Excess Volatility? The Australian Stock Market from 1883 to 1999

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Abstract

Are share markets too volatile? While it is difficult to ignore share market volatility it is important to determine whether volatility is excessive. This paper replicates the Shiller (1981) test as well as applying standard time series analysis to annual Australian stock market data for the period 1883 to 1999. While Shiller's test suggests the possibility of excess volatility, time series analysis identifies a long-run relationship between share market value and dividends, consistent with the share market reverting to its fundamental discounted cash flow value over time.

JEL Classification: G12, C22, C32, C51, C52

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1. Introduction

There is considerable empirical evidence to support the argument that stock markets are more volatile than the discounted cash flow pricing model suggests (Campbell and Shiller, 1987, Gillies and LeRoy, 1991, LeRoy, 1989, LeRoy and Porter, 1981, Scott, 1985, Shiller, 1981, 1988, 1990, and West, 1988a). While the work of Shiller (1981) and LeRoy and Porter (1981) publicised this argument, a fairly large number of empirical tests supporting the excess volatility argument followed. This additional work corrected many of the problems associated with the earlier research, including improved statistical tests as well as alternative methods of analysis. Yet, during this period there was little success in explaining the phenomenon (Gillies and LeRoy, 1991). It appears there is no acceptable replacement for the discounted cash flow model. Bubbles and fads have been suggested (Gillies and LeRoy, 1991, Shiller, 1990 and West, 1988b) though West (1988b) argues that these explanations are not convincing. Two explanations that have generated substantial interest are non-constant discount rates (Cochrane, 1992, Cuthbertson and Hyde, 2002, Gillies and LeRoy, 1991, Kleidon, 1988b) and non-constant growth rates (Barsky and De Long, 1993) though these extensions are not the subject of this study.

Not all researchers accept that stock market prices are excessively volatile. For example, Ackert and Smith (1993), Barsky and De Long (1993), Cochrane (1992), Kleidon (1986a and 1986b), Marsh and Merton (1986) and Shea (1989) provide various rebuttals. While Shea (1989) questions some of the statistical tests applied in tests of excess volatility, Ackert and Smith (1993) argue that care is required with the definition of dividends particularly in Shiller's data set. Further, Barsky and De Long (1993), Kleidon (1986a and 1986b) and Marsh and Merton (1986) infer that Shiller's result is peculiar to the assumed dividend process underlying the price calculation. They show that if dividends are non-stationary then Shiller's variance bounds are incorrect and the finding of excess volatility is invalid.

This paper focuses on the question of excess stock market price volatility and the appropriateness of the discounted dividend valuation model using annual observations of real stock market value and real dividends for the Australian stock market. Unit root tests are applied in the analysis of the underlying processes driving real dividends and real stock market value, and tests for cointegration and vector error correction models are used in the analysis of the underlying relationship between these two variables. The analysis suggests that the value of the equity market tends to revert to its equilibrium or fundamental value over time even after substantial shocks such as the 1929 and 1987 equity market crashes. The stock market data for the period from 1882 to 1999 was supplied by the Australian Stock Exchange and an inflation index, the retail price index, was obtained from the Reserve Bank of Australia (section 3). The results from the analysis are reported in Section 4 and a summary is provided in Section 5. A review of the literature is provided in the following section.

2. Literature Review

Shiller (1981) produced the most influential paper in this controversy. He argues that stock returns are more volatile than suggested by the present value model. There are three key assumptions underlying this analysis: constant growth rate, constant discount rate, and stationary dividend series. Shiller (1981) calculates real dividends and real stock market prices and detrends these series to remove an assumed constant geometric growth factor. The traditional discounted cash flow model is relied upon to estimate the real stock market value, P_t, in terms of the present value of expected real dividends.

$$P_t = \sum_{k=0}^{\infty} \gamma^{k+1} E_t(D_{t+k}) \tag{1}$$

where $\gamma = \dfrac{1}{1+r}$ = constant real discount factor $(0 < \gamma < 1)$,

r = constant required return, r,

$E_t(.)$ = expectations operator as at time t,

D_{t+k} = real dividend k periods from time t paid at the end of the period $t+k$.

The long run growth is removed from P_t and D_t using a long run growth factor, $\gamma^{t-T} = (1+g)^{t-T}$, with g the growth rate and T the base year. Shiller(1981) estimates the growth rate by regressing the natural log of price on an intercept and time trend, $\ln(P_t) = a+bt+\varepsilon_t$, and setting $\gamma = e^b$. The real price and real dividends are adjusted for growth using the growth factor such that:

$$p_t = \frac{P_t}{\lambda^{t-T}} = \frac{P_t}{(1+g)^{t-T}} \text{ and } d_t = \frac{D_t}{\lambda^{t-T}} = \frac{D_t}{(1+g)^{t-T}} \tag{2}$$

Defining $\lambda\gamma = \bar{\gamma}$. The real stock market value as per equation (1) may now be rewritten in terms of real growth adjusted expected dividends.

$$p_t = \sum_{k=0}^{\infty} (\lambda\gamma)^{k+1} E_t d_{t+k} = \sum_{k=0}^{\infty} \bar{\gamma}^{k+1} E_t d_{t+k} \tag{3}$$

The growth rate is defined to be less than the discount rate to ensure a finite price and so it is expected that $\bar{\gamma} = \lambda\gamma = \frac{1+g}{1+r} < 1$. Shiller (1981) restates $\bar{\gamma} = \frac{1}{1+\bar{r}}$ which is the discount factor for the detrended real price, p_t, and detrended real dividend series, d_t. The discount rate is derived by taking unconditional expectations over equation (3) and summing the resulting infinite series.

$$E(p) = E\left(\sum_{k=0}^{\infty} \bar{\gamma}^{k+1} E_t d_{t+k}\right) = \sum_{k=0}^{\infty} \bar{\gamma}^{k+1} E(d) = \left(\frac{\bar{\gamma}}{1-\bar{\gamma}}\right) E(d) \tag{4}$$

Given the definition of $\bar{\gamma} = \frac{1}{1+\bar{r}}$, the discount rate can be written as the ratio of the mean growth adjusted real dividend to the mean growth adjusted real price or:

$$E(p) = \left(\frac{1/(1+\bar{r})}{1-1/(1+\bar{r})}\right) E(d) = \frac{1}{\bar{r}} E(d) \tag{5}$$

$$\bar{r} = E(d)/E(p).$$

Thus the appropriate discount rate, $\bar{r}$, for the adjusted series is estimated by taking the ratio of expected value of the detrended real dividend to the expected value of the detrended real price. Shiller (1981) suggests another formulation of the problem with the price stated in terms of the actual (ex post) subsequent dividends:

$$p_t = E_t(p_t^*) \text{ where } p_t^* = \sum_{k=0}^{\infty} \bar{\gamma}^{k+1} d_{t+k} \tag{6}$$

Estimation of price using equation (6) involves summing over an infinite series of dividend terms. The dividend process is estimated recursively by taking the average growth adjusted real price from the full sample, *E*(*p*), as the present value of dividends at the end of the sample. The price, p_t*, is calculated beginning with the most recent observation and then solving recursively back to the first observation using the equation:

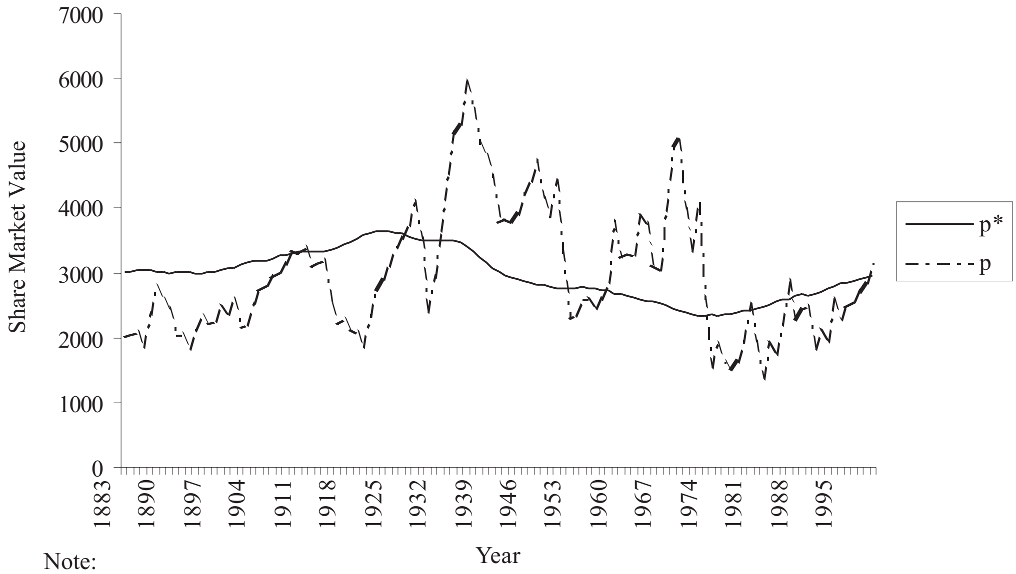
$$p_t^* = \bar{\gamma}(p_{t+1}^* + d_t) \tag{7}$$

This is simply the present value at time *t* of the sum of the price and the dividend received at time *t+1*. Figure 1 plots both the series of growth adjusted real prices, p_t and perfect foresight present-value-based prices, p_t* for the Australian share market. The results are similar to figures 1 and 2 reported in Shiller (1981).

The forecast error for the present value based prices, p_t*, is defined as $u_t = p_t^* - p_t$. This can be rewritten as $p_t^* = p_t + u_t$ and this equation leads to the best known of the three variance bounds proposed by Shiller (1981). Given rational expectations, the forecast is uncorrelated with the forecast error and so this provides a lower bound for the variance.

$$\text{var}(p_t^*) = \text{var}(u_t) + \text{var}(p_t) \text{ and so } \text{var}(p_t^*) \geq \text{var}(p_t) \tag{8}$$

Figure 1
Share Price Index and Ex-Post Rational Price
(Real Prices and Dividends adjusted for Growth, 1883-1999)



Note:
Both the real price and real dividend series are detrended by dividing by the long run exponential growth factor and the base year is set at 1999. The variable $p*$ is the present value of the observed subsequent real detrended dividends with the present value of dividends at 1999 assumed equal to the average real detrended price for the period. $p*$ is calculated recursively beginning at 1999 with the average real detrended price for the period and then the $p*$ value for 1998 is calculated using $p_{1998*}\bar{\gamma}(p_{1998}{*}+d_{1998})$ where dividends are received at the end of the period and $\bar{\gamma}$ is the discount rate.

The bound[1] is a hurdle value rather than a statistical test and the lack of a statistical test for significance generates some criticism. In the same year, LeRoy and Porter (1981) develop statistical tests of excess volatility supporting Shiller's finding. Given these results both Shiller (1981) and LeRoy and Porter (1981) reason that stock prices are too volatile for the stock market to be efficient in a present value sense.

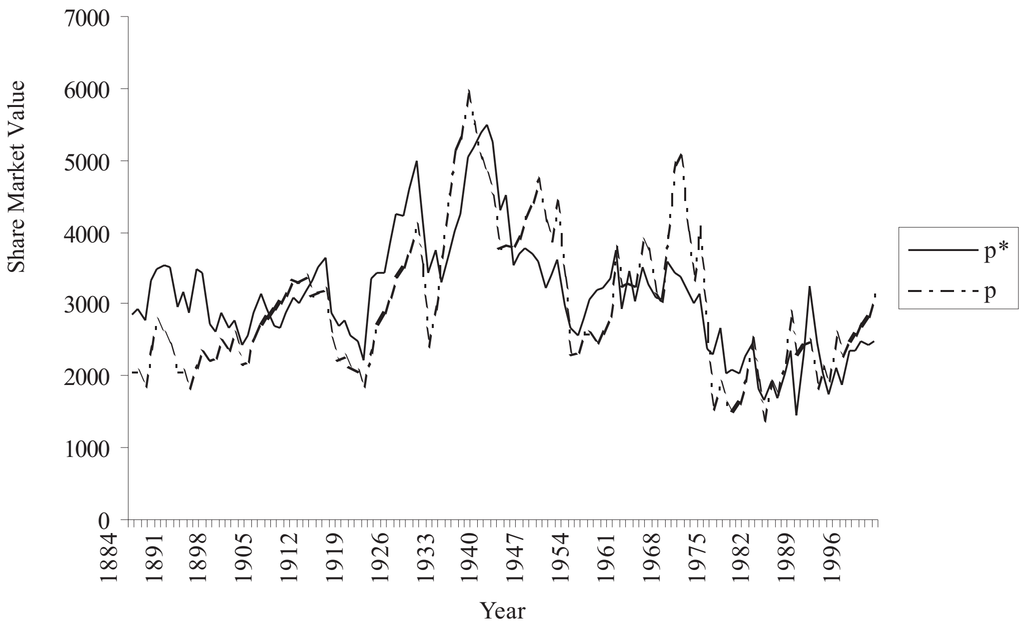
The suggestion that stock markets are excessively volatile has generated substantial discussion. For example Flavin (1983) and Kleidon (1986a) argue that Shiller's variance bound tests are subject to a small sample bias towards rejection of the bounds. Marsh and Merton (1986) show the variance bounds tests are sensitive to the assumed dividend process and if dividends are non-stationary Shiller's variance bounds are reversed. Kleidon (1986b) uses simulations to further highlight the impact of a non-stationary dividend process on Shiller's variance bounds.[2] While Gillies and LeRoy (1991) agree that an important criticism of the Shiller result is the reliance on the assumption of a stationary dividend process, they question whether this assumption can adequately explain the magnitude of the excess volatility observed by Shiller.

The assumption of a simple random walk process without drift provides an indication of the impact of relaxing Shiller's assumption of stationary dividends. In this case the expected dividend for some time in the future is the current observed dividend or $E_t d_{t+k} = d_t$ (for all integers k > 0) and so given an infinite sequence of dividends, the stock market value follows a simple perpetuity formula rather than requiring perfect knowledge of the future stream of dividends. Given equation (3):

$$\begin{aligned} p_t &= \sum_{k=0}^{\infty} \bar{\gamma}^{k+1} E_t d_{t+k} \\ &= \bar{\gamma} E_t d_t + \bar{\gamma}^2 E_t d_{t+1} + \bar{\gamma}^3 E_t d_{t+2} + \ldots \\ &= d_{t+1} \bar{\gamma} \left(1 + \bar{\gamma} + \bar{\gamma}^2 + \ldots\right) \\ &= d_{t-1} \frac{\bar{\gamma}}{(1-\bar{\gamma})} = \frac{d_{t-1}}{\bar{r}} \end{aligned} \tag{9}$$

To provide some indication of the impact of this change in assumptions, the theoretical price, p_t*, is recalculated using the perpetuity formula detailed in equation (9) and this is graphed in Figure 2. With this adjustment the volatility of the theoretical stock market value is much closer to the volatility of the actual market value.

Figure 2
Share Price Index and Valuation Based on Prior Dividend
(Real Prices and Dividends adjusted for Growth, 1883-1999)



Note:
Both the real price and real dividend series are detrended by dividing by the long run exponential growth factor and the base year is set at 1999. The variable *p** is calculated using the constant dividend perpetuity model given the dividend for the previous period, observable now, and constant discount rate calculated for the sample, $\bar{\gamma}$. This is written as $p_t^* = d_{t-1} / \bar{r}$.

One further criticism of the Shiller analysis involves the removal of the geometric trend from the time series. While Nelson and Kang (1984) highlight the problems arising from the removal of a deterministic trend from a non-stationary process, Kleidon (1986b), Marsh and Merton (1986) and Campbell and Shiller (1987) make this point more forcefully. Thus the removal of the impact of growth over the period may also adversely affect the conclusions drawn in early tests for excess volatility.

There are clearly problems with the early tests for excess volatility. As a result a second generation of tests appeared in the literature (Gillies and LeRoy, 1991). These tests account for many of the problems identified in the earlier literature including adjustment for non-stationary dividends. Some of these tests (for example, Mankiw, Romer and Shapiro, 1985 and 1991, Scott, 1985), though not all, identify excessive volatility. One test, developed by West (1988a) and applied in Ackert and Smith (1993), provides an important example of the impact of limiting analysis to the payment of cash dividends. While West (1988a) found evidence supporting the existence of excess volatility using Shiller's original data, Ackert and Smith (1993) argue that the dividend data used by Shiller (1981) and West (1988a) is narrowly defined and ignores cash flows from share repurchases and takeover distributions, alternative sources of cash particularly evident after 1970 when Shiller's graphical analysis is particularly persuasive. With the use of a more broadly defined measure of shareholder cash receipts, Ackert and Smith (1993) find little evidence of excessive volatility.

A series of papers by Campbell and Shiller (1987, 1988a and 1988b) also adjust for some of the problems observed in the early excess volatility literature and there is little clear rejection of the discounted cash flow model. Cochrane (1992) also considers this question suggesting that changing discount rates provide an important explanation for the observed variation in stock prices. In general, the more recent tests either provide support for the discount cash flow model or fail to provide a clear rebuttal of the present value model.

Barsky and De Long (1993) propose that a non-constant dividend growth rate explains the unexpected variation in stock market returns. Their reasoning is couched within the Gordon (1962) model. They argue that Shiller's constant growth rate adjustment is invalid, assuming that the natural log of real dividends follows a complex non-stationary process. This assumption appears reasonable given a crude model of value, real dividends multiplied by 20, accounts for over three fifths of the variation in long run changes in stock market value.[3] This simple approximation provides a substantial improvement over the model used in Shiller (1981). Although, Barsky and De Long (1993) find that stock value is more volatile than expected they argue this greater volatility is explained by variation in the dividend growth rate. Their adjusted pricing model accounts for much of the long run variation in observed prices. Given this alternative view on dividend processes, Barsky and De Long (1993) argue the present value model "… retains considerable power."

Thus there is still some uncertainty about the ability of the discounted cash flow model to explain observed stock market volatility. Possible explanations include modelling time-varying dividend growth rates (Barsky and De Long, 1993) and time-varying discount rates (Cochrane, 1992) though the task of assessing these alternative explanations is left to future research.

3. Data

Australian share price data is used in this paper in a test of the present value model and its ability to explain variation in stock market value. End-of-calendar-year share market price index and accumulation[4] index values are obtained from the Australian Stock Exchange for the period from 1882 to 1999.[5] The indices are constructed using three series, the Commercial and Industrial Index from 1875-1936, the Sydney All Ordinaries Index Calculated Retrospectively from 1937-1957, the Sydney All Ordinaries Index from 1958-1979 and finally the Australian Stock Exchange price index for the remainder of the study period, 1980-1999. The share market price index values are calculated using the average index value for the month of December each year. While the share price index is used as a measure of the value of the market, the dividend series is extracted from the accumulation and price indices. The indices do not include adjustment for share repurchases or takeover distributions and so the statistical tests reported here are to some extent biased towards rejection of the discounted cash flow model (Ackert and Smith, 1993). This bias should not be large for two reasons. First, there were no share repurchases permitted in Australia prior to the easing of legal restrictions in 1989 and little evidence of share repurchases prior to the further relaxation of the legislation in 1998 (Mitchell, Dharmawan and Clarke, 2001). Second, the impact of takeover distributions should be fairly small because Australian takeover targets are generally small relative to the acquiring firm and thus have a limited impact on the value weighted accumulation index used in this study.

The dividend yield and nominal dividend amount are calculated as follows:

$$dy_t = \frac{A_t}{A_{t-1}} - \frac{I_t}{I_{t-1}} \quad \text{and} \quad div_t = dy_t * I_{t-1} \qquad (10)$$

where

dy_t = dividend yield for the period *t-1* to *t*,

div_t = nominal annual dividend per index unit received over the period *t-1* to *t*,

A_t = accumulation index value at time *t*,

I_t = price index value at time *t*

An annual retail price index is used to estimate real price and real dividends. The annual inflation rate is estimated using retail price index numbers from 1882 to 1999 with base year value of 100.0 at the end of 1945. The Australian Bureau of Statistics publication, 28.5 Retail Price Index Numbers (a)(b) - 1850 to 1999 is the source of this inflation rate series. The index numbers are for Sydney from 1850 to 1900; from 1901 to 1980 they are the weighted average inflation rate for the six state capital cities; and from 1981 onwards they are the weighted average of retail price inflation across the eight capital cities in Australia.

Real values are obtained taking 1999 as the base year and scaling the price and dividends accordingly. Thus

$$P_t = I_t * \frac{\pi_b}{\pi_t} \text{ and } D_t = div_t * \frac{\pi_b}{\pi_t} \quad (11)$$

where π_t is the inflation index at time t. and π_d is the inflation index at the base year, 1999. The natural log of real dividends and the natural log the real price are then calculated for later analysis.

Table 1
Descriptive Statistics for the Period 1883 to 1999

	Mean	Std. Dev.	Min	Max	*ρ(1)*	r*(2)*
Log of Real Stock Market Value	6.955	0.660	5.598	8.045	0.94	0.88
Log of Real Dividends	3.920	0.5358	2.78	4.821	0.94	0.89

Note:
This table includes the mean, standard deviation (Std.Dev.), minimum (Min.) and maximum (Max.), first order autocorrelation coefficient ($\rho(1)$) and second order autocorrelation coefficient ($\rho(2)$) for annual observations of the natural log of real stock market value and the natural log of real dividends expressed in index units. The nominal dividends are obtained from the accumulation (A_t) and price indices (I_t). The dividend yield is defined as $dy_t = A_t/A_{t-1} - I_t/I_{t-}$ and this is converted to price index units given $div_t = dy_t{*}I_{t-1}$. Real stock market values are calculated using the nominal Australian stock exchange (ASX) price index values and the retail price change index obtained from the Australian Bureau of Statistics using 1999 as the base year. There are 117 observations for the years 1883 to 1999 inclusive.

Summary statistics are reported in Table 1 including the mean, standard deviation, minimum, maximum and first and second order autocorrelations. Augmented Dickey Fuller unit root test statistics are reported in Table 2. Appropriate lag choice is important for these tests and so two approaches are selected for analysis. The first approach is to arbitrarily select 5 and 10 lags. The second approach relies on the Akaike Information Criterion (AIC) and the Schwarz Criterion (SC) to determine the appropriate number of lags for testing and in each case these criteria suggest one lag.[6] There is always a tradeoff in lag selection, with misspecification if there are too few lags and over-fitting if there are too many lags (Hall, 1994). In Table 2, lag choice has no impact on the unit root tests with consistent evidence of one unit root in both the share market value series and the dividend series. As a check on the traditional unit root tests the K is undertaken and the results are reported in Table 3. These results support the finding of a unit root in the process with rejection of the null of stationary process for lags 1, 5, and 10.

Perron (1990) highlights the impact of a discontinuity in the mean of a process for unit root tests. Similar sorts of breaks could occur in this study at points where different indices are spliced together.[7] For the current data there are new share market indices beginning in 1937, 1958 and 1980 respectively. To assess the impact of the use of different indices, tests are undertaken at each of the splice dates following the approach detailed in Perron (1990). For each of the splice dates the time series are first regressed on a constant and dummy variable, set equal to zero for observations up to the splice date and then set equal to one for all following observations. Augmented Dickey Fuller tests are then run on the residuals from this regression using the critical values provided by Perron (1990). The one lag Augmented Dickey Fuller test statistics for the splice years 1937, 1958 and 1980 are –3.01, -2.28 and –2.47 for the log real share market value and –2.75, -2.25 and –2.24 for the log real dividends respectively. The 5% critical values for a sample of 100 observations with splice dates at 50%, 60% and 80% of the sample are –3.38, -3.38 and

–3.22 respectively. Given these critical values we cannot reject a null of unit root even after adjustment for the impact of splicing the indices on these dates.

There is evidence of considerable persistence in both the log real dividends and the log real price and the unit root test results are consistent with the assumption that both the log of real dividends and the log of real share market value are unit root processes.[8]

Table 2
Augmented Dickey Fuller Tests for Unit Root (1883 to 1999)

Variable	*ADF test statistic*
Log of Real Stock Market Value	
1 lag (implied by the AIC and SC criteria)#	-3.00
5 lags	-2.71
10 lags	-2.52
Log of Real Dividends	
1 lag (implied by the AIC and SC criteria)	-2.86
5 lags	-2.26
10 lags	-1.62

Note
There is evidence of significant lag at lag 8 at conventional statistical levels though both the AIC and the SC ignore this result.
The MacKinnon critical value for rejection of hypothesis of a unit root at the 5% level is 3.45. Lag selection includes arbitrary selection of 5 and 10 lags as well as relying on the AIC and the SC for lag selection and these criteria suggest one lag in each case.

Table 3
A Further Test for Unit Root in Dividends and Stock Market Value

	1 Lag	*5 Lags*	*10 Lags*
ETA μ tests			
Log of Real Stock Market Value	4.76*	1.73*	1.02*
Log of Real Dividends	5.00*	1.79*	1.04*
ETA τ tests			
Log of Real Stock Market Value	0.72*	0.30*	0.20*
Log of Real Dividends	0.86	0.34*	0.22*

Note
* significant at the 5% level of significance. Lag selection follows the ADF tests reported in Table 2. The KPSS test takes the null of a stationary process rather than the usual null of a non-stationary process adopted in the ADF tests. The critical value for μ at the 5% level of significance is 0.46. The critical value for τ at the 5% level of significance is 0.15.

4. Analysis

The core results of Shiller (1981) are critical to the debate that ensued over the 1980s and the early 1990s and so the results are repeated in Table 4 along with comparable results for Australian stock market data. For the Australian market, as for the USA, the stock price volatility of 976.549 exceeds the hypothesised bound of 378.596. This is almost three times the bound.

Table 4
Comparison of the Shiller (1981) Based Estimates for the USA and Australia

	Australian Stock Exchange Share Price Data	*Shiller (1981), S&P IndexData*	*Shiller (1981), Modified Dow IndustrialData*
Sample period	1883-1999	1871-1979	1928-1979
$E(p)$	2967.463	145.500	982.600
$E(d)$	140.201	6.989	44.760
$\bar{r} = E(d)/E(p)$	0.047	0.048	0.456
$\bar{r}^2 = (1+\bar{r})^2$-1	0.097	0.098	0.093
$b = \ln(\lambda)$	0.017	0.015	0.019
$\sigma(b)$	(0.001)	(0.001)	(1.004)
$cor(p,p^*)$	0.193	0.392	0.163
$\sigma(d)$	36.575	1.481	9.828
Volatility estimates			
$\sigma(p)$	976.549	50.120	355.900
$\sigma(p^*)$	378.596	8.968	25.800

Note:
The choice of parameters estimated for Australian Stocks and for US stocks follow Shiller (1981). Prices, p, and dividends, d, are inflation adjusted and adjusted for growth, λ, over the period with expected values of *E(p)* and *E(d)*. For the Australian data the base year is set at 1999. The price, p^*, is calculated beginning in 1999, assuming the average growth adjusted real price for the sample, *E(p)* reflects the price at the end of 1999 and then discounting the sum of dividends and the *ex post* rational price at the end of the period using the discount rate as $\bar{r}$ per equation (7).

Kleidon (1986b) showed if the dividends follow a random walk then the best estimate of future dividends is the dividend just observed. To gauge the impact of this change in assumption, the bound is re-estimated by assuming the real price is adequately represented by the perpetuity, $\frac{d_{t-1}}{\bar{r}}$ where current dividends are the best estimate of future dividends. This results in doubling of the bound from 378.596 to 812.882. The argument for excess volatility is now far less convincing. In Figure 2 the theoretical price is much closer to the observed stock market value and the new theoretical price exhibits volatility levels much closer to those observed in the share market. The arguments of Barsky and De Long (1993), Kleidon (1986a, 1986b, 1988a and 1988b) and Marsh and Merton (1986) concerning the assumed underlying dividend process seem well founded.

Shiller also assumed the data could be detrended in a meaningful way. If both real dividend and real price follow unit root processes then detrending is not valid (Nelson and Kang, 1984). Given the results of unit root tests reported in the previous section the detrending technique applied in the original Shiller (1981) paper is flawed (Kleidon, 1986a, 1986b, 1988a and 1988b and Marsh and Merton, 1986).

Barsky and De Long (1993) and Campbell and Shiller (1988b) suggest the possibility of a long run relationship between real price and real dividends. Following the literature, the real price is defined in terms of the Gordon (1962) model with constant dividend growth.

$$P_t = \frac{D_t(1+g)}{(r-g)} \quad (12)$$

Taking logs and rearranging equation (12) we obtain:

$$\ln(P_t) = \ln\left(\frac{1+g}{r-g}\right) + \ln(D_t) = c + \ln(D_t) \quad (13)$$

Given a constant discount factor (*c*), there is a linear relationship between the log real price, the discount factor and the log real dividends. Johansen tests for cointegration are conducted to test for evidence of this linear relationship between log real dividends and log real price for the Australian market. The results, reported in Table 5, identify one cointegrating vector and this result is insensitive both to the choice of statistic and to the lag choice (one through 10). The cointegrating vector, using a two-lag model, is (1, -2.165, -1.222). This means that, given equation (13), the share market value parameter is one, the discount factor parameter is -2.165 and the dividend parameter is –1.222.

Table 5
Johansen Tests for Cointegration

	Eigenvalue	*Statistic*	*5 percent critical value*
Trace statistic			
No cointegrating vectors	0.140	19.220*	15.41
At most one cointegrating vector	0.017	2.010	3.76
Maximum eigen-value statistic			
No cointegrating vectors	0.140	17.211*	14.07
At most one cointegrating vector	0.017	2.010	3.76

Note: * denotes rejection of the hypothesis at the 5% level. The test statistics reported here are for a VECM of order two with intercept in both the VAR and the error correction vector. Lag selection is based on a general to specific search starting from 10 lags. The trace test indicates 1 cointegrating vector at the 5% level. The Maximum eigen-value test also indicates there is one cointegrating vector at the 5% level. The test was also conducted for lags 1 through 10 with no change in the finding of one cointegrating vector at the 5% level of significance.

If two time series are cointegrated then the time series have a vector error correction model representation (Banerjee, Dolado, Galgraith and Hendry, 1993) and so a vector error correction model is used in the following analysis. This facilitates analysis of the impact of the longer-run effects (error correction term) as well as identifying the impact of short-run lead/lag relationships between dividends and stock market value. An important task in estimation of the vector error correction model is identification of an appropriate number of lag terms. A commonly used approach is the initial identification of a general model (10 lags in this case), which is reduced to a specific, more parsimonious, model using F-tests and t-tests to remove statistically insignificant lags. The final model obtained using this approach includes two lags. The AIC and SC criteria were also used though both suggested inclusion of only one lag. While the one-lag model exhibited substantial serial correlation in the residuals there was no evidence of statistically significant serial correlation in the two-lag model residuals and so the two-lag model was chosen for analysis. The results of vector error correction estimation are reported in Table 6.

There are two equations reported in Table 6. The first is for the natural log of the real share market value (LRP) and the second is for the natural log of dividends (LRP). The error correction term parameters identify the impact of long-run adjustments on share market value and dividends with the error correction term parameter for the share market value being negative and significant at the 10% level while the parameter is insignificant in the dividend equation. The actual error correction term is estimated as:

$$\ln(P_t) - 2.165 - 1.222\ln(D_t) \quad (14)$$

Table 6
Vector Error Correction Model

	D(LRP) parameter	*t-statistic*	*D(LRD) parameter*	*t-statistic*
Error Correction Term Parameter	-0.18	-1.77^{+}	0.10	1.18
D(LRP(-1)	0.13	0.95	-0.28	-2.54*
D(LRP(-2)	0.09	0.59	0.25	2.07*
D(LRD(-1)	-0.14	-0.85	0.05	0.39
D(LRD(-2)	-0.34	-2.26*	-0.32	-2.55*
Constant	0.02	1.59	0.02	1.66
Adjusted R-squared	0.04		0.14	
F-statistic	1.84		4.81*	
	Chi-square	*Prob.*		
LM test for serial correlation $\chi^2(10)$	0.61	0.96		
Model restrictions				
- Exclude lag 1; $\chi^2(2)$	33.81*	0.00		
- Exclude lag 2; $\chi^2(4)$	13.18*	0.01		
- Exclude DLRD terms in DLRP equation, $\chi^2(2)$	5.33^{+}	0.07		
- Exclude DLRP terms in DLRD equation, $\chi^2(4)$	10.82*	0.00		
- Restrict error correlation term parameters for LRP and already to one, $\chi^2(1)$	6.41*	0.01		
- Index splice date dummy effects, $\chi^2(6)$	3.67	0.89		

Note: * denotes rejection of the null hypothesis at the 5% level and + denotes rejection of the null hypothesis at the 10% level. D(LRD(-i)) is the change in the log of the real dividend lagged i periods. D(LRP(-i)) is the change in the log of the real stock value lagged i periods. The lag length is chosen using a general-to-specific search beginning at lag 10 and removing terms that are not statistically significantly different from zero from the model. The error correction term is constructed from the cointegrating vector that identifies the normalised parameters for the share market value, the discount factor (constant term) and dividends making up equation (13), (1, -2.165 and –1.222). Thus the error correction term is defined as:

LRP - 2.165 - 1.222 already.

The LM test is a joint test for serial correlation in the residuals given 10 lags. The model restrictions include restricting the four first lag terms to zero, restricting the four second lag terms to zero, restricting the two lagged dividend terms in the share market value equation to zero, restricting the two lagged share market value terms in the dividend equation to zero, restricting the cointegrating vector parameters for the share market value and dividends to one, and restricting dummy variables included to capture the index splice date effect to zero.

The error correction parameter, estimated for the error correction term, is sometimes called the speed of adjustment parameter and it indicates how quickly the economy moves back to the long run equilibrium level after a shock. Assume the economy is in equilibrium with an error correction term equal to zero. If there is a positive shock to dividends then equation (14) shows that the error correction term will become negative. To assess the impact of this shock on future share market value it should be noted that the product of the error correction term and error correction parameter (-0.18 in Table 6) is positive. Thus the long-run effect of a positive shock to dividends is initially an increase in the next period share market value and, in the absence of further shocks, the error correction term will ultimately drive the share market value up to its new equilibrium level consistent with the increase in dividends. Dividends appear to be exogenous with respect to long-run pricing errors because there is no statistically significant error correction parameter in the dividend equation.

The dividend parameter in the cointegrating vector is equal to 1.222 and this parameter is statistically significantly greater than one as indicated by the chi-square test statistic of 6.41 in Table 6, a result that is also observed in the long-return regression reported in Barsky and De Long (1993).

The intercept term, or discount factor, in the cointegrating vector also provides some information about the Australian share market. If the growth rate is set at the average over the period, 1.7% (Table 4), then the intercept estimate of 2.165 suggests a stock market discount rate of around 13.4%. This seems a little high given the continuously compounded real stock market return mean of 6.8% and median of 8.4% for the period 1883 to 1999. Further, this is also high when compared with the geometric average of 8.26% reported in Officer (1989) as an estimate for the Australian share market risk premium for the period 1882 to 1987. Although the full estimation details are not reported here, it is found that when the vector error correction model is re-estimated with the dividend parameter constrained to one the constrained error correction term takes the form:

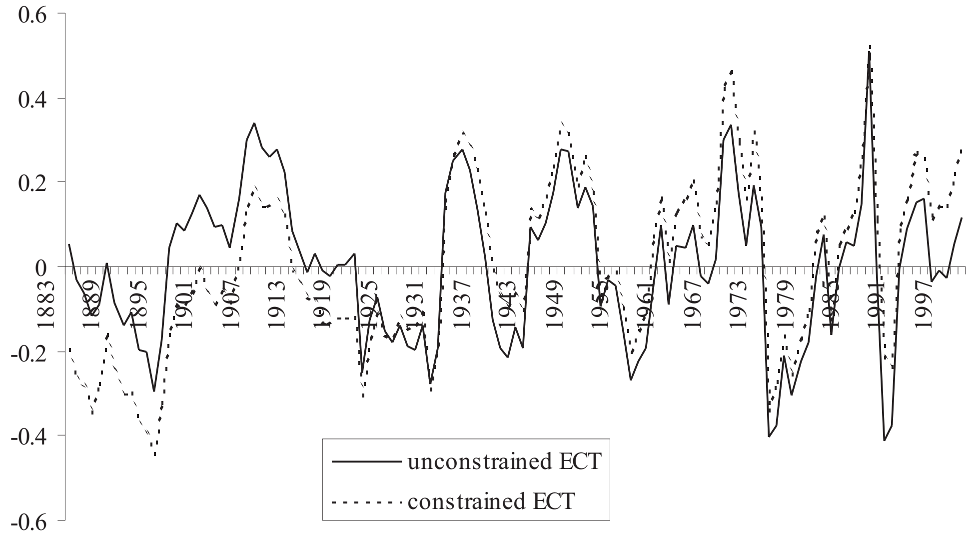
$$\ln(P_t) - 3.036 - \ln(D_t) \qquad (15)$$

The implicit stock market discount rate is now 6.5%, a value much closer to the average market return for the period than is the case for the unconstrained error correction term. Figure 3 provides an indication of the time changing nature of the error correction term from 1883 through to 1999 for both the unconstrained error correction term (equation 14) and for the constrained error correction term (equation 15).

Lagged difference terms provide an indication of the short-run effects on share market value and dividends. For example, with reference to the lagged dividend terms in Table 6, an increase in dividends in one year tends to be followed by a decrease in dividends and share market value in future years. This possibly captures the cyclical nature of the share market and variation in the ability of firms to maintain dividends over time. The direction of the short-run relationship between lagged changes in share market value and current changes in dividends varies with lag choice and so it is difficult to draw strong conclusions from this result. Finally, lagged changes in share market value appear to have little predictive ability over future changes in share market value. It could be argued this is expected in an efficient market.

The error correction term parameters suggest that while shocks to prior period dividends and share market value do occur there is a tendency for share market value to return the fundamental discounted cash flow value while dividends appear to be exogenous.

Figure 3
Long Run Pricing Errors



Note: The long run pricing errors, or error correction terms (ECT), are defined as per equation (14) and equation (15). Equation (14) describes the unconstrained ECT equation and equation (15), where the share market value and dividend parameters are constrained to equal to one, describes the constrained ECT equation. These equations reflect the long run changes in the relationship between real price and real dividends over time.

Further, the results suggest that there are feedback effects from dividends to share market value and from share market value to dividends in the short-run.

5. Conclusions

The arguments of Shiller (1981) appear to be a little too pessimistic for the Australian stock market though the results of this paper also indicate the need for some care in the use of the discounted cash flow model. Holding the discount rate and the growth rate constant over the study period, there is evidence of a long-run relationship with share market value reacting to previous period dividend shocks or to share market value shocks. These long-run effects tend to drive share market value back to its fundamental value. The long-run fundamental value is roughly consistent with the discounted cash flow model with log prices a linear function of log dividends though the one-to-one movement predicted by the discounted cash flow model is not observed. It appears stock market price is more sensitive to dividend variation than predicted. Though the parameter estimate of 1.222 is fairly close, it is statistically significantly different from the predicted value of 1.000. Nevertheless, the discounted cash flow model explains much of the long run variation in stock market value. There is also some evidence of short-term effects though these effects are not the topic of this paper.

Stock market value appears to be anchored to the long run relationship identified in the cointegrating vector though there are periods where considerable discrepancies exist. Perhaps these periods of pricing discrepancy could be explained by variation in dividend growth (Barsky and De Long, 1993) and time varying discount rate (Cochrane, 1992). This certainly provides a question for future research.

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Endnotes

1. Shiller develops two other variance bounds though these add little to the discussion as the results are consistent for each of the bounds.

2. In a later paper, Shiller (1988) criticises Kleidon's simulations because they appear to be sensitive to parameter choice.

3. This is strikingly close to discounting real dividends in perpetuity at the real share market discount rate of around 5% observed in a number of the studies.

4. The accumulation index includes the impact of dividends as well as changes in value.

5. The Australian Stock Exchange has only recently made this data available. A similar index was used in estimation of equity premia by Officer (1989) and in analysis of time changing volatility in Kearns and Pagan (1993).

6. An anonymous reviewer suggested this alternative approach.

7. The need for testing for this effect was raised by an anonymous reviewer. Each splicing point is tested individually in this paper though an alternative approach, not followed here, is to test all three of the splice points jointly.

8. Note that the unit root process for log real price indicates there is no simple mean reversion of real share market value toward its long run average. The following analysis suggests that the share market reverts to its long run fundamental value determined by the discounted cash flow model.

References

Ackert, Lucy, F. and Smith, Brian F., 1993, "Stock Price Volatility, Ordinary Dividends, and Other Cash Flows to Shareholders", *Journal of Finance*, 48, 4, 1147-1160.

Banerjee, Anindya, Dolado, Juan, J., Galgraith, John, W. and Hendry, David, F., 1993, *Co-Integration, Error-Correction, and the Econometric Analysis of Non-Stationary Data*, Oxford University Press, Oxford.

Barsky, Robert, B. and J. Bradford De Long, 1993, "Why Does the Stock Market Fluctuate", *Quarterly Journal of Economics*, 108, 2, 291-311.

Campbell, John. Y. and Shiller, Robert. J., 1987, "Cointegration and Tests of Present Value Models", *Journal of Political Economy*, 95, 1062-1088.

Campbell, John. Y. and Shiller, Robert. J., 1988a, "Stock Prices, Earnings, and Expected Dividends", *Journal of Finance*, 43, 661-676.

Campbell, John. Y. and Shiller, Robert. J., 1988b, "The Dividend-Price Ratio and Expectations of Future Dividends and Discount Factors", *Review of Financial Studies*, 3, 195-228.

Cochrane, John, H., 1992, "Explaining the Variance of Price-Dividend Ratios", *Review of Financial Studies*, 5, 243-280.

Cuthbertson, Keith and Stuart Hyde, 2002, "Excess Volatility and Efficiency in French and German Markets", *Economic Modelling*, 19, 399-418.

Flavin, Marjorie A., 1983, "Excess Volatility in the Financial Markets: A reassessment of the Empirical Evidence*", Journal of Political Economy*, 91, 6, 929-956.

Gillies, Christian and LeRoy, Stephen, F., 1991, "Econometric Aspects of the Variance-Bounds tests: A Survey", *Review of Financial Studies*, 4, 4, 753-791.

Gordon, Myron, 1962, *The Investment, Financing and Valuation of the Corporation*, Irwin, Homewood, IL.

Hall, Alistair, 1994, "Testing for a Unit Root in Time Series with Pretest Data-Based Model Selection", Journal of Business and Economic Statistics, 12, 4, 481-470.

Kleidon, Allan, W., 1986a, "Bias in Small Sample Tests of stock Price Rationality", *Journal of Business*, 59, 2, 237-261.

Kleidon, Allan, W., 1986b, "Variance Bounds Tests and Stock Price Valuation Models", *The Journal of Political Economy*, 94, 5, 953-1001.

Kleidon, Allan, W., 1988a, "The Probability of Gross Violations of a Present Value Variance Inequality: Reply", *The Journal of Political Economy*, 96, 5, 1093-1096.

Kleidon, Allan, W., 1988b, "Bubbles, Fads and Stock Price Volatility Tests: A Partial Evaluation: Discussion", *The Journal of Finance*, 43, 3, 656-660.

LeRoy, Stephen, F., 1989, "Efficient Capital Markets and Martingales", *Journal of Economic Literature*, 27, 4, 1583-1621.

LeRoy, Stephen, F., and Porter, Richard D., 1981, "The Present Value Relation: Tests Based on Implied Variance Bounds", *Econometrica*, 49, 3, 555-574.

Mankiw, N. G., D. Romer and M. D. Shapiro, 1985, "An Unbiased Reexamination of Stock Market Volatility", Journal of Finance, 40, 677-687.

Mankiw, N. G., D. Romer and M. D. Shapiro, 1991, "Stock Market Forecastability and Volatility: A Statistical Appraisal", *Review of Economic Studies,* 58, 455-477.

Marsh, Terry, A. and Robert C. Merton, 1986, "Dividend Variability and Variance Bounds Tests for the Rationality of Stock Market Prices", *American Economic Review*, 76, 3, 483-498.

Mitchell, Jason, D., Dharmawan, Grace V. and Clarke, Alex W., 2001, "Managements' Views on Share Buy-Backs: An Australian Survey", *Accounting and Finance*, 41, 1/2, 93-129.

Nelson, Charles, R. and Kang, Heejong, 1984, "Pitfalls in the Use of Time as an Explanatory Variable in regression", *Journal of Business and Economic Statistics*, 2, 1, 73-82.

Officer, R. R., 1989, "Rates of Return to Shares, Bond Yields and Inflation Rates: An Historical Perspective", *Share Markets and Portfolio Theory*. R. Ball, P. Brown, F. J. Finn and R. R. Officer. St. Lucia, Qld., University of Queensland Press**,** 207-211

Pagan, Adrian, A. and Kearns, Phillip, 1993, "Australian Stock Market Volatility: 1875-1987", *Economic Record,* 69, 205, 163-178.

Perron, Pierre, 1990, "Testing for a Unit Root in a Time Series with Changing Mean", *Journal of Business and Economic Statistics*, 8, 2, 153-162.

Scott, Louis, O., 1985, "The Present Value Model of Stock Prices: Regression Tests and Monte Carlo Results", *The Review of Economics and Statistics*, 67, 4, 599-605.

Shea, Gary, S., 1989, "Ex-Post Rational Price Approximations and the Empirical Reliability of the Present-Value Relation", *Journal of Applied Econometrics*, 4, 2, 139-159.

Shiller, Robert, J., 1981, "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?", *The American Economic Review*, 71, 3, 421-436.

Shiller, Robert, J., 1988, "The Probability of Gross Violations of a Present Value Variance Inequality", *The Journal of Political Economy*, 96, 5, 1089-1092.

Shiller, Robert, J., 1990, "Market Volatility and Investor Behavior", *The American Economic Review*, 80, 2, 58-62.

West, Kenneth, D., 1988a, "Dividend Innovations and Stock Price Volatility", *Econometrica*, 56, 1, 37-61.

West, Kenneth, D., 1988b, "Bubbles, Fads and Stock Price Volatility Tests: A Partial Evaluation", *The Journal of Finance*, 43, 3, 639-655.