

What Drives Stock Prices? Identifying the Determinants of Stock Price Movements

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Abstract

In this paper, we show that the data has difficulty distinguishing between a stock price decomposition in which expectations of future real dividend growth is a primary determinant of stock price movements and a stock price decomposition in which expectations of future excess returns is a primary determinant. The inability of the data to distinguish between these very different decompositions arises from the fact that movements in the price-dividend ratio are very persistent while neither real dividend growth nor excess returns are. From a market fundamentals perspective, most of the information about low frequency movements in dividend growth and excess returns is contained in stock prices and not the series themselves. As a result, the data is incapable of distinguishing between the two competing decompositions. We further show that this inability to identify the source of stock price movements is not solely due to poor power and size properties of our statistical procedure, nor is it due to the presence of a rational bubble.

1. Introduction

Prior to 1981, much of the finance literature viewed the present value of dividends to be the principal determinant of the level of stock prices. However, Leroy and Porter (1981) and Shiller (1981) found that, under the assumption of a constant discount factor, stock prices were too volatile to be consistent with movements in future dividends. This conclusion, known as the excess volatility hypothesis, argues that stock prices exhibit too much volatility to be justified by fundamental variables. While a number of papers challenged the statistical validity of the variance bounds tests of Leroy and Porter and Shiller, on the grounds that stock prices and dividends were non-stationary processes [see Flavin (1983), Kleidon (1986), Marsh and Merton (1986), and Mankiw, Romer, and Shapiro (1991)], much of the subsequent literature, nonetheless, found that stock price movements could not be explained solely by dividend variability as suggested by the present value model with constant discounting [see West (1988a), Campbell and Shiller (1987)].¹

Relaxing the assumption of constant discounting, Campbell and Shiller (1988, 1989) and Campbell (1991) attempt to break up stock price movements (returns) into the contributions of changes in expectations about future dividends and future returns. They employ a log-linear approximation of stock returns and derive a linear relationship between the log price-dividend ratio and expectations of future dividends and future stock returns. They further assume that the data generating process of dividend growth and the log price-dividend ratio could be adequately characterized by a low order vector autoregression (VAR). Using the VAR to forecast future dividend growth and future stock returns, they were able to decompose the variability of current

¹ Cochrane (1991, 1992), Epstein and Zin (1991), and Timmerman (1995) have argued that fluctuations in stock prices can be explained by time-varying discount rates and future excess returns. Other studies, (e.g. Marsh and Merton (1987), Lee (1996,1998), and Bulkeley and Harris (1997)) find that expectations of future earnings contribute more to fluctuations in stock prices. On the existence of bubbles or fads, see West (1988b) and Flood (1990).

stock returns into the variability of future dividend growth and future stock returns. They attribute most of the movements in stock prices to revisions in expectations about future stock returns rather than to future dividend growth. Campbell and Ammer (1993) extend the log-linear approximation and the VAR approach to an examination of bond returns as well as stock returns. They find that expectations of future excess returns contributed more to the volatility of stock returns than did movements in expected future dividends.²

In this paper, we argue that there is a fundamental problem in identifying the sources of stock price movements. The problem lies in the fact that stock prices (or more specifically price/dividend ratios) are very persistent but neither real dividend growth nor excess returns are. Figure 1 plots the log price-dividend ratio from 1953:2 to 2001:4. It is clear from this figure that the log price-dividend ratio shows substantial persistence. Standard Dickey-Fuller tests fail to reject the null hypothesis of a unit root in the log price-dividend ratio.³ In the standard market fundamentals stock price valuation model, movements in the P/D ratio are explained by movements in the expected values of real dividend growth, real interest rates, and excess returns (the latter two making up required return). It turns out that real interest rates, which have a substantial low frequency component, do not move over time in a manner which would explain the low frequency movements in the price-dividend ratio. Thus, a market fundamentals explanation of persistent stock price movements requires movements in excess returns and/or real dividend growth to be persistent as well. However, a look at movements in real dividend growth and excess returns over time (Panel A and B of Figure 2) reveals that these are very volatile, containing little discernable low frequency movement. Hence, while the log price-

² Cochrane (1992) using an alternative methodology to decompose the variability of stock prices also found the variability of excess returns to be more important than the variability of dividend growth.

³ We computed augmented Dickey-Fuller t-statistics for lags lengths from 1 to 12 (with no time trend). The t-statistics range from -1.23 to 0.42, none of which are significant at conventional significance levels.

dividend ratio exhibits substantial persistence, its market fundamental components do not.

Because of the apparent lack of low frequency movements in either excess returns or real dividend growth, it is not possible to identify which of these is more important in producing long-swings in the price-dividend ratio. More formally, we show that the data cannot distinguish between a model in which there are small permanent changes in dividend growth or a model in which there are small permanent changes in excess returns. In a five variable system that includes log price-dividend ratio, real dividend growth, short and long term interest rates, and inflation, we find that we cannot reject two alternative vector error correction (VECM) systems each with two cointegrating vectors: one corresponding to stationary real dividend growth and stationary term premium and the other corresponding to stationary excess returns and stationary term premium.

The inability of the data to distinguish between these alternative models has enormous consequences for VAR stock price decompositions. We show that the relative importance of dividends and excess returns for explaining stock price volatility is very sensitive to the specification of the long-run properties of the estimated VAR. For the model in which excess returns is assumed to be stationary but real dividend growth is assumed to be nonstationary, it is real dividend growth and not excess returns that is a key contributor to stock price movements. The relative contributions reverse when we reverse the assumptions about stationarity. Thus, in contrast to much of the previous literature, we argue that the data cannot distinguish between a decomposition in which expectations about future real dividend growth are substantially more important than expectations about future excess returns and a decomposition in which the reverse is true.

The remainder of this paper is organized as follows. In Section 2, we review the log-

linear, VAR approach to stock price decomposition pioneered by Campbell and Shiller and used by many subsequent studies. In Section 3, we show how alternative assumptions about low frequency movements in stock market fundamentals can be described in terms of restrictions on cointegrating vectors in a vector error-correction model. In section 4, we test alternative specifications of the VECM/VAR used to describe the time series properties of the data and, hence, to calculate expectations of future stock market fundamentals. These tests include the Johansen (1991) test for cointegration as well as tests in which the cointegrating vector is prespecified (as in Horvath and Watson (1995)). Section 5 presents stock price decompositions for alternative models and demonstrates how sensitive these are to the specification of the VECM. In section 6, we discuss whether low frequency movements in real dividend growth or excess returns are plausible, at least on statistical grounds, and discuss why our results differ from much of the previous literature. In section 7, we examine whether our findings could be the consequence of poor power and size properties of our statistical approach. In section 8, we discuss whether our results reflect the existence of a rational bubble in stock prices. We find, however, that the data do not appear to support the existence of a rational bubble in our data. Section 9 provides a summary and conclusion.

2. Stock Price Decompositions

The stock price (returns) decompositions of Campbell and Shiller (1988, 1989), Campbell (1991), and Campbell and Ammer (1993) start with a log-linear approximation of the accounting identity: $1 \equiv (R_{t+1})^{-1} (P_{t+1}/D_{t+1} + 1)(D_{t+1}/D_t)/(P_t/D_t)$ where R_{t+1} is gross stock returns, P_t/D_t is price-dividend ratio, and D_{t+1}/D_t is one plus real dividend growth. Log linearizing and breaking the rate of return on stocks into the real return on short-term bonds (the

ex-post real interest rate), r_t , and the excess return of equity over short term bonds, e_t , yields:

$$p_t = E_t[\rho p_{t+1} + d_{t+1} - (r_{t+1} + e_{t+1}) + k], \quad (1)$$

where p_t is the log price-dividend ratio, d_t is real dividend growth and $\rho = \exp(\bar{p}) / (1 + \exp(\bar{p}))$,

$k = \log(1 + \exp(\bar{p})) - \rho \bar{p}$ where \bar{p} is the average log price dividend ratio over the sample.

Recursively substituting we obtain:

$$p_t = \sum_{j=0}^{\infty} \rho^j (E_t d_{t+1+j} - E_t r_{t+1+j} - E_t e_{t+1+j}) + \frac{k}{1-\rho}. \quad (2)$$

Thus, stock prices are a function of expectations of future real dividend growth, expectations of future real interest rates, and expectations of future excess returns. Similarly, surprises in excess returns can be written as:

$$e_t - E_{t-1} e_t = \sum_{j=1}^{\infty} \rho^j [(E_t - E_{t-1}) d_{t+j} - (E_t - E_{t-1}) r_{t+j} - (E_t - E_{t-1}) e_{t+j}]. \quad (3)$$

Surprises in excess returns are a function of revisions in expectations about future real dividend growth, future real interest rates, and future excess returns. One can construct similar decompositions of bond yields and returns (see Campbell and Ammer (1993)).

In order to evaluate the above expressions, Campbell and Shiller (1988, 1989), Campbell (1991) and Campbell and Ammer (1993) propose estimating a VAR to calculate expectations of future real dividend growth, real interest rates, and excess returns. We extend their framework to allow for cointegration among the variables and consider a vector error correction model (VECM). Let the vector of time series given by $y_t = (p_t, d_t, i_t, l_t, \pi_t)'$, where p_t is log price-dividend ratio, d_t is real dividend growth, i_t is the yield on short-term bonds, l_t is the yield on long-term bonds, and π_t is the inflation rate. Consider the following vector error correction model:

$$\Delta y_t = \mu + \alpha\beta' y_{t-1} + \sum_{i=1}^{m-1} C_i \Delta y_{t-i} + v_t, \quad (4)$$

where y_t is the 5×1 vector of possibly $I(1)$ variables defined above, β is a $5 \times r$ matrix whose r columns represent the cointegrating vectors among the variables in y_t , and α is a $5 \times r$ matrix whose 5 rows represent the error correction coefficients, and C_i is a 5×5 matrix of parameters. If the matrix, $\alpha\beta'$ is of rank 5 (or $r = 5$), then the VECM system is a standard levels VAR. The intercept term plays no role in our stock market decompositions but does have an effect on inference about the rank of $\alpha\beta'$.

We can take the above VECM (or VAR) and write it as a first order linear system (suppressing the intercept):

$$Y_t = AY_{t-1} + V_t, \quad (5)$$

with $Y_t = (y_t', y_{t-1}', \dots, y_{t-m+1}')$,

$$A = \begin{pmatrix} I + C_1 + \alpha\beta' & C_2 - C_1 & \dots & C_{m-1} - C_{m-2} & -C_{m-1} \\ I & 0 & \dots & 0 & 0 \\ 0 & \ddots & 0 & \vdots & \vdots \\ \vdots & 0 & \ddots & 0 & \vdots \\ 0 & \dots & 0 & I & 0 \end{pmatrix}, \quad (6)$$

and

$$V_t = \begin{pmatrix} v_t \\ 0 \\ \vdots \\ 0 \end{pmatrix}. \quad (7)$$

Equation (5) is called the companion form of the VAR. Using the companion form of the VAR, one can easily calculate expectations of variables in the system according to the formula:

$$E_t Y_{t+k} = A^k Y_t.$$

Given the variables in our system, we can evaluate expectations of d_t and r_t in equations (2) and (3):

$$\begin{aligned}
p_t &= \sum_{j=0}^{\infty} \rho^j (H_d A^{j+1} Y_t - (H_i A^j - H_\pi A^{j+1}) Y_t - E_t e_{t+1+j}) + \frac{k}{1-\rho} \\
&= H_d (I - \rho A)^{-1} A Y_t - (H_i - H_\pi A) (I - \rho A)^{-1} Y_t - \sum_{j=0}^{\infty} \rho^j E_t e_{t+1+j} \quad (8)
\end{aligned}$$

where $H_d = (0, 1, 0, \dots, 0)$, $H_i = (0, 0, 1, 0, \dots, 0)$, and $H_\pi = (0, 0, 0, 0, 1, 0, \dots, 0)$ are $1 \times 5m$ vectors that selects real dividend growth, short term interest rate, and inflation, respectively. The term $H_d A^{j+1} Y_t$ is the expectation of real dividend growth at $t+j+1$ while the term $(H_i A^j - H_\pi A^{j+1}) Y_t$ is the expectation of real return on short-term bonds at $t+j+1$.

Using (8) we can decompose the log price/dividend ratio into the contributions of expectations of future real dividend growth, real interest rates, and excess returns. The contribution of expectations of future real dividend growth is given by $H_d (I - \rho A)^{-1} A Y_t$ while the contribution of expectations of future real interest rates is $-(H_i - H_\pi A) (I - \rho A)^{-1} Y_t$. The contribution of expected returns can be treated as a residual after subtracting the contributions of future real dividend growth and future real interest rates from the actual log price-dividend ratio. For actual excess returns,

$$\begin{aligned}
e_t - E_{t-1} e_t &= \sum_{j=1}^{\infty} \rho^j [H_d A^j V_t - (H_i A^{j-1} - H_\pi A^j) V_t - (E_t - E_{t-1}) e_{t+j}] \\
&= H_d (I - \rho A)^{-1} \rho A V_t - (H_i \rho - H_\pi \rho A) (I - \rho A)^{-1} V_t - \sum_{j=1}^{\infty} \rho^j (E_t - E_{t-1}) e_{t+j} \quad (9)
\end{aligned}$$

Once again the contribution of expected future values of e_t can be calculated as a residual. Note

that in order to evaluate equations (8) and (9), the roots of the matrix ρA must be less than one.⁴

3. Specification of the VAR

As can be seen from equations (8) and (9), the companion matrix from the VAR, A , is crucial in the stock price decomposition, and, hence, care must be taken in the specification of the underlying VAR. This includes a careful assessment of the number of stochastic trends in the system. In addition, to specifying the number of stochastic trends in the system, we can evaluate alternative economic interpretations of the cointegrating vectors. These correspond to alternative assumptions about the presence of permanent changes in real dividend growth, excess returns, real interest rate, etc.

For example consider, the system described above that includes the log price dividend ratio (p_t), real dividend growth (d_t), short-term interest rate (i_t), long-term interest rate (l_t), and inflation (π_t). Define the ex post real interest rate as $r_t = i_{t-1} - \pi_t$. Using the log approximation employed by Campbell and Shiller, we can write excess stock returns over short-term bonds as:

$$e_t = \rho p_t - p_{t-1} + d_t - (i_{t-1} - \pi_t) + k. \quad (10)$$

Further, rewriting excess returns yields:

$$e_t = (\rho - 1)p_t + d_t - i_t + \pi_t + k + \Delta p_t + \Delta i_t. \quad (11)$$

Under the assumption that Δp_t and Δi_t are stationary, then stationary excess returns implies that

$(\rho - 1)p_t + d_t - i_t + \pi_t$ should be stationary. Thus, we can examine a linear combination of

⁴ If we include excess returns in the VAR (as in Campbell and Ammer (1993)) rather than dividend growth, then the contribution of dividend growth is a residual. It does not substantially affect the results if the model is estimated with excess returns instead of dividend growth.

variables to evaluate whether excess returns are stationary even though the excess returns variable is not included directly in the system. Similarly, if the term premium is stationary (and Δi_t is stationary) then the interest rate spread, $i_t - i_t$, will be stationary. Thus, given our five variable system of $(p_t, d_t, i_t, l_t, \pi_t)$, a model in which excess returns is stationary implies the cointegrating vector $(\rho-1, 1, -1, 0, 1)$, while a stationary term premium implies the cointegrating vector $(0, 0, -1, 1, 0)$. Alternatively, a model in which real dividend growth is stationary implies the trivial cointegrating vector $(0, 1, 0, 0, 0)$. We can also evaluate a model in which the real interest rate is stationary by examining the cointegrating vector $(0, 0, 1, 0, -1)$.⁵

Given that stock prices are determined solely by expectations of future real dividend growth, real interest rates and excess returns (i.e. no bubbles), then the particular structure of the cointegrating vectors in turn provides some insight as to the economic interpretation of stochastic trends in the system. Consider our five variable system that includes log price-dividend ratio, real dividend growth, short and long-term nominal interest rates, and inflation. If there are, say, two cointegrating vectors, this in turn implies that there are three stochastic trends in our system. If the cointegrating vectors correspond to stationary excess stock returns and term premium, then the three stochastic trends would correspond to stochastic trends in real dividend growth, real interest rate, and inflation. If, on the other hand, real dividend growth and the term premium are stationary then stochastic trends are present in excess returns, real interest rate, and inflation.⁶

⁵ We can similarly derive restrictions for stationary excess returns, stationary real dividend growth and stationary term premium for a system that includes excess returns rather than dividend growth, $(p_t, e_t, i_t, l_t, \pi_t)$.

⁶ Campbell and Ammer (1993) in their analysis treat $\log(p/d)$, real interest rate, excess returns, and the interest rate spread as stationary series; only nominal interest rates were treated as nonstationary. For the five variable system that we examine, the four cointegrating vectors implied by Campbell and Ammer (1993) model are: $(1, 0, 0, 0, 0)$ or stationary log price-dividend ratio, $(0, 0, 1, 0, -1)$ or stationary real interest rate, $(0, 0, -1, 1, 0)$ or stationary term premium, and $(0, 1, 0, 0, 0)$ or stationary real dividend growth. Note these cointegrating vectors also imply stationary excess returns.

4. Empirical Results

The data employed in this paper are quarterly and cover the period from 1953:2 to 2001:4. The price-dividend ratio is the S&P 500 composite stock price index for the last month of each quarter divided by nominal dividend flow for the SP500 composite index over the past year.⁷ In our empirical analysis we will consider the 10-year Treasury bond rate and the 3-month Treasury bill yield as our interest rate series. Inflation is calculated as the natural log growth in the Consumer Price Index over the quarter. Real dividend growth is nominal dividend growth less CPI inflation.

A. Tests For Number of Cointegrating Vectors

We test for cointegration in order to help specify the vector error correction model. Table 1 presents the Johansen result for various sample periods for the system that includes log price-dividends, real dividend growth, short and long term interest rates, and inflation.⁸ Table 2 presents Johansen test results when we replace real dividend growth in the system with log linear approximation for excess returns (equation 10).⁹ In Tables 1 and 2, column 1 shows the ending date of the sample period, column 2 reports the number of cointegrating vectors that cannot be rejected according to the Johansen (1991) lambda-max test, while column 3 of Table 1 reports the results of the Johansen (1991) trace test. The lambda-max test and trace test do not always

⁷ We use as dividends the end-of-quarter S&P 500 dividend yield multiplied by the end-of-quarter SP500 Composite index. We convert the price-dividend ratio and dividends to quarterly flows by dividing dividends by four.

⁸ Note that for each sample period we calculate a new value of ρ .

⁹ An intercept is included in the VAR/VECM, but in the Johansen analysis this is restricted to be in the so-called equilibrium error (the intercept, no drift case). The number of lags in the VAR is set at four. This is the number of lags selected if one sequentially adds lags until the additional lag is not statistically significant. The Akaike Information Criterion chooses two lags for our system, but there is substantial residual serial correlation remaining in the some of the equations (we use LM-test for serial correlation of order four). With four lags only one of the equations displays significant serial correlation. We consider four lags to be a good compromise between parsimony and adequately capturing the dynamics in the data. The results are essentially unchanged if we increase the number of lags to 6 but fewer lags tend to suggest fewer than three stochastic trends.

agree on the order of cointegration; the lambda-max test generally finds one or two cointegrating vectors while the trace test generally finds two to three cointegrating vectors. However, as the sample period lengthens evidence for two cointegrating vectors increases.¹⁰

We next test which of the alternative cointegrating vectors discussed above appear to be consistent with the data. Given that there appears to be two cointegrating vectors, we consider pairs of cointegrating vectors. Column 4 of Tables 1 and 2, reports the chi-squared statistic and p-value for the joint restriction that excess stock returns and term premium are stationary. Column 5 reports the chi-squared statistic and p-value for the joint restriction that real dividend growth and the term premium are stationary. For many of the sample periods, we fail to reject both sets of cointegrating relationships.¹¹ Interestingly, the likelihood functions for these two models are quite close suggesting that the data does not strongly favor one model over the other.

B. Tests Taking Cointegrating Vectors as Known.

As we suggested above, we can write several alternative characterizations of stochastic trends among market fundamentals in terms of specific restrictions on known cointegrating vectors. Thus, in addition to the Johansen analysis, we can test and evaluate competing assumptions about long-run market fundamentals directly. We do so by testing restrictions on the VECM as in Horvath and Watson (1995).

Again, let $Y_t = (p_t, d_t, i_t, l_t, \pi_t)'$, where p_t is log price dividend ratio, d_t is real dividend growth, i_t is the short-term nominal interest rate, l_t is the long-term nominal interest rate, and π_t is

¹⁰ These results are consistent with the findings of Goyal and Welch (2003) who find that the log price-dividend ratio has become more persistent in recent time periods.

¹¹ We reject for all sample periods restrictions on the cointegrating vectors that correspond to the joint hypothesis of stationary excess returns and stationary real dividend growth and the joint hypothesis of a stationary real interest and a stationary term premium.

the inflation rate. Consider the error correction model (suppressing the intercepts)¹²:

$$\Delta Y_t = C(L)\Delta Y_{t-1} + \alpha\beta'Y_{t-1} + u_t.$$

Suppose we wanted to test the null hypothesis of stationary excess returns and stationary term premium but nonstationary real dividend growth, real interest rate, and inflation against the alternative hypothesis of nonstationary inflation, stationary real rate, excess returns, real dividend growth, and term premium, similar to the VAR examined by Campbell-Ammer (1993). The alternative hypothesis implies a vector error correction model with

$$\alpha = \begin{pmatrix} \alpha_{11}^{CA} & \alpha_{12}^{CA} & \alpha_{13}^{CA} & \alpha_{14}^{CA} \\ \vdots & \vdots & \vdots & \vdots \\ \alpha_{51}^{CA} & \alpha_{52}^{CA} & \alpha_{53}^{CA} & \alpha_{54}^{CA} \end{pmatrix} \text{ and } \beta' = \begin{pmatrix} \rho - 1 & 1 & -1 & 0 & 1 \\ 0 & 0 & -1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & -1 \end{pmatrix}.$$

Note that the first cointegrating vector in β' is just a representation for stationary excess returns.

For the model with nonstationary real dividend growth, real interest rates, and inflation and stationary term premium and stationary excess returns, we can write the VECM as

$$\alpha = \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \vdots & \vdots \\ \alpha_{51} & \alpha_{52} \end{pmatrix} \text{ and } \beta' = \begin{pmatrix} \rho - 1 & 1 & -1 & 0 & 1 \\ 0 & 0 & -1 & 1 & 0 \end{pmatrix}.$$

This model is just a special case of Campbell and Ammer VECM where the third and fourth columns of error correction terms are zero.

To test the null hypothesis of stationary excess returns and term premium, nonstationary real dividend growth, real interest rate, and inflation against the alternative hypotheses we simply test $\alpha_{j3}^{CA} = \alpha_{j4}^{CA} = 0, j = 1, \dots, 5$.¹³ Note that we are essentially testing the joint hypothesis of

¹² As in the Johansen analysis above, we consider the case in which there is an intercept in the VECM but no drift in the stochastic trends when conducting inference. However, like Horvath and Watson we estimate the VECM without restrictions.

¹³ Because the cointegrating vectors are assumed to be known there is no problem of having parameters that are not

nonstationary real dividend growth and nonstationary real interest rate in this vector system. Similarly, if we wished to test the null hypothesis of stationary real dividend growth and term premium and nonstationary excess returns, real interest rate, and inflation against the alternative hypothesis of the Campbell and Ammer specification, we test $\alpha_{j1}^{CA} = \alpha_{j4}^{CA} = 0, j = 1, \dots, 5$. Other null and alternative hypotheses can likewise be examined, by writing the alternative as an error correction model and the null as restrictions on the error correction terms (α 's). Because of the relatively large number of parameters in the model for our sample size, rather than using the asymptotic tabulated critical values in Horvath and Watson, we present p-values based on an empirical bootstrap of the null model in order to conduct inference.¹⁴

Table 3 presents tests of competing hypotheses about the stationarity/nonstationarity of various market fundamentals. The tests presented in Table 3 are consistent with those of the Johansen analysis. From Table 3, it appears that there is evidence for three stochastic trends (and two cointegrating vectors) in our system. We fail to reject at the 0.05 level the null hypothesis of nonstationary real dividend growth, real interest rate, and inflation and stationary excess returns and term premium versus both the Campbell and Ammer model and a model with stationary real dividend growth, excess returns, and term premium (see test 1 and 2). When we consider a null hypothesis in which excess returns, real interest rate, and inflation were nonstationary but real dividend growth and term premium were stationary, we could not reject this hypothesis at the 0.05 percent level against either alternative (see test 4 and 5). On the other hand, we can reject the hypothesis of four nonstationary variables (real dividend growth, excess returns, real interest

identified under the null of no cointegration.

¹⁴ The empirical bootstrap was based on the estimated null model, which is then used to generate pseudo-data by resampling vectors of empirical residuals. The pseudo-data are generated so that there is no drift in the stochastic trends. The alternative model is then estimated using the pseudo-data and a Wald statistic is calculated for the null hypothesis that the relevant error-correction parameters are zero. A distribution of sample Wald statistics was generated by conducting the above experiment 10,000 times.

rates, and inflation) in favor of a model in which excess returns was stationary (test 3). We can likewise reject the hypothesis of nonstationary real dividend growth, excess returns, real interest rate and inflation in favor of a model in which real dividend growth is stationary (test 6).¹⁵

Tables 1-3 suggest that when considering the entire system as described by our five variable VECM/VAR there is substantial evidence to conclude that either real dividend growth or excess returns is nonstationary but apparently not both. This is in contrast to the previous literature, which has assumed real dividend growth and excess returns to be stationary and is at odds with standard univariate unit-root tests (see below).¹⁶ Unfortunately, the data is not conclusive about whether it is real dividend growth or excess returns that is nonstationary. Assuming normally distributed shocks, the likelihood functions for the two models are very similar with perhaps the edge going to the nonstationary real dividend growth model. Yet, as we show in the next section the decompositions one derives from the VECM/VAR hinge crucially on which variable is assumed to be nonstationary.¹⁷

5. Stock Price Decompositions

We now decompose historical stock price movements into contributions due to expectations of future real dividend growth, real interest rates, and excess returns using the companion form of the estimated VECM model and equation (8). Recall that for the system with real dividend growth, the contributions of real dividend growth and real interest rates are calculated directly while the contribution of excess returns is a residual.

¹⁵ The test results are essentially unchanged if we replace real dividend growth with excess returns in the system.

¹⁶ An exception is Barsky and DeLong (1993).

¹⁷ Strictly speaking the Campbell-Shiller approximation, in which the value of ρ is a function of the sample average of the log price-dividend ratio, only holds if the log price-dividend ratio is stationary. However, our results are essentially unchanged when we use the minimum log price-dividend ratio over the sample to calculate ρ or if we use the maximum log price-dividend ratio over the sample. Thus, our results do not appear to be very sensitive to reasonable values of ρ .

Figures 3-5 display the actual (demeaned) log price-dividend ratio and the implied contribution of expectations of future real dividend growth, future excess returns, and future real interest rates. Figure 3 displays the contributions for the model that assumes nonstationary dividend growth, real interest rate, and inflation and stationary excess returns and term premium. Panel A displays the contribution of expectations of future real dividend growth and the contribution of expectations of future excess returns while Panel B displays the contribution of expectations of future real interest rates. What is striking about Figure 3, relative to what one might expect given the previous literature, is the large contribution of real dividend growth; the contribution of excess returns is substantially smaller than either real dividend growth and real interest rates. Second, there is a large negative correlation between the contribution of dividend growth and the contribution of real interest rates.¹⁸ Finally, there are some interesting interpretations of historical stock price movements. The decomposition suggests that the decline in stock prices in the 1970s was due primarily to pessimism about future dividends (although the decline is mitigated to some extent by the decline in real interest rates that occurred during this period) while the run up in stock prices in the late 1990s was driven primarily by optimism about future dividends. This particular decomposition could be consistent with explanation of Greenwood and Jovanovic (1999) and Hobjin and Jovanovic (2001) who argue that the so-called information technology revolution hurt existing “old technology” firms well before (1970s) the new technology firms begin to prosper (1990s).

However, if we alter the specification of the VECM and assume that excess returns are nonstationary while real dividend growth is stationary, the implied contribution of real dividend

¹⁸ Recall that an increase in future real dividend growth has a positive effect on current stock prices while an increase in future real interest rates has a negative effect. This suggests that the underlying correlation between future real dividend growth and future real interest rates is positive. Note that a positive correlation between real dividend growth and real interest rate is consistent with a consumption based asset pricing model with diminishing marginal utility.

growth and excess returns change dramatically. Figure 4 displays contributions for the model that assumes nonstationary excess returns and stationary real dividend growth. Comparing Figures 3 and 4 demonstrates just how sensitive stock price decompositions are specification of the underlying VECM. In the model with nonstationary excess returns but stationary real dividend growth, expectations of future excess returns rather than real dividend growth are important. In fact, it is almost as if the contributions of excess returns and real dividend growth shown in Figure 3 are switched in Figure 4. For the model with nonstationary excess returns and stationary real dividend growth, the contribution of expectations of future real interest rates (Figure 4b) is very similar to that for the model with nonstationary real dividend growth and stationary excess returns.

When we use a Campbell-Ammer type specification for the VECM, stock price movements are nearly entirely driven by changes in expectations of excess returns (see Figure 5). Neither real dividend growth nor real interest rate have a substantial effect on log price-dividend movements in this specification. Recall, however, that we could not reject specifications underlying Figures 3 and 4 in favor of the Campbell-Ammer specification.

In sum, the nature of stock price decompositions is very sensitive to the specification of the VECM used to model the data and to calculate future expectations of market fundamentals. Depending on which set of restrictions are imposed on the cointegrating vectors, the relative contribution of real dividend and excess returns can change dramatically. The implication is that previous findings that excess returns and not dividends explain most of the stock price variability are not robust to statistically plausible alternative specifications of the data generating process.

6. Interpretation.

As we pointed out above, when the cointegrating vectors are restricted to imply stationary excess returns and term premium, these same restrictions suggests stochastic trends are present in real interest rates, real dividend growth, and inflation. Similarly, a system in which real dividend growth and term premium are stationary imply stochastic trends in excess returns, real interest rates, and inflation. The possibility of persistent changes in real dividend growth and, to a lesser extent, excess returns is at odds with much of the previous literature. In this section, we try to reconcile our findings with the previous literature.

Because permanent movements in market fundamentals, in particular real dividend growth or excess returns, are potentially very important contributors to historical stock price movements, we use a multivariate version of the Beveridge and Nelson (1981) decomposition to infer a long-run or permanent real dividend growth (or excess returns) series. The Beveridge-Nelson “trend” or long-run value of variable x_t is just $x_t^\tau = \lim_{k \rightarrow \infty} E[x_{t+k} | \Omega_t]$, where Ω_t denotes information set at time t . Using the companion form of the VECM/VAR, the Beveridge-Nelson trend for real dividend growth is just:

$$d_t^\tau = \lim_{k \rightarrow \infty} H_d A^k Y_t \quad (12)$$

while for excess returns the permanent component is:

$$e_t^\tau = \lim_{k \rightarrow \infty} [(\rho - 1)H_p + H_d - H_i + H_\pi] A^k Y_t, \quad (13)$$

where H_p , H_d , H_i , and H_π are (1x5m) vectors that select the current values of p_t , d_t , i_t , and π_t , respectively.

Figure 6 displays the implied long-run real dividend growth series from the model with nonstationary real dividend growth and stationary excess returns (note for this model the long-

run excess returns is just a constant). The implied long-run real dividend growth series is well within historical variation of actual real dividend growth. The variance of innovations in long-run real dividend growth is substantially smaller than the variance of innovations in actual real dividend growth (3.97×10^{-2} versus 1.52) suggesting that quarterly changes in long-run real dividend growth are relatively small.¹⁹ The implied long-run real dividend growth also seems plausible given historical movements in real dividend growth. In the seventies, actual real dividend growth was substantially lower than in the previous decade and this is in part reflected (albeit with a lag) in a decline in the implied long-run real dividend growth series. Beginning in 1982, implied long-run real dividend growth increased and was followed later in the decade by an increase in actual real dividend growth. In the mid 1990s, both the implied long-run real dividend growth and actual real dividend growth increased. In 2000-2001 we do see divergence between actual real dividend growth and implied long-run real dividend growth, with actual real dividend growth falling substantially while implied long-run real dividend growth remaining relatively high.

Figure 7 displays the implied long-run excess returns from the model with nonstationary excess returns and stationary real dividend growth (for this model long-run real dividend growth is a constant). Again, long-run excess returns is well within the historical variation of actual excess returns and is substantially less volatile (the variance of innovations in long-run excess returns are 4.12×10^{-2} while the variance of innovations in actual excess returns is 50.80). In fact, actual excess returns are so volatile that their movements dwarf those of the implied long-run excess returns series. Note a relatively small decline in long-run (i.e. future) excess returns is consistent with high, but temporary, actual (i.e. current) excess returns. The stock price

¹⁹ The variance of innovations to long-run real dividend growth is $H_D A_{LR} \Omega A_{LR}' H_D'$, where $A_{LR} = \lim_{k \rightarrow \infty} A^k$ and Ω is variance/covariance matrix of residuals from the estimated VECM.

decomposition based on the VECM with nonstationary excess returns suggests that the high excess stock returns of the late 1990s resulted from a relatively small decline the future excess returns (i.e. a decline in the equity premium).

As suggested in the introduction, neither real dividend growth nor excess returns shows much persistence. When examined in a univariate context, standard tests reject the unit-root hypothesis for both real dividend growth and excess returns. Standard augmented (with five lags) Dickey-Fuller t-statistics are -3.58 for real dividend growth and -6.26 for excess returns; both reject the unit-root null at conventional significance levels. The fact that innovations in the implied permanent components of real dividend growth and excess returns are several times smaller than innovations in the actual series may explain why standard univariate unit root tests strongly reject at conventional levels. Such small variances for innovations in long-run components, suggest that large sample periods are likely to be needed to detect unit-roots in these data. This conjecture is, in fact, borne out when we apply standard Dickey-Fuller tests to simulated real dividend growth data based on the estimated VECM with nonstationary real dividend growth (but stationary excess returns). A Dickey-Fuller t-statistic of -3.58 has a bootstrap p-value of 0.265 (the 0.05 critical value for the augmented Dickey-Fuller t-statistics is -4.38). This suggests that we would actually fail to reject the unit-root null if the appropriate finite sample critical values were used. Similarly, for the VECM in which excess returns was nonstationary and real dividend growth was stationary, a Dickey-Fuller t-statistic of -6.26 for excess returns has a bootstrap p-value of 0.192 (the 0.05 critical value for the augmented Dickey-Fuller t-statistic on excess returns is -6.89). Again, we would fail to reject the unit-root null if the appropriate finite sample critical values were used.

Recall that innovations in the implied long-run component of real dividend growth and

excess returns are so small relative to innovations in the actual series themselves, that actual real dividend growth and excess returns may have relatively little information about low frequency movements in these series. It is, in fact, the log price-dividend ratio that contains most of the information about long-run real dividends or excess returns. As stock prices depend on expectations of future real dividends, real interest rates, and excess returns off into the distant future, persistent innovations in these variables result in large changes in current stock prices. Thus, small permanent changes in market fundamentals can have relatively large effects on the log price-dividend ratio.

To see this clearly, suppose d_t , r_t , and e_t are described by an unobserved components model with a permanent or trend component and a stationary component,

$$x_t = x_t^\tau + x_t^c, \quad x = d, r, \text{ and } e \quad (14)$$

with

$$x_t^\tau = x_{t-1}^\tau + \varepsilon_t^{x^\tau} \quad (15)$$

and

$$x_t^c = \theta_x x_{t-1}^c + \varepsilon_t^{x^c} \quad (16)$$

where $\varepsilon_t^{x^\tau}$ and $\varepsilon_t^{x^c}$ are white noise error terms. If we evaluated equation (2) using equations (14)-(16), we find

$$p_t = \frac{1}{1-\rho} (d_t^\tau - r_t^\tau - e_t^\tau) + \frac{\theta_d}{1-\rho\theta_d} d_t^c - \frac{\theta_r}{1-\rho\theta_r} r_t^c - \frac{\theta_e}{1-\rho\theta_e} e_t^c + \frac{k}{1-\rho} \quad (17)$$

A small permanent change in a market fundamental ($d_t^\tau, r_t^\tau, e_t^\tau$) can cause a large change in log price-dividend ratio; in our data the term $1/(1-\rho)$ has a value of 124.2. On the other hand, a temporary change in a market fundamental may have substantially smaller effects on stock prices. For example, when theta is equal to .8, the effect on p_t is just 3.88. Thus, a permanent

change in market fundamentals that is barely reflected in the current value of market fundamentals may nonetheless have an important effect on the price-dividend ratio.

To further demonstrate that log price-dividend contains most of the information about long run real dividend and/or long-run excess returns, Figure 8 overlays long-run real dividend growth, d_t^r , implied by the model with nonstationary real dividend growth (but stationary excess returns) with the negative of long-run excess returns, $-e_t^r$, from the model with nonstationary excess returns (but stationary real dividend growth). From the figure, we observe that these two series are nearly identical! The figure suggests that most of the information about long-run real dividend growth or excess returns is coming from the log price-dividend series and not real dividend growth or excess returns directly.

As we noted above, the VECM with nonstationary real dividend growth and stationary excess returns and the VECM with stationary real dividend growth and nonstationary excess returns have very similar likelihood values; they appear to explain the data equally well. The reason is that stock prices contain almost all of the information about long-run real dividend growth or long-run excess returns. It is not possible to determine whether real dividend growth or excess returns is responsible for the low frequency movements in stock prices; it is similar to having only one equation (log price/dividend ratio) with which to solve for two unknowns (long-run real dividend growth and excess returns).

7. Power properties of the cointegration tests

It is well known that unit-root and tests with a null of no cointegration can have low power against persistent stationary alternatives. Could our findings of three stochastic trends be the result of poor power properties of the tests we employ? As Horvath and Watson point out, an

advantage of the multivariate or systems approach to testing for cointegration is that, by adding variables that covary with the variable of interest, one can increase the power of the test. But this is at the cost of adding additional parameters, which tends to lower the power of the test. It is not clear which effect dominates.

In order to determine the size and power properties of the tests we employed above, we conduct a small Monte Carlo experiment. First, we use actual data to estimate a maintained model that is then assumed to be the true data generating process in the subsequent Monte Carlo experiment. This data generating process is used to generate pseudo-data (by resampling actual residuals) to which we apply the test for (no)cointegration. In these tests, we set the null hypothesis to be either the VECM with nonstationary real dividend growth and stationary excess returns or the VECM with stationary real dividend growth and nonstationary excess returns. The alternative hypothesis in each case is the VECM with stationary real dividend growth and stationary excess returns. We generate five hundred pseudo-data samples, each time using a bootstrap (of the pseudo-data and null model) to make statistical inferences, and count the percentage of times the null model is rejected. If the data generating process corresponds to the null model, then our experiment examines the size of test. If the data generating process corresponds to the alternative model, then our experiment examines the power of the test. For comparison, we also examine a finite sample Dickey-Fuller test whose critical values are also based on a bootstrap of the null model.

From Table 4, we observe that the multivariate test has quite reasonable power properties against alternative of stationary real dividend growth, excess returns, and term premium, certainly compared to a bootstrap Dickey-Fuller test. When the data generating process implies stationary real dividend growth and excess returns, regardless of whether the null is

nonstationary real dividend growth or excess returns, at a .05 significance level we correctly reject the null over seventy-five percent of the time. This is substantially more frequently than when we use the bootstrap Dickey-Fuller test. Furthermore, perhaps not surprisingly, the nominal size of the bootstrap inference appears to be close to the actual size (although the Dickey-Fuller statistics tend to reject slightly less often than the nominal size of the test, see Panel 4B). Thus, our finding that there appears to be only two cointegrating vectors rather than three in our system is not solely the result of poor power properties of our tests.²⁰

8 Could the our results be due to the presence of a rational bubble?

What we have shown thus far is that there are some statistically plausible market fundamentals representations that explain low frequency stock price movements. As we argued above, stock prices may have more information about long-run movements in market fundamentals than the market fundamentals themselves. Nonetheless, could our results reflect non-fundamental behavior such as irrational exuberance or a rational bubble? Indeed, the fact that stock prices are very persistent while real dividend growth and excess returns are apparently stationary, could be interpreted as evidence of a bubble (see Hamilton and Whiteman (1985), Diba and Grossman (1988)).

To see how the presence of a rational bubble would affect our analysis, consider the following model. Again, consider the expectational log linear approximation given by equation (1). Let the market fundamentals solution, given by equation (2), be denoted by f_t . Then a solution to equation (1) can be characterized by:

²⁰ At the suggestions of a referee, we also examined a smaller system consisting of $(p_t, d_t, i_t - \pi_t)$. For this smaller system, we find evidence consistent with our larger system. Namely, the data appear to support the presence of a stochastic trend in either dividend growth or excess returns (but not both) as well as a stochastic trend for the real interest rate.

$$p_t = f_t + b_t, \quad (18)$$

where b_t is a stochastic process that satisfies the equation $E_t b_{t+1} = \frac{1}{\rho} b_t$. The b_t is similar to a standard stock market bubble except that it holds for the log linear approximation rather than the standard present value model.²¹ This so-called bubble term would imply a nonstationarity log price-dividend ratio even if market fundamentals were stationary.

How would the presence of this “bubble” affect our analysis above? In the presence of a “bubble”, actual excess returns is given by

$$e_t = \rho p_t - p_{t-1} + d_t - i_{t-1} + \pi_t + k = \rho f_t - f_{t-1} + d_t - i_{t-1} + \pi_t + k + v_t^b, \quad (19)$$

where v_t^b is unpredictable random shock to the “bubble” term. Thus, the presence of a “bubble” will not manifest itself as explosive actual excess returns. However, when we tested for stationarity of excess returns in our system, we, in fact, tested the stationarity of

$$(\rho - 1)p_t + d_t - i_t + \pi_t = (\rho - 1)f_t + d_t - i_t + \pi_t + (\rho - 1)b_t. \quad (20)$$

This term does in fact depend on the “bubble”. Thus, the presence of a “bubble”, in addition to implying nonstationarity of p_t , would imply that our test would fail to reject nonstationary excess returns.

We have two responses. First, while our model could not reject the null hypothesis of nonstationary excess returns and stationary real dividend growth, neither could our model reject the null hypothesis of nonstationary real dividend growth and stationary excess returns; the second hypothesis is inconsistent with presence of a “bubble”. Second, the “bubble” in log price-dividend implies additional testable restrictions than just the nonstationarity of p_t —it

²¹ The reason we continue to work with log linear approximation is that with time varying returns the basic present value equation is now a nonlinear difference equation which makes examination of a rational bubble substantially more difficult.

implies that Δp_t is nonstationary as well.²²

We test for the nonstationarity of Δp_t in the systems context as we did in Section 4.

Consider the VECM implied by the market fundamentals model in which real dividend growth and term premium were stationary, but log price-dividend (and excess returns), real interest, and inflation were nonstationary:

$$\Delta Y_t = C(L)\Delta Y_{t-1} + \alpha\beta'Y_{t-1} + u_t,$$

with $Y_t = (p_t, d_t, i_t, l_t, \pi_t)'$ and $\beta' = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 \end{pmatrix}$. Because the level of the log price-

dividend ratio, p_t , does not appear in any of the cointegrating vectors, we can rewrite this VECM in terms of Δp_t :

$$\Delta \tilde{Y}_t = \tilde{C}(L)\Delta \tilde{Y}_{t-1} + \tilde{\alpha}\tilde{\beta}'\tilde{Y}_{t-1} + \tilde{u}_t,$$

with $\tilde{Y}_t = (\Delta p_t, d_t, i_t, l_t, \pi_t)'$ and $\tilde{\beta}' = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 \end{pmatrix}$. To test null hypothesis of

nonstationarity of Δp_t , we simply test whether the elements of the first column of $\tilde{\alpha}$ are zeros.²³

We can in fact strongly reject this null hypothesis. The Wald statistic is 64.26 with a p-value of 0.000.

Strictly speaking the VECM testing approach of Horvath and Watson is a two sided test while test of stationarity is really a one-sided test (see discussion of this in Horvath and Watson).

This raises the possibility that we could reject the null hypothesis that $\tilde{\alpha}_{j1} = 0$ for $j = 1, \dots, 5$

²² In fact, a bubble implies no amount of differencing will render p_t stationary.

²³ More precisely, we test the null hypothesis of nonstationary Δp_t , nonstationary real interest rate and inflation but stationary real dividend growth and term premium against the alternative hypothesis of stationary Δp_t (but nonstationary p_t and excess returns), nonstationary real interest rate and inflation, and stationary real dividend growth and term premium.

simply because the coefficient on Δp_t in the $\Delta^2 p_t$ equation ($\tilde{\alpha}_{11}$) is positive as would be the case if a bubble were present. However, it is unlikely that this is the case in our application. The coefficient $\tilde{\alpha}_{11}$ is estimated to be -1.048 (with a t-statistic of -7.55), so the rejection is not due to $\tilde{\alpha}_{11}$ being positive.²⁴ In sum, this evidence does not support the presence of a “bubble” in the log linear approach taken in this paper. Of course, these results do not rule out the possibility that other non-fundamental factors, such as irrational exuberance, herd behavior, or fads, play a role in stock price variation, but it is not clear what testable restrictions these types of models would have for our data.

9. Concluding Comments

This paper argues that the data do not speak strongly to the determinants of low frequency movements in stock prices. Our results for VAR-type decompositions are similar to those found in some of our previous work in which we use an entirely different methodology (Balke and Wohar, 2002). In that work, we employ a state-space model to model the dynamics of the log price-dividend ratio along with long-term and short-term interest rates, real dividend growth, and inflation. We show that the decompositions of stock price movements are very sensitive to what assumptions one makes about the presence of permanent changes in either real dividend growth or excess stock returns. When we allowed real dividend growth to have a permanent component but excess stock returns only to have a transitory component, real dividend growth is found to explain much more of the movement in stock prices than does excess stock returns. When we reverse this assumption, the relative contributions of excess stock returns and real dividend growth are reversed also. The results in the current paper suggest that

²⁴ When we use univariate Dickey-Fuller test (a one-sided test of nonstationarity), we also reject strongly the null of nonstationarity in favor of stationary alternative.

the sensitivity of stock market decompositions is present in VAR decompositions as well.

The possibility that market expectations about changes in future real dividend growth may be a more important determinant of stock prices than typically ascribed to in the literature has been recognized in some other studies as well. For example, Barsky and DeLong (1993) show that large swings in the stock market could be rationalized if market participants believe that permanent changes in dividend growth are possible. They go on to show that an ARIMA(0,1,1) model for dividend growth with a large negative moving average term can explain both dividend growth and stock prices. In a recent paper, Timmerman (2001) proposes that structural breaks in the underlying dividend process, about which investors have only imperfect information, can explain stock price movements. In the time periods immediately following a structural break in the dividend process, investors cannot rely on historical data to arrive at a new revised estimate of mean dividend growth and instead gradually update their beliefs as new information arises. Timmerman argues that his model can explain several stock price (ir)regularities such as skewness, excess kurtosis, volatility clustering, and serial correlation in stock returns.

One puzzle that arises from our analysis (both in this paper and that in state-space approach of Balke and Wohar (2002)) is that from a statistical point of view, persistent changes in real dividend growth and excess returns are equally likely. In order to identify the relative importance of real dividend growth or excess stock returns for stock price variability one is likely to need additional information beyond that of stock price, real dividend growth (or excess returns), and interest rate data typically used in the stock price decomposition literature. For example, information on relative transactions costs and their effect on investor's asset allocations (see Heaton and Lucas (1999)), information about the underlying determinants of a time varying

equity premium (Campbell and Cochrane (1999)), or indicators of long-run economic growth might be helpful in distinguishing between changes in expectations of future real dividend growth and excess returns. Alternatively, one might attempt tying real interest rate and risk premium movements not only to the level of assets prices as done in Balke and Wohar (2002) but to movement in the covariance structure of asset prices as well. Finally, one might formally incorporate prior information about the relative importance of real dividend growth and excess returns by taking a Bayesian approach to stock price decompositions.

| Table 1: Cointegration Results: Lag Length in Levels VAR=4. Real Dividend Growth Specification | | | | |
|---|--|---|---|---|
| Sample period ending in: | Number of cointegrating vectors determined by lambda max test (**-95%,*-90%) | Number of cointegrating vectors determined by trace test (**-95%,*-90%) | Chi-squared test of restriction of stationary excess returns and term premium (p-value) | Chi-squared test of restriction of stationary real dividend growth and term premium (p-value) |
| (1) | (2) | (3) | (4) | (5) |
| 1987:4 | 1 * | 1 ** | 14.1105 [.028] | 17.2348 [.008] |
| 1990:4 | 0 | 3 * | 10.6893 [.098] | 13.9440 [.030] |
| 1995:4 | 1 * | 2 ** | 8.8732 [.181] | 12.2647 [.056] |
| 1999:4 | 2 * | 2 * | 6.9910 [.322] | 9.4382 [.150] |
| 2000:4 | 2 * | 2 ** | 13.0324 [.043] | 12.0268 [.061] |
| 2001:4 | 2 ** | 2 ** | 10.0794 [.121] | 11.2786 [.080] |

| Table 2: Cointegration Results: Lag Length in Levels VAR=4. Excess Return Specification | | | | |
|--|--|---|---|---|
| Sample period ending in: | Number of cointegrating vectors determined by lambda max test (**-95%,*-90%) | Number of cointegrating vectors determined by trace test (**-95%,*-90%) | Chi-squared test of restriction of stationary excess returns and term premium (p-value) | Chi-squared test of restriction of stationary real dividend growth and term premium (p-value) |
| (1) | (2) | (3) | (4) | (5) |
| 1987:4 | 1 ** | 3* | 13.5078 [.036] | 13.6942 [.033] |
| 1990:4 | 1 * | 3 ** | 8.9164 [.178] | 9.9641 [.126] |
| 1995:4 | 1 ** | 3 * | 9.048 [.171] | 10.6195 [.101] |
| 1999:4 | 2 * | 2 * | 6.9388 [.327] | 7.2588 [.298] |
| 2000:4 | 1 ** | 2 ** | 13.3699 [.038] | 10.2782 [.113] |
| 2001:4 | 2 * | 2 ** | 10.2783 [.113] | 8.8277 [.184] |

Table 3.
Test of alternative specifications of VECM
Real Dividend growth in system

| Test | Null Hypothesis | Alternative Hypothesis | Wald Stat. | [P-value] |
|------|--|--|------------|-----------|
| 1. | Nonstationary: Real dividend growth real interest rate inflation Stationary: excess returns term premium | Nonstationary: Inflation Stationary: Real Dividend growth real interest rate excess returns term premium (Campbell-Ammer) | 23.13 | [0.265] |
| 2. | Nonstationary: Real dividend growth real interest rate inflation Stationary: excess returns term premium | Nonstationary: Real interest rate inflation Stationary: Real Dividend growth excess returns term premium | 14.57 | [0.107] |
| 3. | Nonstationary: Real dividend growth real interest rate inflation excess returns Stationary: term premium | Nonstationary: Real Dividend growth real interest rate inflation Stationary: Excess returns term premium | 28.96 | [0.001] |
| 4. | Nonstationary: excess returns real interest rate inflation Stationary: Real dividend growth term premium | Nonstationary: Inflation Stationary: Excess returns real interest rate Real dividend growth term premium (Campbell-Ammer) | 24.91 | [0.176] |
| 5. | Nonstationary: excess returns real interest rate inflation Stationary: Real dividend growth term premium | Nonstationary: Excess returns real interest rate inflation Stationary: Real Dividend growth term premium | 15.97 | [0.074] |
| 6. | Nonstationary: excess returns real interest rate inflation Real dividend growth Stationary: term premium | Nonstationary: Excess returns real interest rate inflation Stationary: Real Dividend growth term premium | 27.48 | [0.001] |

Table 4. Power and Size of Bootstrap Inference for Cointegration

| Panel A. Examination of Power | | | |
|---|-----------------|--|------------------------------|
| Data Generating Process (alternative hypothesis): Stationary real dividend growth, excess returns, term premium, nonstationary real interest rate and inflation | | | |
| | | Percentage of times correctly reject the null hypothesis | |
| Null Hypothesis | Nominal p-value | Multivariate approach with bootstrap inference | Bootstrap Dickey-Fuller Test |
| 1. Nonstationary: real dividend growth real interest rate, inflation | 0.01 | 0.454 | 0.096 |
| | 0.05 | 0.770 | 0.428 |
| | 0.10 | 0.896 | 0.668 |
| 2. Nonstationary: excess returns, real interest rate, inflation | 0.01 | 0.534 | 0.022 |
| | 0.05 | 0.802 | 0.116 |
| | 0.10 | 0.910 | 0.202 |
| Panel B. Examination of Size | | | |
| Data Generating Process: Null Hypothesis | | | |
| | | Percentage of times incorrectly reject the null hypothesis | |
| Null Hypothesis | Nominal p-value | Multivariate approach with bootstrap inference | Bootstrap Dickey-Fuller Test |
| 1. Nonstationary: real dividend growth real interest rate, inflation | 0.01 | 0.012 | 0.006 |
| | 0.05 | 0.050 | 0.018 |
| | 0.10 | 0.078 | 0.074 |
| 2. Nonstationary: excess returns, real interest rate, inflation | 0.01 | 0.016 | 0.002 |
| | 0.05 | 0.070 | 0.018 |
| | 0.10 | 0.112 | 0.048 |

Note: For the tests above the alternative hypothesis is: stationary real dividend growth, excess returns and term premium with nonstationary real interest rate and inflation

REFERENCES

- Balke, Nathan, and Mark E. Wohar, "Low-Frequency Movements in Stock Prices: A State-Space Decomposition," *Review of Economics and Statistics*, 84:2, (2002), 649-667.
- Barsky, Robert B., and J. Bradford DeLong, "Why Does the Stock Market Fluctuate?" *Quarterly Journal of Economics*, 58 (May 1993): 291-311.
- Beveridge, Stephen, and Charles R. Nelson, "A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the 'Business Cycle'" *Journal of Monetary Economics* 7 (1981):151-74.
- Bulkley, G., and R.D.F. Harris, "'Irrational Analysts' Expectations as a Cause of Excess Volatility in Stock Prices," *The Economic Journal*, 107 (1997): 359-371.
- Campbell, John Y., "A Variance Decomposition for Stock Returns," *Economic Journal*, 101, (1991): 157-179.
- Campbell, John Y., and J. Ammer, "What Moves the Stock and Bond Markets? A Variance Decomposition for Long-term Asset Returns," *Journal of Finance*, 48, (1993): 3-48.
- Campbell, John Y., and John H. Cochrane, "By Force of Habit: A Consumption Based Explanation of Aggregate Stock Market Behavior," *Journal of Political Economy*, vol. 107, no. 2 (April 1999): 205-251.

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

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

Campbell, John Y., and Robert J. Shiller, "The Dividend-Price Ratio and Expectations of Future Dividends and Discount Factors," *Review of Financial Studies*, 1, (1989): 195-228.

Cochrane, John, H., "Volatility Tests and Efficient Markets: A Review Essay," *Journal of Monetary Economics*, 27, (June 1991): 463-485.

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

Diba, Behzad T., and Herschel I. Grossman, "Explosive Rational Bubbles in Stock Prices?" *American Economic Review*, 78 (1988), 520-530.

Epstein, L.G., and S.F., Zin, "Substitution, Risk Aversion and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework," *Journal of Political Economy*, 99 (1991): 263-286.

Flavin, M.A., "Excess Volatility in the Financial Markets: A Reassessment of the Empirical Evidence," *Journal of Political Economy*, 91 (December 1983): 929-956.

Flood, R.P., "On Testing For Speculative Bubbles," *Journal of Economic Perspectives*, 4 (1990): 85-101.

Goyal, Amit, and Ivo Welch, "Predicting the Equity Premium with Dividend Ratios," *Management Science*, 49:5 (2003), 636-654.

Greenwood, Jeremy, and Boyan Jovanovic, "The Information-Technology Revolution and the Stock Market," *American Economic Review* 89 (May 1999): 116-122.

Hamilton, James D. and Charles H. Whiteman, "The Observable Implications of Self-fulfilling Expectations," *Journal of Monetary Economics*, 16 (1985), 353-374.

Heaton, John and Deborah Lucas, "Stock Prices and Fundamentals," in *NBER Macroeconomic Annual 1999*: 213-262.

Hobijn, Bart and Boyan Jovanovic "The Information-Technology Revolution and the Stock Market: Evidence," *American Economic Review*, 91 (2000), 1203-1220.

Horvath, Michael T. K. and Mark W. Watson, "Testing for Cointegration When Some of the Cointegrating Vectors Are Prespecified," *Econometric Theory*, 11 (1995): 984-1014.

Johansen, Soren, "Estimation and Hypothesis Testing of Cointegrating Vectors in Gaussian Vector Autoregressive Models," *Econometrica*, 59 (1991): 1551-1580.

- Kleidon, A. W., "Variance Bounds Tests and Stock Price Valuation Models," *Journal of Political Economy*, 94, (October 1986): 953-1001.
- Lee, Bong-Soo, "Time-Series Implications of Aggregate Dividend Behavior," *Review of Financial Studies* 9, (2) (1996): 589-618.
- Lee, Bong-Soo, "Permanent, Temporary, and Non-fundamental Components of Stock Prices," *Journal of Financial and Quantitative Analysis*, 33 (March 1998): 1-32
- LeRoy, S.F. and R. Porter, "The Present Value Relation: Tests Based on Variance Bounds," *Econometrica* 49 (1981): 555-577.
- Mankiw, N. Gregory, David Romer, and M.D. Shapiro, "Stock Market Forecastability of Volatility: A Statistical Appraisal," *Review of Economic Studies*, 58 (1991): 455-477.
- Marsh, T.A., and R.C. Merton, "Dividend Variability and the Variance Bounds Tests for the Rationality of Stock Market Prices," *American Economic Review*, 76, (June 1986): 483-498.
- Shiller, Robert J., "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?" *American Economic Review*, 71 (June, 1981) : 421-436.
- Timmerman, Allan, "Cointegration Tests of Present Value Models With a Time-varying Discount Factor," *Journal of Applied Econometrics*, 10, (1995): 17-31.

Timmerman, A., "Structural Breaks, Incomplete Information, and Stock Prices," *Journal of Business and Economic Statistics*, 19 (July 2001): 299-314.

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

West, Kenneth D., "Bubbles, Fads, and Stock Price Volatility Tests: A Partial View," *Journal of Finance*, 43 (1988b): 619-639.

Figure 1: $\log(P/D)$

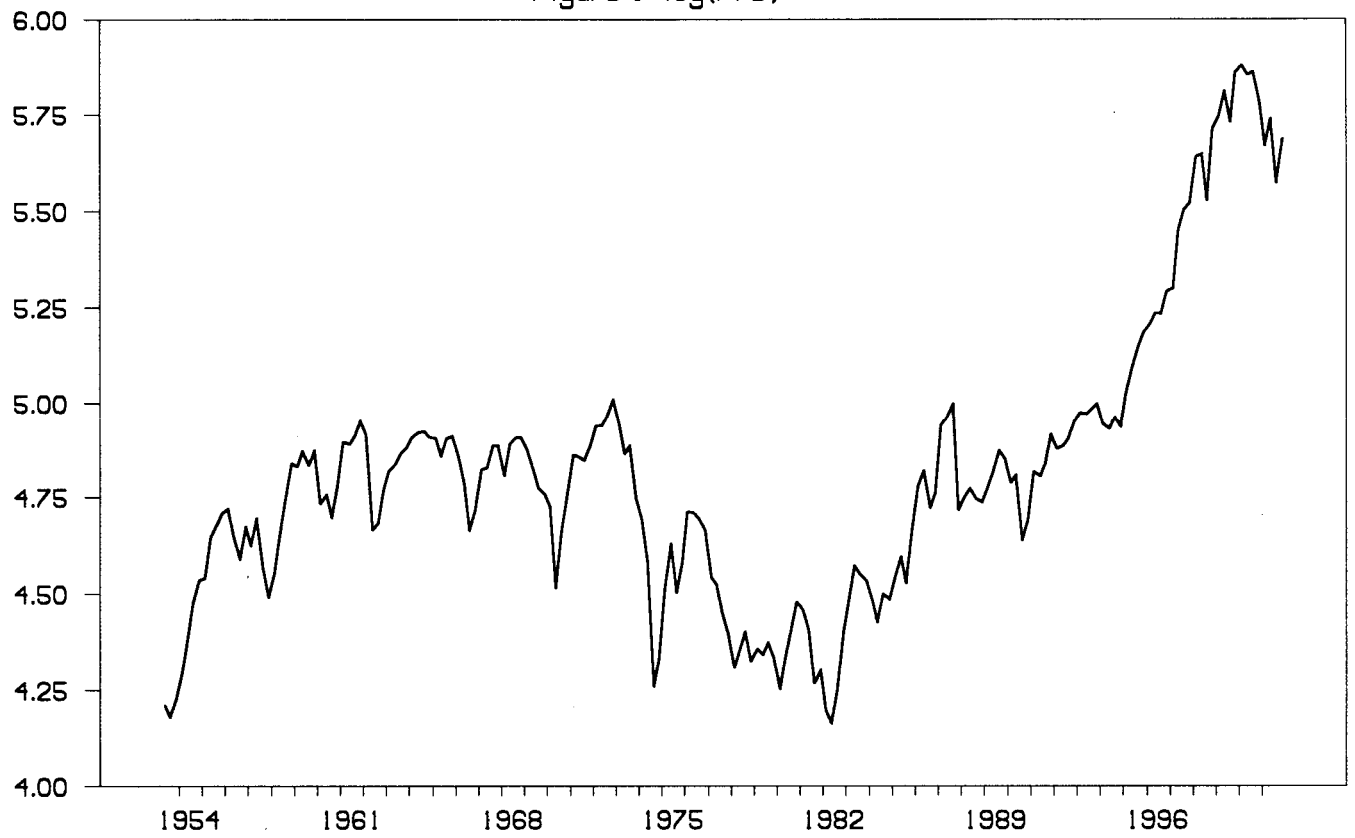
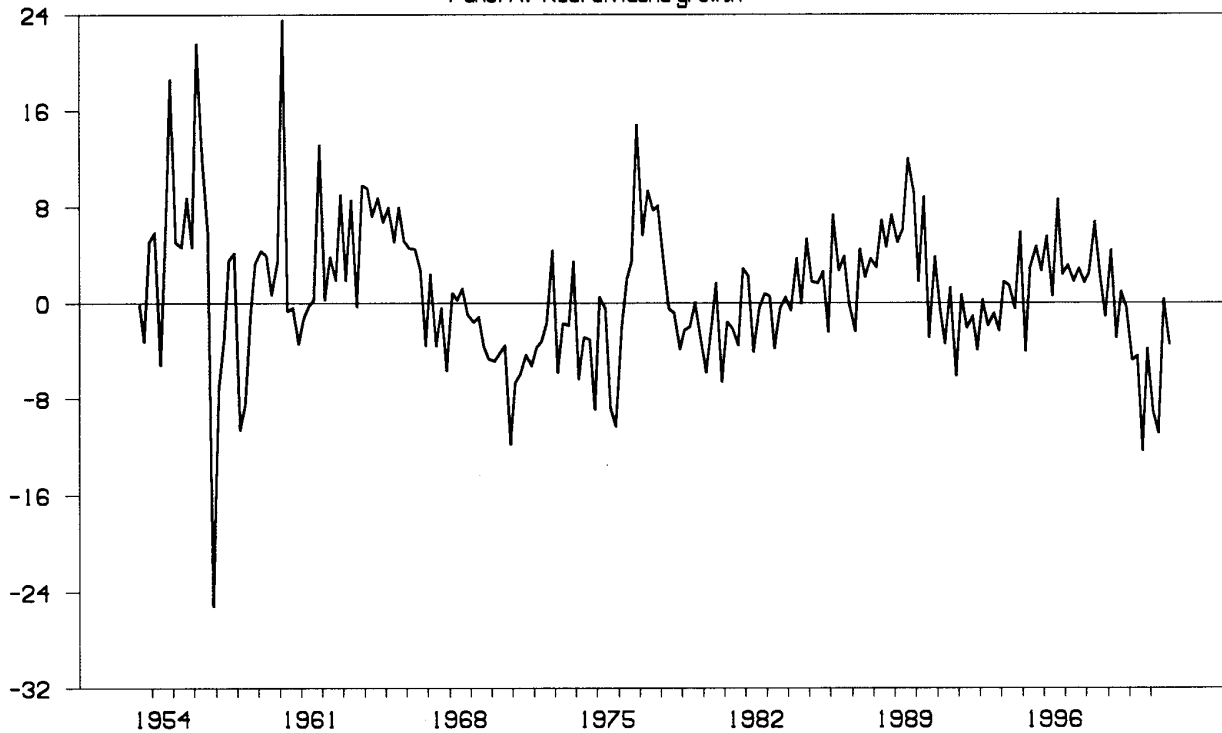


Figure 2.

Panel A. Real dividend growth



Panel B. Excess stock returns

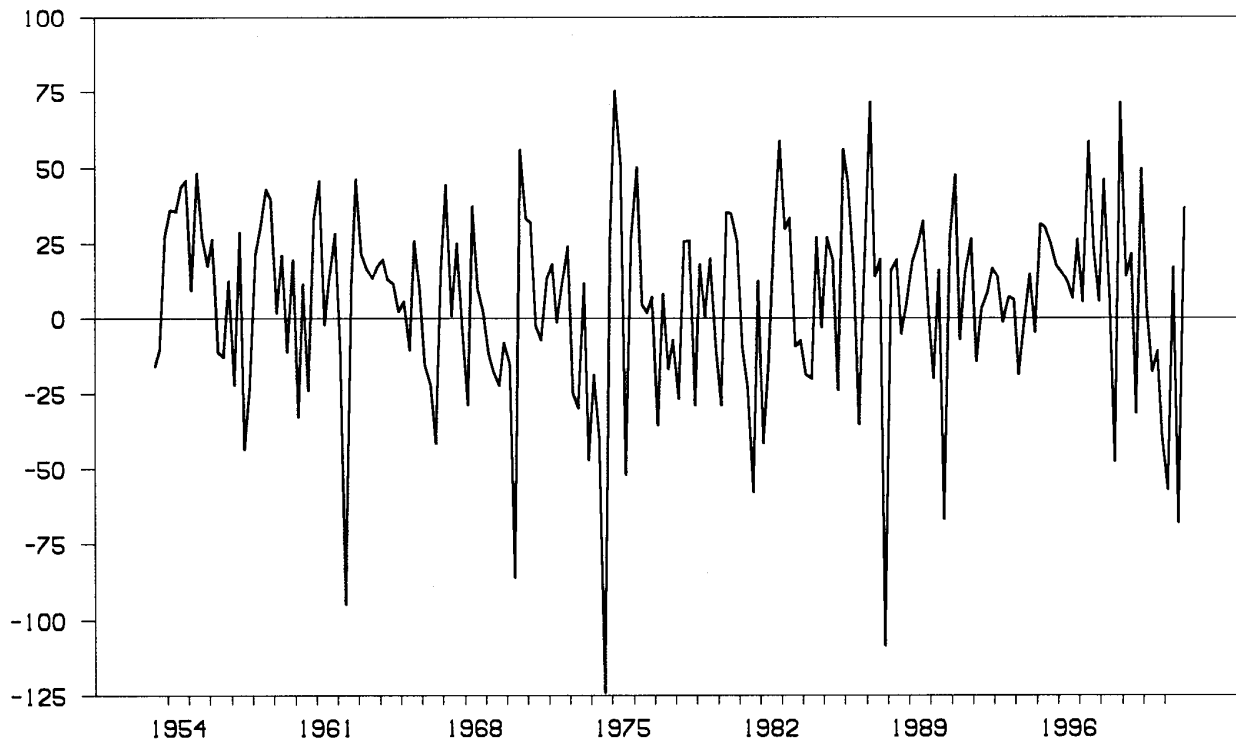


Figure 3. Panel A. Contribution of Market Fundamentals to Log Price/Dividend

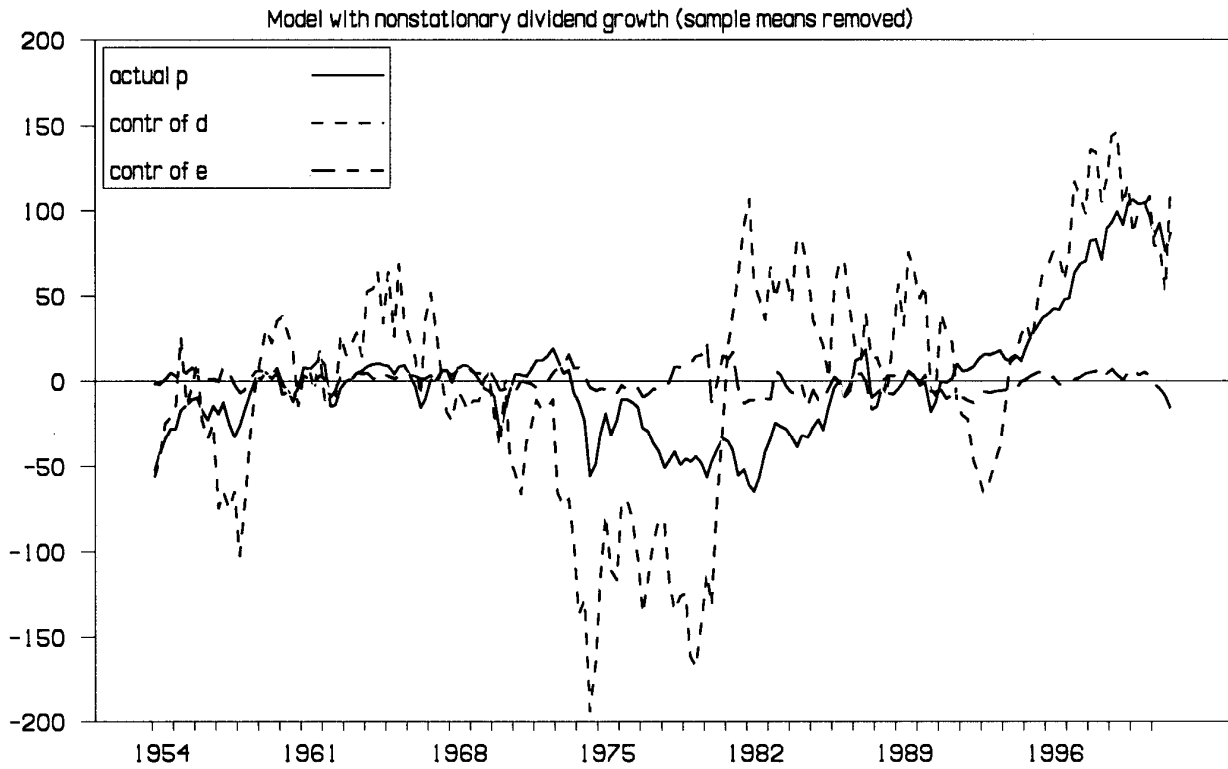


Figure 3. Panel B. Contribution of Market Fundamentals to Log Price/Dividend

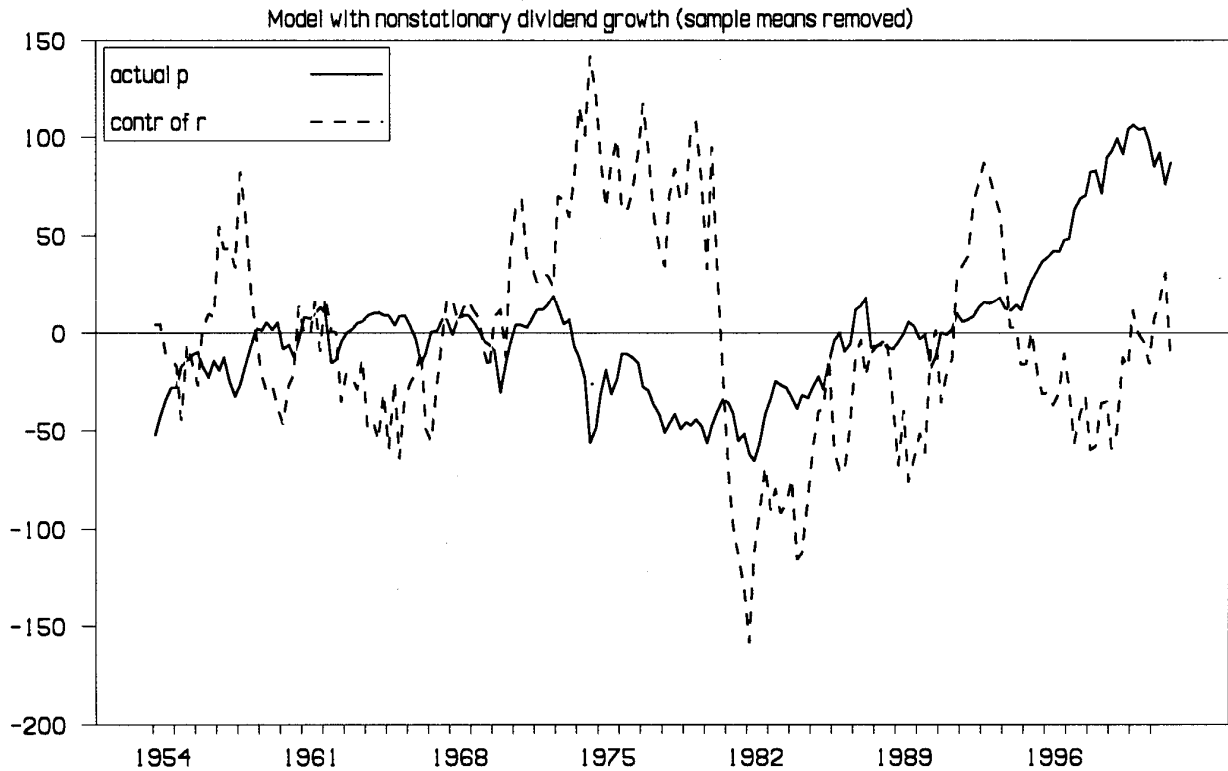


Figure 4. Panel A. Contribution of Market Fundamentals to Log Price/Dividend

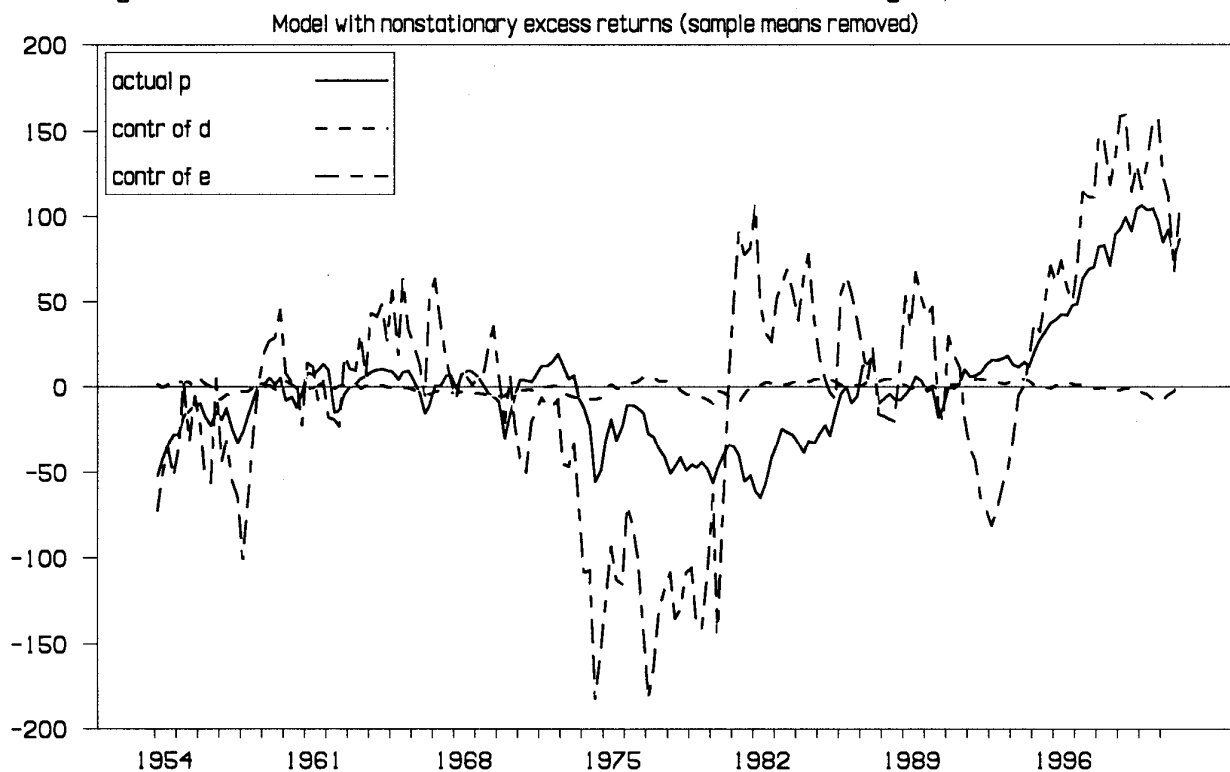


Figure 4. Panel B. Contribution of Market Fundamentals to Log Price/Dividend

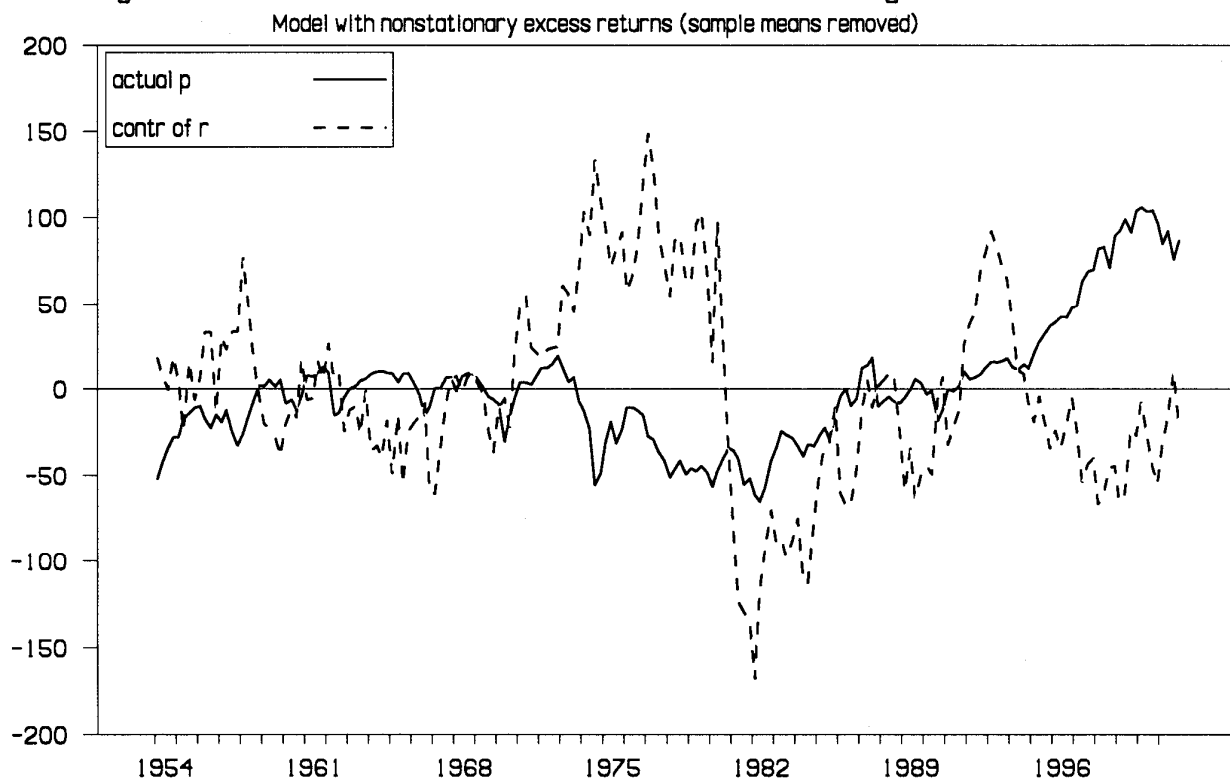


Figure 5. Panel A. Contribution of Market Fundamentals to Log Price/Dividend
Model with Campbell-Ammer Type VAR (sample means removed)

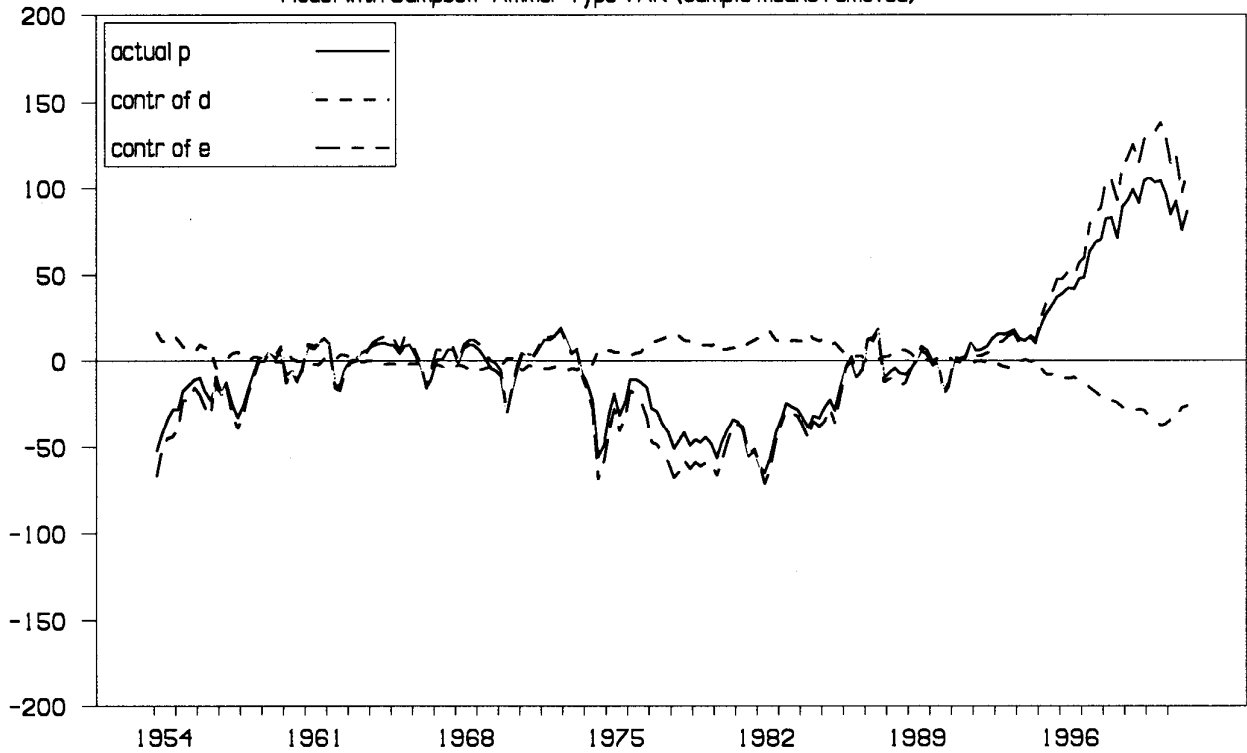


Figure 5. Panel B. Contribution of Market Fundamentals to Log Price/Dividend
Model with Campbell-Ammer Type VAR (sample means removed)

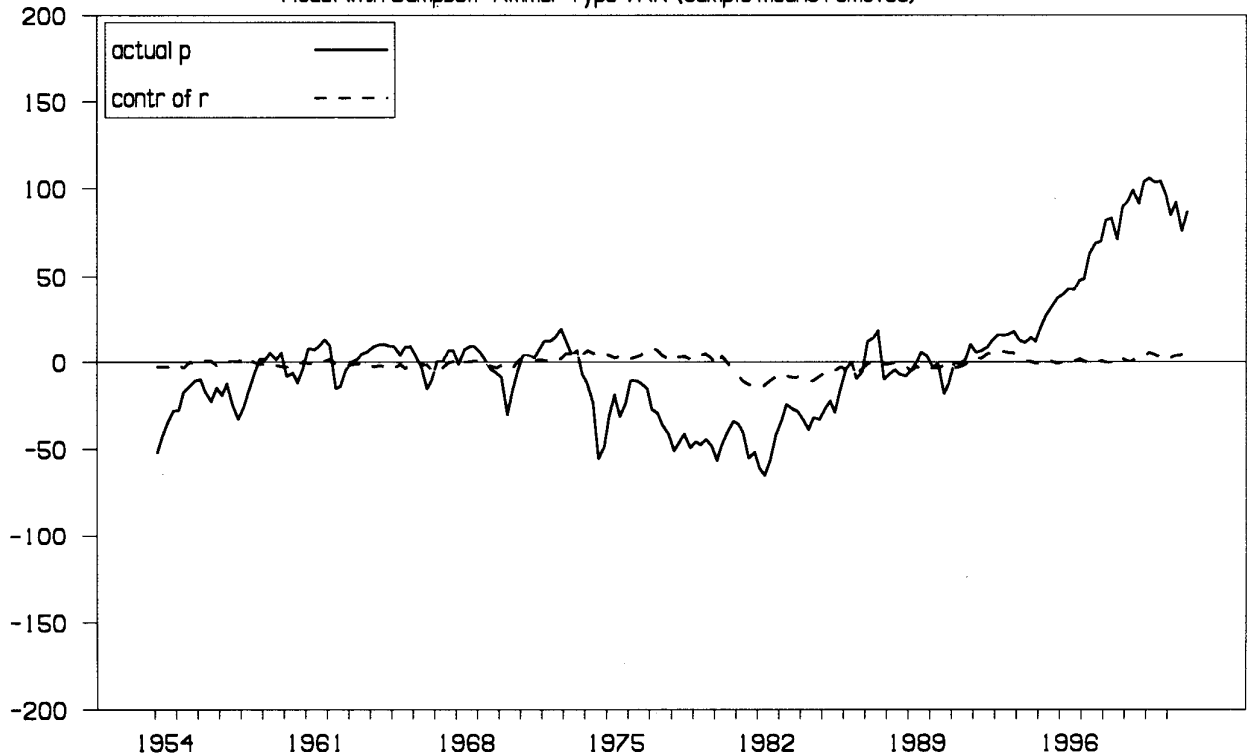


Figure 6. Real dividend growth and Beveridge-Nelson Trend
From Model with Nonstationary Dividend Growth

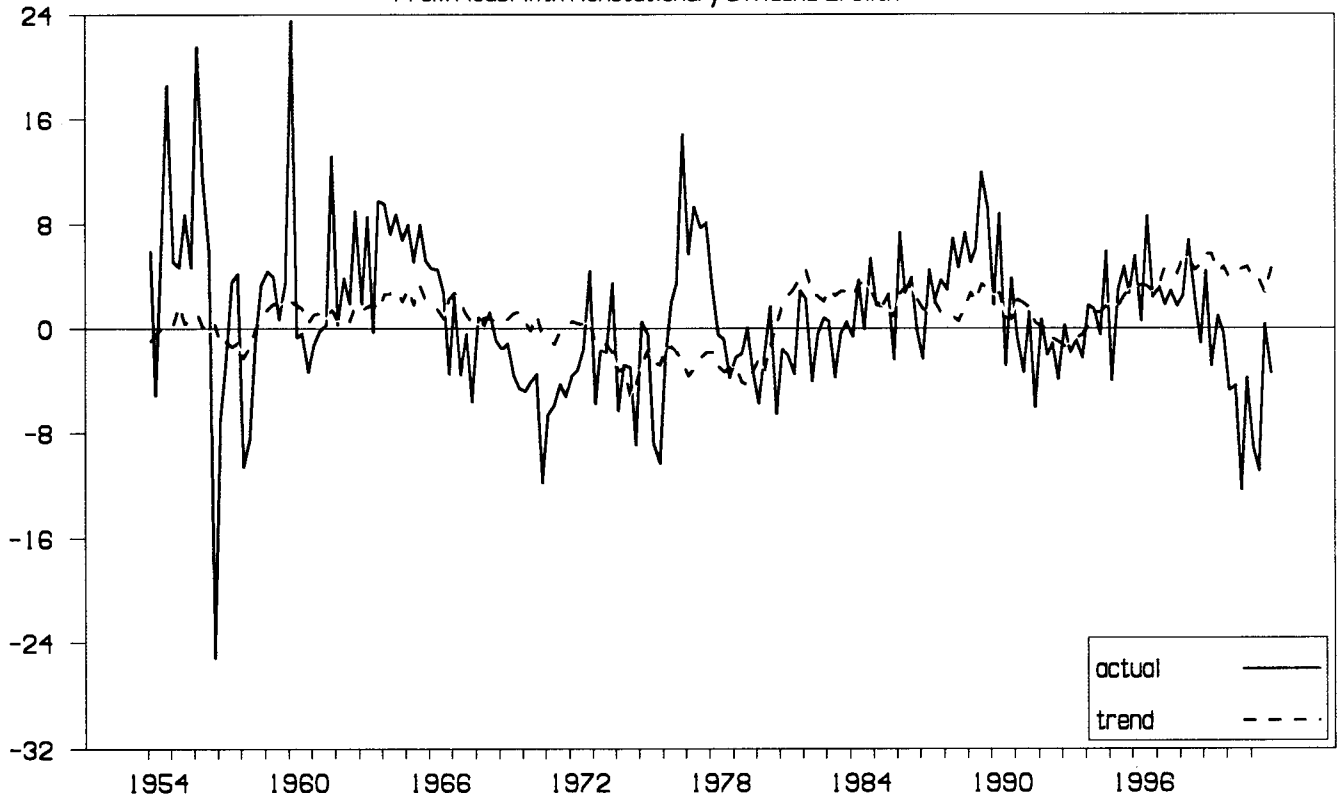


Figure 7. Excess Stock Returns and Beveridge-Nelson Trend
From Model with Nonstationary Excess Returns

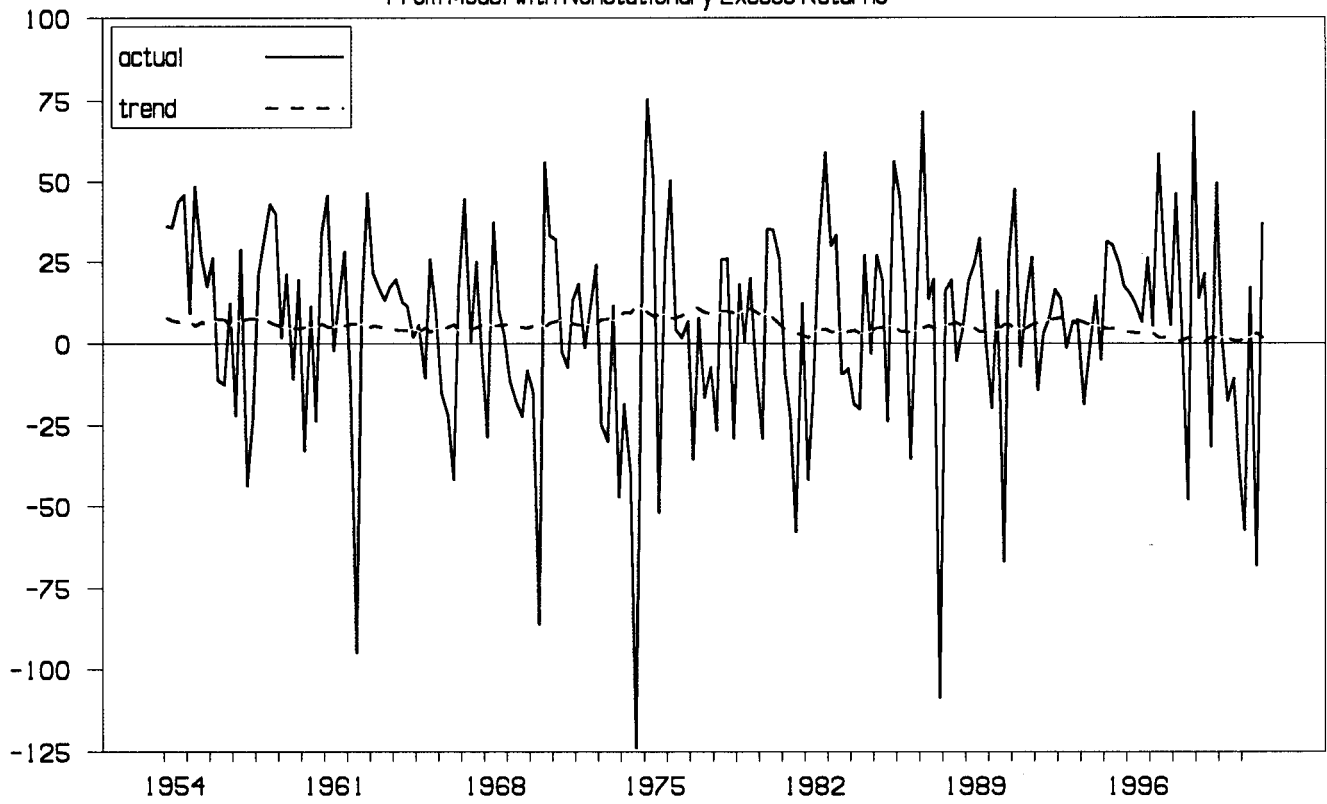


Figure 8. Long-run real dividend growth and minus long-run excess returns
(sample means removed)

