Do UK Stock Prices Deviate from Fundamentals?

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Abstract: This article examines the deviation of the UK market index from market fundamentals implied by the simple dividend discount model and identifies other components that also affect price movements. The components are classified as permanent, temporary, excess stock returns and non-fundamental innovations in terms of a multivariate moving average model [Lee 1998]. We find that time varying discounted rates play an active role in explaining price deviations.

***Keywords*:** Sims-Bernanke Variance Decomposition; Trivariate Moving Average

1 INTRODUCTION

For many years, stock markets were generally thought of as behaving in accordance with the Efficient Market Hypothesis (EMH). However, recent empirical investigations have found substantial evidence that the stock price movements deviate excessively from their fundamental values. Cuthbertson et al. [1997] conducted a test for market efficiency applying the VAR methodology of Campbell and Shiller [1989] to an annual UK stock index series from 1918 to 1993. Under several assumptions regarding equilibrium expected returns, their results clearly reject efficiency using the VAR metrics under the null that expected returns are constant.

No matter what causes it, the excess volatility of stock prices points to the fact that a fraction of stock price variation may arise from dynamic forces in markets not related to fundamental factors. In this paper this non-fundamental factor is identified by means of a Sim-Bernanke Variance Decomposition.

The logged dividend-price ratio model is known as dynamic Gordon model. It attributes the variation in stock prices to the change in expected future dividend growth and discount rates. (The dividend-price ratio will be discussed further in the next section.) Campbell and Shiller [1988, 1989] find that there is substantial unexplained variation in the dividend-ratio model. This implies that not just fundamentals from expected future dividend growth and the changing discount rates are adequate to account for the variation in stock prices. Chung and Lee [1998] applied this hypothesis to Asian pacific countries including Korea, Japan, Singapore and Hong Kong using a trivariate moving-average method.

We use a multivariate moving-average method to analyse the movements of stock prices in relation to the innovations in fundamentals (dividends and discount rates) and non-fundamentals on the UK stock market. The objective is to examine the extent of the deviation of the UK total market stock index from fundamentals by means of a Sims-Bernanke variance decomposition. Cochrane [1991] and Campbell and Ammer [1993] suggested that the future excess stock returns should be viewed as one factor that captures the unexpected change in stock returns. We also examine whether this non-fundamental element, the excess stock return, has a role in explaining the variation in stock prices on the UK market.

In the process we estimate a moving-average model. The model (Model I) allows for time varying interest rates, while it assumes that the expected real (one-period) stock returns are constant. The model consists of dividends, interest rates and prices, where the first two factors are treated as fundamentals.

The remainder of the paper is organised as follows. Section 2 presents the time-series model for logarithms of prices, dividends, real interest rates and expected excess return. Section 3 describes data sets and empirical results. Section 4 concludes the paper.

2 RESEARCH ISSUE AND METHOD

2.1 Model I: A Log Linear Model with time-varying Interest Rates

2.1.1 The time series representation of dividend growth rate (Δdt) and real interest rate (rt)

We denote the real price of a stock at the beginning of time period *t*, as P_t, and the real dividend paid during period t as D_t. Therefore, the continuously compounded return of the prices in period *t* can be written as

$$R_t = \log (P_{t+1} + D_t) - \log (P_t) \qquad (1)$$

Campbell and Shiller [1988, 1989] use a Taylor approximation of equation (1) and express stock return at time *t* as a linearization of logged real dividend (d_t), logged real price (p_t) and a constant:

$$Rt \approx \xi \equiv (1 - \rho) d_t + \rho p_{t+1} - p_t + k \qquad (2)$$

Where $\rho = \dfrac{1}{1+\exp(\overline{d-p})} = \exp(g-R)$,
with *R* equal to the sample mean stock return and *g* equal to the sample mean dividend growth rate. *k* is a constant term. Equation (2) is rewritten in terms of the dividend-price ratio $\delta_{t+1} = d_t - p_{t+1}$ and dividend growth rate Δd_t as:

$$R_t \approx k + \delta_t + \rho\delta_{t+1} + \Delta d_t \qquad (3)$$

If we solve equation (3) forward, and impose the no price bubble condition:

$$\lim_{j\to\infty} \rho^j p_{t+1} = 0$$

We have one version of dividend-price ratio:

$$\delta = E \sum_{j=0}^{\infty} \rho^j (R_{t+j} - \Delta d_{dt+j}) - \frac{k}{1-\rho} \qquad (4)$$

Equation (4) says that the log dividend-price ratio (δ) can be expressed as a discounted value of all future returns (R_{t+j}) and dividend growth rates (Δd_{t+j}).

We impose the restriction that expected excess returns on stock, over some alternative asset with return r_t, are constant:

$$ER_t = Er_t + c \qquad (5)$$

In empirical work, we take r_t to be the real return on short term commercial paper. Substituting (5) into (4), we obtain:

$$\delta_t = E_t \sum_{j=0}^{\infty} \rho^j (r_{t+j} - \Delta d_{dt+j}) - \frac{c-k}{1-\rho} \qquad (6)$$

ρ is the average ratio of stock prices to the sum of stock prices and dividends. By using $\delta_t = d_{t-1} - p_t$ and adding an error term that is a linear combination of non-fundamental shocks, e_{nt}, this equation can be rewritten as:

$$s_{2t} \equiv p_t - d_{t-1} = E_t \sum_{j=0}^{\infty} \rho^j (\Delta d_{dt+j} - r_{t+j}) + \eta_t (7)$$

Where $\eta = \sum_{K=0}^{\infty} \delta_3^K e_{nt-k}$

We allow for an error term η_t in the model to capture the extent of prices deviation from the dividend-price model. This is the source of the non-fundamental component in Model I.

2.1.2 The time series representation of changes in prices (Δpt)

Following Equation (2) above, given that

$$\Delta p_{t+1} + p_t = p_{t+1} \quad and\ \delta_{t+1} = d_t - p_{t+1},$$

substituting the change in prices (Δp_t) and the dividend-price ratio (δ) into equation (2), we have

$$R_t = k + (1 - \rho) \delta_{t+1} + \Delta p_{t+1} \qquad (8)$$

Equation (8) can be thought of as a different equation that relates R_t to future dividend-price ratio (δ_{t+1}) and future changes in price (Δp_{t+1}).

In the simple dividend discount model, the stock price is expressed as the present value of dividends discounted at a constant rate. In this paper we allow for time variation in the discount rate. Therefore, the unexpected real stock return is related not only to the news about future dividend growth, but also to real interest rates.

2.2 A Log Linear Trivariate Moving-Average Model

Unlike the results from previous studies on the US stock market, the unit root tests for the UK data show that the dividend yields have a significant stochastic trend and are thus non-stationary. In other words, the spreads between logged prices and dividends (s_{2t}) are not stationary. Fortunately, according to Equation (6), the behaviour of dividend-price ratio can be alternatively accounted for by dividend growth rates and interest rates.

We find a cointegrating relationship between the stock price and dividend series on the UK total market price index. To incorporate these findings described, we consider a 3 x 1 vector z_t consisting of dividend growth rates Δd_t, discount rates r_t and changes in stock prices Δp_t. Then by the Wold representation theorem, there is a trivariate moving-average representation (TMA) of z_t = $[\Delta dt, rt, \Delta pt]'$.
We have time-varying discount rates in Model I.

Our trivariate moving-average model of z_t is expressed as:

$$\begin{bmatrix} \Delta d_t \\ r_t \\ \Delta p_t \end{bmatrix} = \begin{bmatrix} \sum_k c_{11}^k e_{1t-k} + \sum_k c_{12}^k e_{2t-k} + \sum_k c_{13}^k e_{nt-k} \\ \sum_k c_{21}^k e_{1t-k} + \sum_k c_{22}^k e_{2t-k} + \sum_k c_{23}^k e_{nt-k} \\ \sum_k c_{31}^k e_{1t-k} + \sum_k c_{32}^k e_{2t-k} + \sum_k c_{33}^k e_{nt-k} \end{bmatrix}$$
(9)

where e_{1t}, e_{2t} and e_{nt} represent three types of innovations from dividends growth rates, discount rates and non-fundamental component. They are serially uncorrelated by construction, and are assumed to be contemporaneously uncorrelated by an orthogonalization.

In order to define the three innovations as temporary, permanent and non-fundamental components, the following restrictions are imposed:

$\Sigma_k c^k_{12} = 0$, $\Sigma_k c^k_{13} = 0$ and $\Sigma_k c^k_{23} = 0$ for all k.
(10)

The restriction $\Sigma_k c^k_{12} = 0$ distinguishes the temporary innovation e_{2t} from the permanent innovation e_{1t}. This means that the cumulative effect of e_{2t} on the first variable, Δd_t of the system equations is zero. In other words, e_2 may have a temporary effect, rather than a permanent effect on Δd_t. e_{2t} is thus called the temporary innovation in fundamentals and captures the marginal contribution of r_t in explaining stock price movements. In contrast, without the restriction on e_1, it would be allowed to have permanent effect on dividend growth rates (Δd_t) and discount rates (r_t).

Similarly, the restrictions that $\Sigma_k c^k_{13} = 0$ and $\Sigma_k c^k_{23} = 0$ for all k identify e_{nt} as non-fundamental innovations in that they do not have an effect on dividend growth rates or discount rates. Under this restriction, any innovation that affects either dividends or discount rates, directly or indirectly, is fundamental. The innovation that affects only stock prices without affecting dividends and interest rates is non-fundamental. Therefore, in this trivariate model the three types of innovations are defined based on their long-term effects on the variables and their relation to the fundamental variables.

2.3 A Restricted VAR Model

The moving average representation is obtainable by inverting a trivariate vector autoregression (TVAR) model of z_t with non-orthonormalised innovations and the associated restrictions on this TVAR model. The VAR approach postulates that the unobserved components of the returns can be written as linear combinations of innovations to observable variables [see Campbell 1991]. The coefficients in these linear combinations are identified by estimating the time-series model of z_t to construct the forecasts of the discounted value of futures dividends, real interest rates and prices. We estimate the following trivariate Var model of z_t:

$$\begin{bmatrix} \Delta d_t \\ r_t \\ \Delta p_t \end{bmatrix} = \begin{bmatrix} \sum_k a_{11}^k \Delta d_{t-k-1} + \sum_k a_{12}^k r_{t-k-1} + \sum_k a_{13}^k \Delta p_{t-k-1} + u_{1t} \\ \sum_k a_{21}^k \Delta d_{t-k-1} + \sum_k a_{22}^k r_{t-k-1} + \sum_k a_{23}^k \Delta p_{t-k-1} + u_{2t} \\ \sum_k a_{31}^k \Delta d_{t-k-1} + \sum_k a_{32}^k r_{t-k-1} + \sum_k a_{33}^k \Delta p_{t-k-1} + u_{3t} \end{bmatrix}$$
(11)

Where u_t is a 3×1 vector, $[u_{1t}, u_{2t}, u_{3t}]'$. $u_t = z_t - E(z_t \mid z_{t-s}, s \geq 1)$, and var $(u_t) = \Omega = [\sigma_{ij}]$ for $i, j = 1, 2$, and 3. That is, u_t is a non-orthonormalized innovation in z_t. The trivariate model of z_t with the restrictions in Equation (9) provides restrictions that identify e_{1t}, e_{2t}, and e_{nt} as permanent fundamental, temporary fundamental, and non-fundamental innovation, respectively.

3 DATA AND EMPIRICAL RESULTS

3.1 Data

We use monthly data from the UK stock market. The total market price index and dividend yields are downloaded from the Datastream for period of 1986:1 - 2000:2, giving 170 observations. The dividends are calculated from dividend yields (DY_t):

$D_t = P_t \times DY_t$, $\qquad d_t = \text{Ln}(D_t)$

Table 1 Unit Roots Tests.

	ADF Test	KPSS Test	
		ETA(mu)	ETA(tau)
d_t	-2.4899	3.3188**	0.5706**
Δd_t	-4.0023**	0.6466	0.09166
r_t	-3.3981*	0.5574*	0.1358
Δr_t	-12.3560**	0.03412	0.02535
s_{2t}	*-1.6744*	7.9938**	2.3988**
Δs_{2t}	-6.0475**	0.04513	0.03783
ε_t	-9.8100**	0.0304	0.0321
$\Delta\varepsilon_t$	-7.6873**	0.04789	0.02595
p_t	-0.9098	5.5177**	1.4974**
Δp_t	-9.8180**	0.0367	0.0366

Critical Values:	**H_o:**		10%	5%	1%
ADF Test	Non-stationary		-3.44	-2.87	-2.57
KPSS Test	Stationary	ETA(mu)	0.347	0.463	0.739
		ETA(tau)	0.119	0.146	0.216

Note: This table presents the results of ADF tests and KPSS test on all the variables concerned and their first order differences. * and ** denote the significant level of 95% and 99%. The lag lengths in the tests were chosen using Akaike Information Criteria

Table 2 Johansen's Bivariate Tests for Cointegration.

H0:	***H_1:***	λ_{max}			***Trace***		
		Statistic	95%	90%	Statistic	90%	
r = 0	**r = 1**	43.2543	15.8700	13.8100	48.2741	20.1800	17.8800
R ≤ 1	**r = 2**	5.0198	9.1600	7.5300	5.0198	9.1600	7.5300

Notes: r represents the number of linearly independent cointegrating vectors. Trace statistic = $-\Sigma T\Sigma_{i=r+1}^{n} Ln(1-\lambda); \lambda\lambda_{max} = -TLn(1-\lambda)$, where T is the number of observations, n is the dimension of x, and λ is the ith smallest squared canonical correlations in Johansen [1988, 1991] or Johansen and Juselius [1990, 1992]. The critical values are from Enders [1995].

3.2 Tests for Unit Roots and Cointegration

The results of unit root tests for all relevant variables and their first differences are reported in Table 1. We use Augmented Dickey-Fuller (ADF) tests and KPSS tests. [Kwiatkowski et al. 1992].

Table 1 presents the summary of the unit root tests for all relevant series and their first differences. We cannot accept the null of unit root for the spread between dividends and prices (s_{2t}). We have also found that the real interest rates r_t and excess stock returns are stationary with and without a time trend, respectively [1]. Therefore, real interest rates (r_t) and excess return (ε_t) can be included in our system equations and modelled directly.

For logged stock prices and logged dividends, they are indicative of I (1) process, as they are non-stationary in levels and both become stationary when differenced at the first order.

This fact makes it possible to check these two series for a cointegrating relationship [see Engle and Granger 1987]. In Table 2 we present the results of cointegration tests using Johansen [1988, 1991] and Johansen and Juselius [1990, 1992] method for dividends and prices. It is shown that both the eigenvalue and trace statistics are in favour of a single cointegrating vector existing. However, when real interest rates are included in testing the cointegration relationship among the three variables, we reject any cointegration at a 5% significant level [2]. Therefore, the error correction term is not added in the trivariate VAR model.

[1] To save the space, the results for cointegration tests of the three variables: Δd_t, r_t and Δp_t are not reported here.

[2] The likelihood ratio test in RATS calculates the statistic: (T - c) (log |Σr| - log |Σu|), where T = number of usable observations, c = number of parameters estimated in each equation of the unrestricted system. The test statistic can be compared to a x2 distribution with degrees of freedom equal to the number of restrictions.

Table 3 Variance Decomposition of Model I.
Relative Importance of Innovations in dividends (e1t), the Real Interest Rates (e2t) and Non-Fundamental Innovation (ent) in the variables in Model I: Zt = [Δdt, rt, Δpt]'

Variables Explained	Δd_t			r_t			Δp_t		
	Innovations in								
Forecasting Horizons	e_{1t} %	e_{2t}	e_{nt}	e_{1t} %	e_{2t}	e_{nt}	e_{1t} %	e_{2t}	e_{nt}
1	100.00	0.00	0.00	49.84	50.16	0.00	0.10	0.05	99.85
	(0.01)			(0.02)			(0.05)		
2	65.77	34.23	0.00	49.79	50.21	0.00	6.43	8.25	85.32
	(0.02)			(0.03)			(0.06)		
3	60.43	39.57	0.00	49.78	50.22	0.00	14.04	15.63	70.33
	(0.03)			(0.03)			(0.06)		
4	58.07	41.93	0.00	49.77	50.23	0.00	18.74	20.20	61.05
	(0.04)			(0.03)			(0.07)		
8	54.94	45.06	0.00	49.76	50.24	0.00	26.95	28.16	44.88
	(0.05)			(0.04)			(0.08)		
12	54.08	45.91	0.00	49.76	50.24	0.00	29.74	30.86	39.40
	(0.05)			(0.04)			(0.08)		
24	53.50	46.50	0.00	49.76	50.24	0.00	31.81	32.87	35.33
	(0.06)			(0.05)			(0.09)		

Notes: This table reports the relative importance of each innovation (e_{1t}, e_{2t}, e_{nt}) in explaining the forecast error variance of three variables in Model II using Sims-Bernanke variance decomposition. The numbers in parentheses are standard errors computed by using a Monte Carlo integration due to Kloek and Van Dijk [1978]. The standard errors are the same for each innovation at a certain forecasting horizon.

3.3 The Results

The results for Model I are presented with standard errors in Table 3. They indicate a close interrelationship between the change in dividends and the real interest rates in that they explain each other's forecast error variance up to nearly 50%. For example, 46.5% of the two-year error variance in the dividends is explained by the interest rates, similarly, 49% of the error variance in the interest rates is explained by the change in dividends.

Table 3 shows that after twenty-four-months more than 35% of the error variance in prices can not be explained by fundamentals.

4 CONCLUSION

Using data sets from the UK stock market, this paper has identified various components that may drive the movements of stock prices and investigated the relative importance of each component in terms of forecast error variance decomposition. Assuming that stock returns can be forecast from dividend growth rates and real interest rates, we identify these two elements as permanent and temporary fundamental components. The model estimated assumes that the excess stock returns are constant and thus do not have any impact on the stock price movements through time. The results indicate that apart from the two fundamental innovations from dividend growth rates and interest rates, more than one third of the forecast error variance of price series is attributed to a market non-fundamental innovation that is unexplained.

We also find that dividend growth rates and real interest rates have a close interrelation with each other.

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