ plus borrowings from the private sector by non-bank financial institutions less the latter’s holdings of currency and bank deposits.
2. Activity variables
   - Retail sales, ABS Catalogue No. 8501.0
   - Employed persons, ABS Catalogue No. 6203.0
3. Price level
   - Index of prices of articles produced by the manufacturing sector, ABS, Catalogue No. 6412.0
4. Risk-free rate
   - 90-day bank-accepted bill rate, RBA, Bulletin.

* The data used are available from the first author on request.
5 Share prices. Source: Personal Investment Magazine.
All-Ordinaries index, Australian Stock Exchange
All-Industries index, Australian Stock Exchange
All-Ordinaries accumulation index, Australian Stock Exchange
All-Industries accumulation index, Australian Stock Exchange
Monthly data are end-of-month share prices.

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