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What Moves Stock Markets? Evidence that 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.

I. 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. Recently, Cuthbertson, Hays and Nitzsche (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.

The use of the variance bounds tests to examine whether stock price movements are consistent with market rationality was initiated by Shiller (1981), under the assumption of a constant discount rate and perfect foresight. He concluded that stock prices are too volatile to be accounted for by the present value of future dividends. Papers by Kleidon (1986) and Marsh and Merton (1986) investigated the validity of Shiller's variance bounds test given that both stock prices and dividends are non-stationary series[1]. Bulkley and Tonks (1989) applied Shiller-type variance bounds tests to annual UK time-series data. Assuming constant equilibrium returns, Bulkley et al found violation of the variance bound and provided an explanation based on the strong form / weak form rational expectations distinction. Another version of the variance bounds test which is valid even when dividends and prices are non-stationary was developed by West (1988a), who reported that a substantial part of price deviation is not accounted for by the simple present value model. In a survey article, Gilles and LeRoy (1991) conclude that there is no longer room for any reasonable doubt about the statistical significance of the excess volatility hypothesis. However, there have been some competing explanations as to why stock prices appear to be excessively volatile, which are consistent with efficient markets, but not the simple constant dividend discount model. Some authors (Mehra and Prescott (1985), Cochrane (1991, 1992), Campbell and Shiller (1988, 1989) and Epsein and Zin (1991)) argue that stock price movements can be rationalised by fluctuations in discount rates, while others find evidence that earnings expectations may partly explain stock price volatility (Marsh and Merton (1987), Lee (1996a) and Bulkley and Harris (1997)).

Another issue to consider has been the argument that there are bubbles in stock prices (West (1988b) and Flood (1990)). "The present value relation is derived based on an Euler equation combined with a transversality condition, when prices do not satisfy the transversality condition, they are thought to contain bubbles." (Lee (1998: p3)). The other extreme of the "bubble" interpretation is the "fad" interpretation, where stock price deviations are thought of as being slowly mean reversing (Shiller (1984), (1989), and West (1988b)). Timmerman (1993, 1994, 2000) proposes the possibility that in between these two extremes the market may price stocks by the present value model but not insert into this model rational expectations forecasts of future dividends. This may be because the true dividend model is unknown and must be learnt in calendar time. Timmerman (1994: p795) argues that "learning is an intuitive candidate for explaining the anomalies: volatility in stock prices may be increased by learning since a shock to dividends will cause a change in agents' forecasting estimates, possibly reinforcing the original shock."

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 contemporaneous regression approach is a frequently used approach (Roll (1988) and Fama (1990a)). A more popular method however is the Vector Autoregressive Model (VAR), which has been employed by Campbell and Shiller (1988, 1989), Campbell (1991) and Campbell and Ammer (1993)[2] to examine the variability of stock prices through time. Campbell and Shiller (1988: p.669) claim that the VAR has many advantages in that "VAR approach enables us to characterise the historical behaviour of the dividend-price ratio in relation to an unrestricted econometric forecast of the future dividends and discount rates". The logged dividend-price ratio model is known as dynamic Gordon model. It attributes the variation in stock prices to the charge 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. Other empirical studies of Blanchard (1979), Flood and Garber (1980), and West (1987, 1988a) are

undertaken on the US stock index and have concluded similar findings in terms of the existence and the extent of a non-fundamental component in stock price movements. Recently, Chung and Lee (1998) applied this hypothesis to Asian pacific countries including Korea, Japan, Singapore and Hong Kong using a trivariate moving-average method. They conclude that a large fraction of the total forecast error variance of stock prices is attributed to non-fundamental elements for all countries.

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. Therefore, in this paper 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 two moving-average models. The first 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 second model (Model II) takes into account the impact of time varying expected excess stock returns on stock prices. Hence the one-period real excess stock returns are added into the model to further explain the variation in stock prices in terms of forecast error variance decomposition.

The remainder of the paper is organised as follows. Section II presents the time-series models 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.

II.   Research Issue and Method

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

1.a.   The time series representation of dividend growth rate (Dd_t) and real interest rate (r_t)

It has been found that long-term prices can be surprisingly powerful forecasting variables. However, to eliminate apparent unit roots in the raw series, prices are most commonly used as elements of yields or yield spreads. For example, Campbell and Shiller (1988, 1989) and Fama and French (1988) use dividend yields to forecast stock returns[3].

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

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

The relationship in Equation (1) is not linear, for it involves the logarithm of the sum of prices and dividends. Given a static world where the stock returns and dividend growth rates are constant through time, 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:

$$Rt \approx \textbf{x}^{o}\ (\ 1 - \textbf{r}\ )\ d_t + \textbf{r}\ p_{t+1} - p_t + k \tag{2}$$

where $\textbf{r} = \dfrac{1}{1 + \exp(\overline{d - p})} = \exp(g - R)$, 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 by Campbell and Shiller (1988) in terms of the dividend-price ratio $\textbf{d}_{t+1} = d_t - p_{t+1}$ and dividend growth rate Dd_t as:

$$R_t \gg k + \textbf{d}_t + \textbf{r}\textbf{d}_{t+1} + Dd_t \tag{3}$$

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

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

We have one version of dividend-price ratio:

$$\boldsymbol{d} = E_t \sum_{j=0}^{\infty} \boldsymbol{r}^j \left(R_{t+j} - d_{t+j} \right) - \frac{k}{1-\boldsymbol{r}} \tag{4}$$

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

Generally it is convenient to impose the restriction that expected excess returns on stock, over some alternative asset with return r_t, are constant, that is:

$$ER_t = Er_t + c \tag{5}$$

Equation (5) implies that there is some variable whose beginning-of-period rational expectation, plus a constant term, c, equals the ex ante return on stock over the period. In empirical work, we take r_t to be the real return on short term commercial paper. Substituting (5) into (4), we obtain the so called dividend-ratio model (also known as dynamic Gordon model) of Campbell and Shiller (1988) expressed as:

$$\boldsymbol{d}_t = E_t \sum_{j=0}^{\infty} \boldsymbol{r}^j \left(r_{t+j} - \Delta d_{t+j} \right) - \frac{c-k}{1-\boldsymbol{r}} \tag{6}$$

This model (equation (6)) explains the log dividend-price ratios as an expected discounted value of all future one-period "growth-adjusted discount rates" discounted at a constant rate $\boldsymbol{r}$, plus a constant. $\boldsymbol{r}$ is the average ratio of stock prices to the sum of stock

prices and dividends. By using $d_t = d_{t-1} - p_t$ and adding an error term that is a linear combination of non-fundamental shocks, e_{nt}, this equation can be rewritten as:

$$s_{2t} = \mathbf{r}_t + d_{t-1} = \mathbf{d}_t = E_t \sum_{j=0}^{\infty} \mathbf{r}^j \left(\Delta d_{t+j} - r_{t+j} \right) + \mathbf{h}_t \tag{7}$$

where $\mathbf{h} = \sum_{K=0}^{\infty} \mathbf{d}_3^K e_{nt-k}$

Given the extensive evidence by Campbell and Shiller (1988, 1989) that a substantial part exists unexplained in the dividend-price ratio, we allow for an error term $\mathbf{h}_t$ 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.

1.b. The time series representation of changes in prices

Following Equation (2) above, given that

$\Delta p_{t+1} + p_t = p_{t+1}$ *and* $d_{t+1} = d_t - p_{t+1}$, substituting the change in prices ($\mathbf{D}p_t$) and the dividend-price ratio ($\mathbf{d}$) into equation (2), we have

$$R_t = k + (1 - \mathbf{r}) \, \mathbf{d}_{t+1} + \mathbf{D}p_{t+1} \tag{8}$$

Equation (8) can be thought of as a different equation that relates R_t to future dividend-price ratio ($\mathbf{d}_{t+1}$) and future changes in price ($\mathbf{D}p_{t+1}$). It says that apart from the dividend-price ratio that reflects the future change in expected returns, the changes in price also have power to explain the one period stock return. Therefore, the one period stock return is related to future expected changes in price through a version of Campbell and Shiller's (1988, 1989) log-linear Taylor approximation.

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 the real interest rates. Under the consumption of the constant expected excess return in Model I, Campbell (1991) and Campbell and Ammer (1993) have related the unexpected stock return in period $t+1$ to changes in the expectations of future dividend growth ($\boldsymbol{D}d_t$) and future real interest rates (r_t)

2.   *Model II: A Log Linear Model with Time-Varying Expected Excess Return*

The basic equation used by Campbell (1991), Campbell and Ammer (1993) and Wu (1999) to explain the unexpected real stock return in period $t+1$ as a function of the changes in rational expectations of future dividend growth rate and future real stock returns is:

$$R_t - E_t R_t = (E_{t+1} - E_t)\sum_{j=0}^{\infty} \boldsymbol{r}^j \Delta d_{t+1+j} - (E_{t+1} - E_t)\sum_{j=1}^{\infty} \boldsymbol{r}^j h_{t+1+j} \tag{9}$$

where E_t denotes an expectation formed at the end of period t, conditional on an information set that includes at least the history of stock prices and dividends, and $\boldsymbol{D}$ denotes a one-period backward difference. Formally, Equation (9) is derived from log-linear dividend-ratio model as described above in Equation (4). It is noted that all the variables in Equation (4) are measured ex post, because they are obtained by the linear Taylor approximation of R_{t+1} and the imposition of the condition that $\boldsymbol{d}_{t+i}$ does not explode as i increases. However, using the ex ante version of Equation (4) to substitute $\boldsymbol{d}_t$ and $\boldsymbol{d}_{t+1}$ out of Equation (3), we can obtain the unexpected real stock return equation as Equation (9)[4].

Under the condition of time varying excess stock return over short-term interest rates, we have

$$e_{t+1} = R_{t+1} - r_{t+1} \tag{10}$$

The difference between Equation (10) and Equation (5) is that the constant term c is replaced by a time varying term known as the future excess stock return e_{t+1}. Substituting Equation (10) into Equation (9), we obtain:

$$e_{t+1} - E e_{t+1} = (E_{t+1} - E_t)\sum_{j=0}^{\infty} r^j \Delta d_{t+1+j} - (E_{t+1} - E_t)\sum_{j=1}^{\infty} r^j r_{t+1+j} - (E_{t+1} - E_t)\sum_{j=1}^{\infty} r^j e_{t+1+j} \qquad (11)$$

Equation (11) is thought of as "a dynamic accounting identity that imposes internal consistency on expectations" by Campbell and Ammer (1993). For instance, given a constant amount of future dividend stream, an increase in expected future returns is accompanied either by a capital loss or by lowered expected excess returns today[5]. For this reason, we consider a second model (Model II) with one more variable, the excess return, e_t, incorporated in to capture the un-expected excess movements in stock prices that cannot be explained by fundamental factors of dividend growth rates and discount rates.

3.   *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.

Based on the price valuation model (dividend discount model), the early work of Campbell and Shiller (1987, 1988 and 1989) and Lee (1995) have claimed evidence that stock prices and dividends are cointegrated with a cointegrating vector of one for S&P 500 index. This finding is in common with ours in testing the 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 Dd_t, discount rates r_t and changes in stock prices Dp_t. Then by the Wold representation theorem, there is a trivariate moving-average representation (TMA) of $z_t = [Ddt, rt, Dpt]'$.

The use of a moving-average model to examine different types of innovations to the stock prices was developed by Chung and Lee (1998), who examine the effect of earnings, dividends and non-market factors on the stock price movements under the assumption that the discount rates are constant through time. In this context we follow Campbell (1991) and Campbell and Ammer (1993) by having time-varying discount rates in Model I and allowing for time varying expected excess stock returns in Model II.

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

$$
\begin{bmatrix} \Delta d_t \\ r_t \\ \Delta p_t \end{bmatrix} = \begin{bmatrix} \sum_k c_{11}^k e_{1t-k} + \sum_k c_{12}^k e_{2t-k} + \sum_k c_{13}^k e_{3t-k} \\ \sum_k c_{21}^k e_{1t-k} + \sum_k c_{22}^k e_{2t-k} + \sum_k c_{23}^k e_{3t-k} \\ \sum_k c_{31}^k e_{1t-k} + \sum_k c_{32}^k e_{2t-k} + \sum_k c_{33}^k e_{3t-k} \end{bmatrix}
\tag{12}
$$

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.

The moving-average representation is an especially useful tool to examine the interaction among the $\{Dd_t\}$, $\{r_t\}$ and $\{Dpt\}$ sequences. The coefficient c_{ij} can be used to generate the effects of two fundamental innovations and non-fundamental innovation on the entire time paths of $\{Dd_t\}$, $\{r_t\}$ and $\{Dp_t\}$ sequences. By notation, the nine elements $c_{ij}(0)$ are

impact multipliers. For example, the coefficient $c_{11}(0)$ is the instantaneous impact of a one-unit change in e_{1t} on $\boldsymbol{D}d_t$. In the same way, the elements $c_{21}(1)$ and $c_{22}(1)$ are the one-period responses of unit changes in e_{1t} an e_{2t} on r_t.

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

$$\Sigma_k \, c^k_{12} = 0, \ \Sigma_k \, c^k_{13} = 0 \ \text{and} \ \Sigma_k \, c^k_{23} = 0 \ \text{for all } k. \tag{13}$$

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, $\boldsymbol{D}d_t$ of the system equations is zero. In other words, e_2 may have a temporary effect, rather than a permanent effect on $\boldsymbol{D}d_t$. 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 ($\boldsymbol{D}d_t$) 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.

4. A Restricted VAR Model

In practice, the innovations in the above moving-average model are not directly observable. However, 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:

$$
\begin{bmatrix} \Delta d_t \\ r_t \\ \Delta p_t \end{bmatrix} = \begin{bmatrix} \sum_k a_{11}^k \Delta d_{t-k-1} + \sum_k a_{12}^k r_t + \sum_k a_{13}^k \Delta p_t + u_{1t} \\ \sum_k a_{21}^k \Delta d_{t-k-1} + \sum_k a_{22}^k r_t + \sum_k a_{23}^k \Delta p_t + u_{2t} \\ \sum_k a_{31}^k \Delta d_{t-k-1} + \sum_k a_{32}^k r_t + \sum_k a_{33}^k \Delta p_t + u_{3t} \end{bmatrix}
\tag{14}
$$

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 $(u_t) = W = [s_{ij}]$ 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 (12) provides restrictions that identify e_{1t}, e_{2t}, and e_{nt} as permanent fundamental, temporary fundamental, and non-fundamental innovation, respectively.

The contemporaneous correlation in the three innovations e_1, e_2 and e_3 are removed by orthogonalizing u_{1t}, u_{2t} and u_{3t} from TVAR model under the certain restrictions imposed. To examine the relative importance of the three different components for the historical behaviour of prices, the forecast error variance decomposition can be used. It is argued that the orthogonalized variance decomposition contains bias in that the component given the first

place in the ordering will have the largest share of variance. This issue is addressed by Enders (1995) who demonstrates that "the importance of the ordering depends on the magnitude of the correlation coefficient among the innovations." Since the three components e_1, e_2 and e_3 are serially uncorrelated by construction, the effect of orthogonalization can be trivial. Each coefficient $c^k{}_{ij}$ for i, j = 1, 2, and 3 in the TMAR Equation (11) represents the response to innovations in particular dependent variable. Again since the covariances of e_1, e_2 and e_n are zero, we can allocate the variance of each element in z_t to the sources in the elements of e and find out the relative importance of fundamental versus non-fundamental components of stock price. By imposing the restrictions on TVAR, we can conduct a restricted VAR analysis and the empirical results are presented in the next section.

5. *Model II: A Log-Linear Trivariate Model with Time Varying Expected Excess Stock Returns*

In this section, we consider a second model with time varying expected excess stock returns (e_t) included in as another fundamental factor. Therefore, the four-variable moving-average representation is expressed as:

$$
\begin{bmatrix} \Delta d_t \\ r_t \\ e_t \\ \Delta p_t \end{bmatrix} = \begin{bmatrix} \sum_k c_{11}^k e_{1t-k} + \sum_k c_{12}^k e_{2t-k} + \sum_k c_{13}^k e_{et-k} + \sum_k c_{41}^k e_{nt-k} \\ \sum_k c_{21}^k e_{1t-k} + \sum_k c_{22}^k e_{2t-k} + \sum_k c_{23}^k e_{et-k} + \sum_k c_{42}^k e_{nt-k} \\ \sum_k c_{31}^k e_{1t-k} + \sum_k c_{32}^k e_{2t-k} + \sum_k c_{33}^k e_{et-k} + \sum_k c_{43}^k e_{nt-k} \\ \sum_k c_{41}^k e_{1t-k} + \sum_k c_{42}^k e_{2t-k} + \sum_k c_{43}^k e_{et-k} + \sum_k c_{44}^k e_{nt-k} \end{bmatrix} \quad (15)
$$

To identify e_{1t}, e_{2t}, e_{et} and e_{nt} as a permanent innovation, a temporary innovation, an excess

return innovation and a non-fundamental innovation, we impose the following restrictions:

$$\Sigma_k c^k_{12} = 0, \; \Sigma_k c^k_{13} = 0, \; \Sigma_k c^k_{14} = 0, \; \Sigma_k c^k_{23} = 0 \; \Sigma_k c^k_{24} = 0 \text{ and } \Sigma_k c^k_{34} = 0 \text{ for all } k.$$

(16)

The restrictions of this four-variable model in Equation (15) say that the stock price series is decomposed into four parts, three are fundamental and one is non-fundamental. The fundamental innovations encompass not only a permanent shock to dividends and a temporary shock to interest rates, but also a third type of shock that affects the expected excess stock return but not dividends or interest rates. The non-fundamental component is driven by a fourth type of shock (e_{nt}) that does not influence fundamental factors such as dividends, interest rates and excess returns, but captures the marginal deviation in stock price movements that cannot be explained by the fundamental elements. The restrictions are, in practice, imposed on the four-variable VAR model of $z_t = [\boldsymbol{D}d_t, r_t, \boldsymbol{e}_t, \boldsymbol{D}p_t]'$ in Equation (15) following the procedure described for Model I.

$$\begin{bmatrix} \Delta d_t \\ r_t \\ \boldsymbol{e}_t \\ \Delta p_t \end{bmatrix} = \begin{bmatrix} \sum_k a^k_{11} \Delta d_{t-k-1} + \sum_k a^k_{12} r_t + \sum_k a^k_{13} \boldsymbol{e}_t + \sum_k a^k_{14} \Delta p_t + u_{1t} \\ \sum_k a^k_{21} \Delta d_{t-k-1} + \sum_k a^k_{22} r_t + \sum_k a^k_{23} \boldsymbol{e}_t + \sum_k a^k_{24} \Delta p_t + u_{2t} \\ \sum_k a^k_{31} \Delta d_{t-k-1} + \sum_k a^k_{32} r_t + \sum_k a^k_{33} \boldsymbol{e}_t + \sum_k a^k_{34} \Delta p_t + u_{3t} \\ \sum_k a^k_{41} \Delta d_{t-k-1} + \sum_k a^k_{42} r_t + \sum_k a^k_{43} \boldsymbol{e}_t + \sum_k a^k_{44} \Delta p_t + u_{4t} \end{bmatrix}$$

(17)

III.   Data and Empirical Results

1.   Data

For the empirical results in this paper we use monthly observations 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, summing up to 170 observations. The dividends are calculated from dividend yields (DY_t):

$$D_t = P_t \acute{\ } DY_t, \qquad d_t = \mathbf{Ln}\ (D_t)$$

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. Two econometric methods, the Augmented Dickey-Fuller (ADF) tests and the KPSS tests are used in this context. The ADF test attempts to account for temporally dependent and heterogeneously distributed errors by including lagged sequences of first differences of the variables in its set of regressors. The null hypothesis of the ADF test is that the variables contain a unit root or they are non-stationary at a certain significance level. However, the power of standard unit root tests with a null hypothesis of non-stationarity has recently been questioned by DeJong et al. (1992) in that these tests often tend to accept the null too frequently against a stationary alternative. It appears that the failure to reject null may be simply due to the standard unit root tests having low power against stable autoregressive alternatives with root near unity. In particular, this knife-edge assumption of an exact unit root could lead to substantial biases. In view of the growing controversy surrounding the general tests for unit root, we here employ a more realistic test – the KPSS test proposed by Kwiatkowski, Phillips, Schmidt and Shin (1992).

The KPSS test has a null hypothesis that an observable series is stationary around a deterministic trend. The series is expressed as the sum of the deterministic tend, the random

walk, and the stationary error, and the test is the LM test of the hypothesis that the random walk has zero variance. The asymptotic distribution of the statistic is derived under the null and under the alternative that the series is difference-stationary. The whole procedure for the KPSS tests calculates Kwiatkowski, Phillips, Schmidt & Shin ETA (mu) and ETA (tau) statistics. With the ETA (mu) statistic, the null hypothesis is that the series $\{X_t\}$ is stationary around a level, while with the ETA (tau) statistic, the null hypothesis accepts that $\{X_t\}$ is trend stationary. These tests are used to complement standard unit root tests as Dickey-Fuller tests. By testing both the unit root hypothesis and the stationary hypothesis, we can distinguish "series that appear to be stationary, series that appear to have a unit root, and series for which the data (or the tests) are not sufficiently informative to be sure whether they are stationary or integrated." (Kwiatkowski, Phillips, Schmidt & Shin (1992)).

(Insert Table 1 here)

Table 1 presents the summary of the unit root tests for all relevant series and their first difference. As is shown in the table, we cannot accept the null of unit root for the spread between dividends and prices (s_{2t}) according to the ADF t-statistic and the KPSS statistics. The magnitude of the KPSS statistics means that the spread is non-stationary at 99% confidence level. We have also found that the real interest rates r_t and excess stock returns are stationary with and without a time trend, respectively[6]. Therefore, the real interest rates (r_t) and excess return (e_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 cointegration 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 cointegration relationship among the three variables, we reject any cointegration at 5% significant level[7].

Therefore, the error correction term is not added in the trivariate VAR model.

(Insert Table 2 here)

3. *The Results*

In order to estimate the TVAR of z_t, we first choose the appropriate order of the lag for variables. The RATS program helps us determine the appropriate lag of one by running the Likelihood Ratio Test for variables in the model. Enders (1995) shows that if the goal is to determine whether a certain lag length is appropriate for all equations, the proper test for this cross-equation restriction is the likelihood ratio test[8]. For the monthly data we start from lags of 5 and test whether each alternative lag of 4, 3, 2, and 1 is significantly binding using the likelihood ratio test. We keep reducing lags until lag one, which means that the lag of one will be the appropriate lag we use for the TVAR model. To save space, the test results for choosing lag length are not reported here[9].

Considering that there can be excessive price volatility due to the January effect, the October 1987 crash and other seasonal effects in the monthly data over the sample period of 1976 to 1999, we attempt to account for these effects by incorporating seasonal dummies. Then we employ the likelihood ratio test again to examine whether these dummies should be added into the model by looking at the significance of the x^2 distribution. Unfortunately, our intuition is not supported, the results indicate that we can not reject the null hypothesis that the inclusion of dummies does not make a statistically significant difference from the original model. To save space again, the results are not reported here[10].

Since we have imposed restrictions that identify each type of innovation, we can examine the relative importance of these innovations using the Sims-Bernanke forecast error variance decomposition. The results of Model I are presented in table three and the results of Model II in Table 4.

(Insert Table 3 here)

The results for Model I are presented with standard errors in Table 3. They indicate the 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. This close interrelationship is self-evident in the integrated financial markets with huge number of investors trading simultaneously on bonds and stocks.

Also, in Table 3, considering the fundamental innovations in dividends and real interest rates to price movements through the 24 forecasting horizons, the significant proportion of real interest rates innovation says that it does have power in explaining the price series over time, as is concluded by Campbell and Shiller (1988, 1989). Nevertheless, it is noted that 61% of stock price movements are driven by the market non-fundamental innovation (e_{nt}) at the end of the next four months, and in twenty-four-months time still more than 35% of the error variance in prices can not be explained by either changes in dividends or discount rates. Among other implications, this indicates the evidence of deviation of stock prices from the simple present value model. Under the assumption of constant discount rates, Allen and Yang (2000) have found that a substantial proportion of the forecast error variance of stock prices is driven neither by the earnings nor by the dividends. In this application we model time variation of the discount rates, which prove to play an active role in explaining price movements. However, there still remains an unexplained portion of 35% in the forecast error variance of stock prices at the end of 24 forecasting months.

(Insert Table 4 here)

Our Model I (with results presented in table three) assumes that the expected excess returns on the stocks are constant and hence have no effect on the stock price movements over time. These unsatisfactory results prompt us to investigate the influence of time varying excess returns on the behaviour of the price series. The Model II has taken time varying excess returns into account and the forecast error variance decomposition is presented in Table 4, where the four types of innovations are identified as permanent fundamental, temporary fundamental, the excess stock return and non-fundamental innovations. The results

from the first two innovations in dividends and interest rates are similar to those in Table 3. For the innovations in excess returns, it is shown that the majority of excess return behaviour, say 70% in two years time (24 months), is explained by its own previous movements.

The more important evidence in Table 4 is observed from the last four columns. It is noted that the excess returns have accounted for the marginal part of price movements that are not explained by the fundamental elements. For example, 23% of two-year price deviation is explained by the excess returns, 40% by the change in dividends, 33% by the discount rates, and only 3% remains to be explained by nun-fundamentals, which is a striking improvement compared to the 33% un-explained part in the Model I.

The role of excess stock returns can also be identified by comparing the combined graphs of the generalised impulse response functions (GIRs) from Model I and Model II, respectively. Figure 1 illustrates the response of changes in stock prices to a one standard deviation shock to permanent and temporary innovations, and Figure 2 illustrates the changes in stock prices to a one standard deviation to three types of innovations including permanent, temporary and excess stock return innovations. It is assumed that when one variable is shocked, the other variables remain unchanged. In Figure 1, the response to non-fundamental innovations has a significant influence in the prices, whereas this is not the fact in Figure 2, where the excess stock returns have accounted for much of the non-fundamental part of the innovation and left the price series hardly influenced by the non-fundamentals. Using data sets on the US financial markets, Campbell (1991), Campbell and Ammer (1993) and Lee (1998) have concluded with similar findings.

IV.   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. The identification of these components is achieved by imposing different types of restrictions on a multivariate moving

average model. Following Campbell and Shiller's (1988, 1989) assumption that the stock returns can be forecast from dividend growth rate and real interest rates, we identify these two elements as permanent and temporary fundamental components. The first 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. In order to examine this unexplained part further, we allow a time varying excess stock return series in the second model. In compliance with Lee's (1998) finding on the US market, the results from Model II show that much of the unexplained part is accounted for by the excess stock returns. At the end of the 24 forecasting periods, only 3% of the price deviations are due to market non-fundamental innovations. The findings in this paper further reject the simple dividend discount model of Gordon, and provide us with evidence of the important role that time varying discount rates and excess stock returns play in explaining the behaviour of stock prices. This conclusion is equivalently illustrated in the generalised impulse response functions of the changes in stock prices in both models.

It is also found that the dividend growth rates and the real interest rates have a close interrelation in explaining each other. Some previous studies (Marsh and Merton (1987), Campbell and Shiller (1988)) have concluded that dividend behaviour is accounted for primarily by permanent changes in the earnings. Therefore, it would be interesting to incorporate in the earnings and investigate the influence of earnings on all the other variables. It is also worth noting that real interest rates play an active role in explaining stock price movements over time, which can not be observed in the tests using US data sets.

Notes

1. Flavin (1988) and Mankiw, Romer and Shapiro (1991) also examine this issue and question the validity of the original variance bounds tests.

2. The first two papers looked at the stock market in isolation, the third one incorporated the bond long-term bond returns to jointly account for the variance of stock returns.

3. For the use of bond yield spreads to forecast futures bond returns, interest rates, and inflation rates, see Campbell and Shiller (1991), Fama (1990b) and Mishkin (1990).

4. For further discussion of derivation of Equation (8), see appendix in Campbell (1991).

5. Campbell and Ammer (1993) provide detailed explanation.

6. The results from the ADF tests shows that r_t is stationary, whereas the KPSS tests only accept that the series is trend stationary at 95% significant level, as indicated in the ETA (tau) statistic.

7. To save the space, the results for cointegration tests of the three variables: $\boldsymbol{D}d_t$, r_t and $\boldsymbol{D}p_t$ are not reported here.

8. The likelihood ratio test in RATS calculates the statistic: $(T - c)$ (log $|\Sigma_r|$ - log $|\Sigma_u|$), 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 x^2 distribution with degrees of freedom equal to the number of restrictions.

9. It can be provided on request.

10. It can be provided on request.

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Table 1. Unit Roots Tests

	ADF Test	KPSS Test	
		ETA(mu)	ETA(tau)
d_t	-2.4899	3.3188**	0.5706**
$\mathbf{D}d_t$	-4.0023**	0.6466	0.09166
r_t	-3.3981*	0.5574*	0.1358
$\mathbf{D}r_t$	-12.3560**	0.03412	0.02535
s_{2t}	*-1.6744*	7.9938**	2.3988**
$\mathbf{D}s_{2t}$	-6.0475**	0.04513	0.03783
e_t	-9.8100**	0.0304	0.0321
$\mathbf{D}e_t$	-7.6873**	0.04789	0.02595
p_t	-0.9098	5.5177**	1.4974**
$\mathbf{D}p_t$	-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 = $-T\Sigma_{i=r+1}^{n}Ln(1-\lambda)$; $\lambda_{max} = -TLn(1-\lambda)$, 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).

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:
$$Z_t = [\mathbf{D}d_t, \mathbf{r}_t, \mathbf{D}p_t]'$$

Variables Explained	$\mathbf{D}d_t$			r_t			$\mathbf{D}p_t$		
	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.

Table 4.   Variance Decomposition of Model II

Relative Importance of Innovations in dividends (e1t), the Real Interest Rates (e2t) and Non-Fundamental Innovation (ent) in the variables in Model II:

$$Z_t = [\Delta d_t, \; r_t, \; e_t, \; \Delta p_t]'$$

Explained Variables	Δd_t		R_t		e_t				Δp_t			
	Innovations in											
Forecast Horizons	e_{1t}	e_{2t}	e_{1t}	e_{2t}	e_{1t}	e_{2t}	e_{et}	e_{nt}	e_{1t}	e_{2t}	e_{et}	e_{nt}
	%			%			%		%			
1	100.00	0.00	50.14	49.86	0.00	0.00	99.99	0.00	2.49	0.02	84.78	12.71
	(0.01)		(1.4)		(5.0)				(0.09)			
2	90.69	9.31	50.20	49.80	4.32	5.78	89.79	0.11	4.83	0.92	82.65	11.60
	(0.02)		(1.9)		(5.3)				(0.13)			
3	86.48	13.52	50.19	49.81	8.09	9.92	81.78	0.21	8.26	2.95	78.10	10.69
	(0.02)		(2.3)		(5.6)				(0.16)			
4	83.44	16.56	50.18	49.82	10.37	12.46	76.89	0.28	12.07	5.64	72.50	9.80
	(0.02)		(2.5)		(5.8)				(0.19)			
8	77.29	22.72	50.18	49.82	13.29	15.88	70.33	0.50	25.11	16.75	51.29	6.85
	(0.02)		(3.1)		(6.2)				(0.29)			
12	74.80	25.20	50.17	49.83	13.44	16.18	69.77	0.61	32.67	24.22	38.04	5.07
	(0.02)		(3.4)		(6.2)				(0.37)			
24	72.54	27.46	50.17	49.83	13.80	16.28	69.16	0.76	40.64	33.07	23.18	3.10
	(0.02)		(3.6)		(6.3)				(0.53)			

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 I 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.

Figure 1. Generalised Impulse Response Functions of $\mathbf{D}p_t$ in Model I
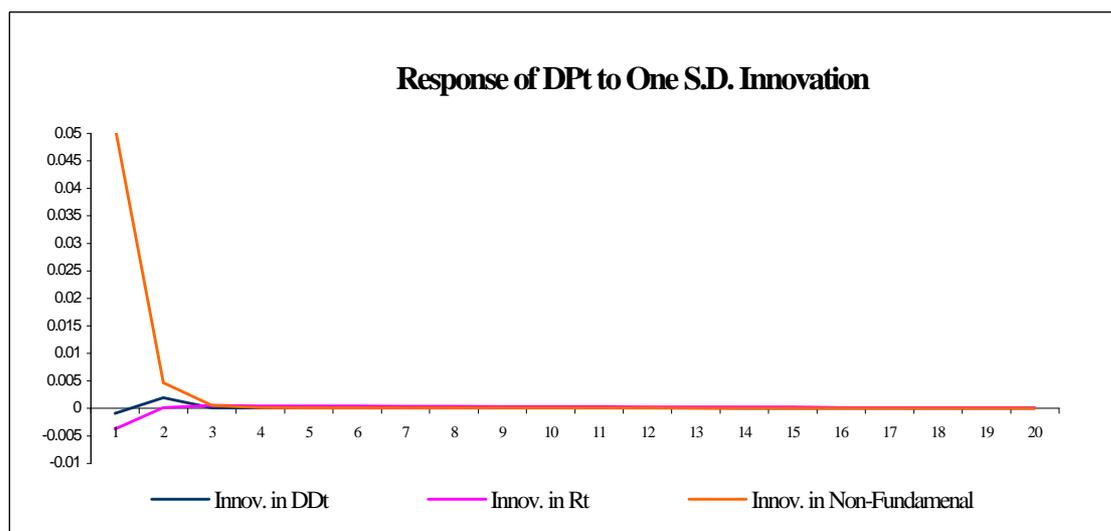

Response of DPt to One S.D. Innovation

Figure 2. **Generalised Impulse Response Functions of Dp_t in Model II**

Response of *DPt* to One S.D. Innovation