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Price dividend models, expectations formation, and monetary policy

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ABSTRACT

This paper applies the Campbell-Shiller (1988) methodology to estimate a price dividend model with volatility and inflation risk, extending existing models in this field. The model fits the data well over the period 1979-2002 for the Euro Area, but less so for the U.S. The latter is interpreted as reflecting fads and is borne out by a decomposition of the price dividend ratio into a fundamental and bubble part. Finally, it is shown that deviations from fundamentals enter significantly in the Fed's interest rate reaction function but at the cost of destabilising monetary policy. Alternatively, in case that Fed policy remained stable, there was not much of attention to asset bubbles. For the Euro Area, historically, the reaction function does not appear to react much to asset prices.

JEL Codes: E44, G12
Key words: dividend price ratio, dynamic Gordon model, asset price bubbles, Taylor rule

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1 INTRODUCTION

This paper builds on the Campbell-Shiller (1988) methodology to develop a dynamic Gordon model with inflation risk for the price dividend ratio and proposes an accounting decomposition of this ratio into a fundamental and bubble component. The performance of this specification is compared with other commonly used models for the U.S. and Euro Area. In addition, the question of whether U.S. and European monetary authorities have responded to deviations of the price dividend ratio from its fundamental value is addressed as in Hayford and Malliaris (2001).

In a static Gordon model (with constant growth and constant risk), the price dividend ratio explains the value of a stock as the inverse of a constant expected return in excess of the growth rate of the firm or the market. Recent research has focused on modelling the price dividend ratio in terms of fundamentals; see, e.g., Cuthbertson, Hayes and Nitzsche (1997), Black and Fraser (1999, 2000), Fornari and Pericoli (2000). These studies use the dynamic Gordon model of Campbell and Shiller (1988) as a starting point and augment it by assuming a particular specification for the equilibrium return process. Yet, to date, no serious attempt has been made to incorporate inflation risk rigorously into this framework, the rationale being that investors only care about the real return on their investment. Yet, given the potential distortionary effect of inflation, it is worthwhile to examine whether a separate inflation risk premium is priced. Moreover, monetary authorities may pay attention to asset prices to set interest rates as they may serve as a leading indicator of economic growth, inflation[1] or bank risk exposures due to changes in financial wealth and/or cost of capital effects. Hence, it may be interesting to consider whether monetary authorities' reaction function has responded systematically to asset price fundamentals and/or bubbles. However, as noted by Miller et al. (2001), policy reactions to asset price developments may create moral hazard problems for investors.

To anticipate the main findings, for the Euro Area, the proposed model –termed the 'variance-covariance' risk model– is in line with the data and performs similar to existing models –viz. constant risk, consumption risk and market volatility risk models. For the U.S., the former estimates deviate significantly from the data and from the other specifications during the 1990s, all showing an upward trend in the price dividend ratio, while the proposed model displays more of a downward trend. One view is that the proposed model may indicate a bubble in the U.S. stock market, while the other models seem to accommodate the high numbers. This view is corroborated by a decomposition of the price dividend ratio in fundamental and bubble components. Furthermore, most specifications of the asset price bubble enter significantly in the Federal Reserve's interest rate reaction function, yet

[1] Viewing the price dividend ratio as a measure of how expensive stocks are, there may be an interaction between asset price inflation and general consumer price inflation (Goodhart, 2001).

rendering monetary policy unstable. In the few cases where U.S. monetary policy remains stable, however, there is not much systematic attention to asset market valuation.

The structure of the paper is as follows. Section 2 outlines the model with inflation risk and section 3 provides comparative empirical evidence for the U.S. and Euro Area. Section 4 estimates the monetary policy reaction function and investigates the added value of the price dividend ratio as an information variable. The last section concludes.

2 THE MODEL

Campbell (1991) defines the one-period log holding return on stocks as $h_{t+1} \equiv \log(P_{t+1}+D_{t+1})-\log(P_t)$, where P_t is the stock price at the end of period t (ex dividend), and D_{t+1} is the dividend paid during period t. The right-hand side of this identity can be loglinearized using a first-order Taylor expansion, as

$$h_{t+1} \approx k + \rho p_{t+1} + (1-\rho)d_{t+1} - p_t \tag{2.1}$$

where lowercase letters are used for logs, ρ and k are parameters of linearization.
Equation (2.1) can be rewritten, so that the dividend price ratio appears in the accounting identity, as

$$\delta_t \approx h_{t+1} - \Delta d_{t+1} + \rho\delta_{t+1} - k \tag{2.2}$$

where $\delta_t = d_t - p_t$, the log dividend price ratio[2] (for dividends paid during period t), other variables are as defined in (2.1). Substituting forward (assuming $\lim_{j\to\infty} \rho^j \delta_{t+j} = 0$), taking expectations at time t, the following specification is obtained:

$$\delta_t = \sum_{j=0}^{\infty} \rho^j E_t\big(h_{t+1+j} - \Delta d_{t+1+j}\big) - k/(1-\rho) \tag{2.3}$$

or, assuming a finite horizon,

$$\delta_t = \sum_{j=0}^{i-1} \rho^j E_t\big(h_{t+1+j} - \Delta d_{t+1+j}\big) + \rho^i E_t \delta_{t+1+i} - k(1-\rho^i)/(1-\rho) \tag{2.4}$$

[2] In order to obtain the results in terms of the price dividend ratio, signs of all variables are switched.

Equation (2.3) is the dividend price expression for an infinite investment horizon, while (2.4) is the one corresponding to a finite i-period investment horizon.

The transition from (2.2) to (2.3) and (2.4) adds an economic content to the otherwise *purely accounting* decomposition. Now, the problem is to specify a process for the expected or equilibrium return $E_t h_{t+1}$.[3] Campbell and Shiller (1988) and Cuthbertson et al. (1997) propose constant risk models, allowing for time-variation in the discount rate, and models with consumption risk and volatility risk. Taking the inflation-augmented capital asset pricing model (CAPM) of Friend, Landskroner and Losq (1976) as a specification of equilibrium returns, instead of the simple CAPM, one easily gets a specification of expected returns in terms of a time-varying safe rate plus a risk premium consisting of the market return variance and the covariance of the market return with inflation, weighted by the coefficient of relative risk aversion multiplied by the portfolio share of risky assets, and the complement of the relative risk aversion coefficient, respectively:

$$E_t h_{t+1} = E_t r_{t+1} + \alpha\,\phi\, E_t V_{t+1} + (1-\alpha) E_t C_{\pi,t+1} \tag{2.5}$$

where r_{t+1} is the time-varying safe rate, V_{t+1} is the instantaneous market return variance, $C_{\pi,t+1}$ is the covariance between the market return and inflation, α is the coefficient of relative risk aversion and ϕ is the portfolio share of risky assets for a representative agent. Substituting expression (2.5) in (2.3) and (2.4), respectively, provides an alternative pricing formula for the dividend price ratio. This specification is new in this context and has so far not been examined in empirical work. For ease of reference, it is called the 'variance-covariance risk model'.

The above specification will be compared against the most commonly used models, more specifically, a constant risk -varying risk free rate model, and two models with time-varying risk premiums, *viz.* the Consumption CAPM (CCAPM) and Merton's intertemporal volatility model. The specification of the equilibrium return for each of these models is as follows:

$$E_t h_{t+1} = E_t r_{t+1} \tag{2.6}$$

$$E_t h_{t+1} = E_t r_{t+1} + \alpha_c\, E_t \Delta C_{t+1} \tag{2.7}$$

$$E_t h_{t+1} = E_t r_{t+1} + \alpha_v\, E_t V_{t+1} \tag{2.8}$$

where r_{t+1} is a risk free rate of return (say, on government bonds); ΔC_{t+1} is the log change in consumption; V_{t+1} is the market return variance; α_v and α_c are coefficients of relative risk aversion with respect to return variance and consumption growth, respectively.

[3] As will become clear from section 3 and Appendix, the other terms in (2.3) and (2.4), *viz.* the expected dividend growth and expected price dividend rate at the end of a finite investment horizon can be computed using observables and vector auto-regression (VAR) estimates.

3 EMPIRICAL EVIDENCE ON PRICE DIVIDEND MODELS

This section describes data and methodology and presents empirical evidence for U.S. and Euro Area quarterly data, in-sample for the period 1979/1-2000/4 and out of sample for the period 2001/1-2002/3. Finally, a methodology and evidence is put forward to identify asset price bubbles.

3.1 Data and Methodology

Data for the U.S. refer to Standard and Poor's S&P500 and St. Louis Economic Database (*FRED*). Euro Area stock market data are drawn from the Morgan Stanley Capital International (*MSCI*) indices for Europe-EMU. All other Euro Area data have been constructed synthetically from individual country statistics (sources: IMF, Eurostat, OECD) using a weighting scheme similar to Beyer et al. (2001), obtained from Valckx (2001).

The methodology closely follows that of Campbell and Shiller (1988) and Cuthbertson et al. (1997) and is explained in more detail in the Appendix. Basically, a vector autoregression (VAR) is estimated containing the price dividend ratio, dividend growth and additional information necessary to obtain a closed form estimate of the future dividend growth and return components. The basic VAR estimates are shown in the Appendix. In a next step, the estimated VAR coefficients are used to construct a theoretical price dividend ratio over a fixed horizon and its constituent parts. As a means to account for non-stationarity, and to get rid of constant terms, all variables are demeaned before entering the VAR. As such, resulting statistics can meaningfully be compared to actual data only in terms of volatility and correlations. One complicating factor for the time-varying risk premium models is to decide on the number for relative risk aversion and the share of risky assets. The standard procedure is to determine this statistic by selecting the number that minimizes a nonlinear Wald statistic that measures the deviation between the actual and theoretical price dividend ratio, over a range of values.

3.2 In-Sample Evidence

The next four tables contain diagnostic statistics over different horizons for the various models presented in section 2 that describe the in-sample estimation results. Subsequently, Figures 1-8 display the various price dividend model estimates.

The tables are ranked by increasing degree of sophistication. Table 1 contains the output for the constant risk model, with an expected return process as in equation (2.6). Table 2 and 3 contain the empirical results for single risk premium models, with return processes according to equation (2.7) and (2.8), respectively. Table 4 contains the estimation results for the proposed variance-covariance risk model, given by equation (2.5). The tables first show a Wald statistic that measures the estimation error, as mentioned in section 3.1. Next, four other error statistics, which sometimes yield different conclusions vis-à-vis the Wald statistic, are presented: viz., the mean error, the mean absolute error, the root mean squared error, and the Granger ratio.[4] Next, correlations between estimated and realised price dividend ratios are displayed. Finally, the contribution of each component to the price dividend decomposition is shown.

Table 1 Constant risk model for U.S. and Euro Area price dividend ratio

U.S.	**1 year**	**2 year**	**3 year**	**5 year**	**10 year**	**Infinity**
Wald	70.29	39.53	25.12	14.30	6.25	68.64
(*p*-value)	(0.000)	(0.000)	(0.000)	(0.015)	(0.283)	(0.000)
Mean error	0.0545	0.0914	0.1083	0.1168	0.1054	-0.0591
MAE	6.69	12.19	17.14	26.32	47.37	260.63
RMSE	8.19	14.75	20.67	31.84	58.13	326.52
Granger ratio	0.817	0.826	0.829	0.827	0.815	0.798
Corr(PD,PD*)	0.779	0.839	0.883	0.932	0.971	0.994
(s.d.)	(0.072)	(0.079)	(0.078)	(0.063)	(0.038)	(0.018)
Contribution (s.d.)						
r_{t+1} :	0.999 (0.62)	1.15 (0.60)	1.136 (0.49)	1.179 (0.54)	1.27 (0.37)	1.36 (0.12)
Δd_{t+1} :	-0.037 (0.70)	-0.176(0.65)	-0.152(0.51)	-0.189(0.55)	-0.276(0.37)	0.36 (0.12)
PD_{t+N} :	0.038 (0.09)	0.027 (0.04)	0.016 (0.02)	0.010 (0.01)	0.006 (.004)	-
Euro Area						
Wald	83.77	49.89	31.62	16.10	6.16	114.02
(*p*-value)	(0.000)	(0.000)	(0.000)	(0.007)	(0.291)	(0.000)
Mean error	-0.3332	-0.975	-1.5543	-2.4538	-3.7753	-0.9173
MAE	10.76	19.63	27.11	39.06	56.97	74.99
RMSE	13.25	24.36	33.80	48.85	71.17	92.58
Granger ratio	0.812	0.806	0.802	0.800	0.800	0.810
Corr(PD,PD*)	0.931	0.960	0.972	0.979	0.983	0.986
(s.d.)	(0.027)	(0.019)	(0.015)	(0.012)	(0.010)	(0.009)
Contribution (s.d.)						
r_{t+1} :	0.78 (0.37)	0.77 (0.25)	0.75 (0.30)	0.84 (0.31)	0.83 (0.18)	0.83 (0.13)
Δd_{t+1} :	0.19 (0.41)	0.21 (0.26)	0.25 (0.31)	0.16 (0.31)	0.17 (0.19)	0.17 (0.13)
PD_{t+N} :	0.03 (0.04)	0.01 (0.01)	0.006 (.009)	0.004 (.004)	0.001 (.001)	-

Notes
This Table presents diagnostic statistics of the constant risk model for the price dividend ratio, over various investment horizons (1 year to infinite horizon), estimated with quarterly data, 1979/1-2000/4. The risk free rate *r* is given by a 10 year government bond rate.
The *Wald* statistic tests for the deviation between actual and theoretical price dividend, and is chi-squared distributed with 1 degree of freedom. Mean error, mean absolute error (MAE), root mean squared error (RMSE) and Granger ratio (MAE/RMSE) are alternative measures of fit. Corr(·) denotes correlation between the respective variables, (s.d.) gives the standard deviation of the statistic, *Contribution* gives the importance of each of the factors in the model summing up to 1: *r* is the 10-year safe rate, Δd dividend growth, PD_{t+N} final-period price dividend ratio. PD (PD*) denotes the actual (model-based) price dividend.

In view of the extension of the dividend price model proposed in section 2, the discussion will focus on how well the variance-covariance risk model (Table 4) compares to existing models (Tables 1 to 3). In terms of fit, for the U.S., the Wald statistic on finite horizons, from 2 to 10 years, indicates a significant gap between theoretical and actual price dividend –considering the low p-values. For a 1-year and an infinite investment horizon, the deviation between the actual and theoretical price

4 Granger (1996) observed that this ratio, the mean absolute error divided by the root mean square error, is usually slightly less than 0.80. The reason being that generally errors are drawn from a distribution with a relatively small variance but sometimes they are drawn from a distribution with a large variance. The latter results in large error statistics. The Granger ratio declines when more drawings are taken from the large variance distribution.

dividend ratio is not statistically significant, which makes this model distinct from the earlier models. Also the behaviour of this statistic is unlike the other models': it remains fairly stable across all horizons and it falls for the infinite horizon. For the other models, it shows a U-shape with (relatively) high beginning and end points. In absolute terms, the Wald stats are smallest for the volatility risk model (Table 3: 3 to 10 year horizons). The Euro Area Wald statistic shows another pattern. Firstly, in Table 4, the intermediate horizons from 2 to 10 years are not significant, while 1-year and infinite horizons are. Secondly, there is a very noticeable U-shape for all models. Thirdly, the best fit (lowest Wald statistics) appears to be the volatility risk model.

Table 2 CCAPM risk model for U.S. and Euro Area price dividend ratio

U.S. (α=2)	**1 year**	**2 year**	**3 year**	**5 year**	**10 year**	**Infinity**
Wald	60.23	28.36	18.20	11.34	6.41	93.88
(p-value)	(0.000)	(0.000)	(0.011)	(0.124)	(0.493)	(0.000)
Mean error	0.26	0.41	0.49	0.55	0.62	1.26
MAE	9.59	16.90	23.10	34.22	59.67	329.1
RMSE	11.69	20.08	27.18	40.31	71.60	408.9
Granger ratio	0.820	0.841	0.850	0.849	0.833	0.805
Corr(PD,PD*)	0.707	0.782	0.842	0.910	0.964	0.994
(s.e.)	(0.097)	(0.125)	(0.128)	(0.102)	(0.054)	(0.017)
Contribution (std)						
r_{t+1} :	0.96 (0.32)	0.95 (0.20)	0.97 (0.14)	0.97 (0.25)	1.06 (0.25)	1.05 (0.03)
Δd_{t+1} :	-0.22 (0.55)	-0.17 (0.31)	-0.17 (0.26)	-0.17 (0.38)	-0.32 (0.50)	-0.30 (0.06)
ΔC_{t+1}:	0.22 (0.24)	0.20 (0.15)	0.19 (0.14)	0.19 (0.16)	0.26 (0.25)	0.25 (0.04)
PD_{t+N} :	0.04 (0.07)	0.02 (0.02)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	-
Euro Area (α=2)						
Wald	168.7	76.62	42.72	20.05	7.59	168.9
(p-value)	(0.000)	(0.000)	(0.000)	(0.005)	(0.371)	(0.000)
Mean error	-1.45	-3.30	-5.01	-7.72	-11.87	-15.79
MAE	16.29	29.36	40.25	57.84	85.05	110.9
RMSE	19.04	34.91	48.48	70.43	104.3	136.4
Granger ratio	0.855	0.841	0.830	0.821	0.816	0.813
Corr(PD,PD*)	0.912	0.941	0.956	0.966	0.973	0.976
(s.e.)	(0.026)	(0.025)	(0.023)	(0.021)	(0.020)	(0.019)
Contribution (std)						
r_{t+1} :	0.61 (0.15)	0.61 (0.37)	0.64 (0.10)	0.63 (0.065)	0.65 (0.12)	0.65 (0.14)
Δd_{t+1} :	0.27 (0.41)	0.56 (2.85)	0.18 (0.30)	0.22 (0.20)	0.19 (0.31)	0.19 (0.40)
ΔC_{t+1}:	0.11 (0.27)	-0.16 (2.54)	0.17 (0.20)	0.15 (0.13)	0.16 (0.19)	0.16 (0.27)
PD_{t+N} :	0.01 (0.013)	-0.002 (0.08)	0.005 (0.004)	0.002 (0.001)	0.001 (0.001)	

Notes
See Table 1. ΔC denotes quarterly real consumption growth (taken from national accounts statistics).

As mentioned above, the prediction error statistics sometimes yield (slightly) different conclusions. Both for the U.S. and Euro Area, errors are smallest for the variance-covariance risk model. When assessing the dynamic behaviour of the estimated price dividend, the variance-covariance risk model in Table 4 is unsatisfactory for the U.S. in some respect: the correlation with the actual price dividend appears to be negative and significantly so over an infinite horizon. However, for the variance risk and consumption risk models, this correlation is positive. For the Euro Area, the variance-covariance risk model shows a relatively positive image: correlations between estimated and actual price dividend are positive (but not significant).

Table 3 Volatility risk model for U.S. and Euro Area price dividend ratio

U.S. (α=10)	**1 year**	**2 year**	**3 year**	**5 year**	**10 year**	**Infinity**
Wald	15.65	12.40	9.59	6.79	5.11	14.76
(p-value)	(0.029)	(0.088)	(0.213)	(0.451)	(0.647)	(0.039)
Mean error	0.13	0.18	0.21	0.24	0.24	0.161
MAE	9.13	14.39	17.78	21.87	28.28	62.81
RMSE	12.80	20.40	25.17	30.49	37.04	75.14
Granger ratio	0.713	0.705	0.707	0.717	0.763	0.836
Corr(PD,PD*)	0.410	0.429	0.457	0.519	0.647	0.905
(s.e.)	(0.282)	(0.366)	(0.465)	(0.650)	(0.894)	(0.609)
Contribution (std)						
r_{t+1} :	1.28 (2.68)	0.90 (3.62)	2.06 (5.25)	0.74 (7.36)	2.15 (3.07)	2.61 (2.63)
Δd_{t+1} :	-0.32 (1.25)	-0.20 (1.26)	-0.59 (2.18)	-0.05 (2.93)	-0.64 (1.34)	-0.83 (1.15)
V_{t+1} :	-0.02 (1.76)	0.28 (2.67)	-0.51 (3.30)	0.30 (4.55)	-0.52 (1.77)	-0.78 (1.48)
PD_{t+N} :	0.06 (0.22)	0.018 (0.13)	0.04 (0.13)	0.003 (0.11)	0.011 (0.02)	-
Euro Area (α=10)						
Wald	8.21	7.87	7.70	7.55	7.24	6.88
(p-value)	(0.315)	(0.344)	(0.359)	(0.626)	(0.404)	(0.441)
Mean error	0.00	-0.11	-0.14	-0.17	-0.19	-0.221
MAE	10.00	14.17	16.85	20.77	27.73	36.55
RMSE	12.55	17.54	20.25	24.40	32.49	43.18
Granger ratio	0.797)	0.808	0.832	0.851	0.853	0.846
Corr(PD,PD*)	0.192	0.342	0.474	0.649	0.807	0.887
(s.e.)	(0.577)	(0.708)	(0.757)	(0.691)	(0.475)	(0.314)
Contribution (std)						
r_{t+1} :	1.45 (3.94)	1.18 (2.20)	1.08 (2.53)	1.26 (3.41)	2.00 (2.24)	1.96 (3.69)
Δd_{t+1} :	0.47 (0.77)	0.37 (0.34)	0.34 (0.45)	0.36 (0.65)	0.48 (0.30)	0.45 (0.71)
V_{t+1} :	-0.96 (4.74)	-0.57 (2.52)	-0.43 (2.90)	-0.62 (3.90)	-1.49 (2.53)	-1.41 (4.37)
PD_{t+N} :	0.04 (0.13)	0.02 (0.04)	0.008 (0.03)	0.005 (0.02)	0.003 (.004)	-

Notes
See Table 1. V denotes market return volatility (measured as squared nominal returns).

The fact that, for the U.S., the Wald and error statistics on the one hand, and the correlations on the other hand, show an opposite picture, is troublesome and certainly is not favourable evidence for the proposed model extension. Alternatively, the results might be interpreted as showing the presence of bubbles in the actual price dividend ratio. As such, it might well be that the two ratios diverge, as suggested by the negative correlations. This interpretation is supported by an inspection of the data in Figures 1 to 4: for the U.S., the ratio has a clear upward trend, and since 1995 values have grown very rapidly, consistent with the *new economy* view for the U.S. stock market (which proved to be a bubble, as with hindsight, it came to and end in 2000). All models –especially when looking at the infinite horizon metrics– track this behaviour to some extent, except the variance-covariance risk model In fact, the latter displays a stagnation after 1995. For the Euro Area, a similar upward pattern is detectable in Figures 5 to 8, but in contrast to the U.S., all model estimates move in the same direction –also after 1995– implying that, if any, the stock market bubble was less visible and/or harder to detect using the models examined here. In Section 3.4, this issue will be addressed more formally by proposing a decomposition into a fundamental and bubble component.

Table 4 Variance-covariance risk model for U.S. and Euro Area price dividend ratio

U.S. (α=2,ϕ=0.2)	**1 year**	**2 year**	**3 year**	**5 year**	**10 year**	**Infinity**
Wald	13.54	17.86	19.08	18.57	17.34	9.974
(p-value)	(0.140)	(0.037)	(0.025)	(0.029)	(0.044)	(0.353)
Mean error	-0.15	-0.47	-0.65	-0.80	-0.80	-0.18
MAE	8.00	12.55	15.37	18.38	22.24	51.87
RMSE	10.47	16.12	19.60	23.20	27.16	66.02
Granger ratio	0.764	0.779	0.784	0.792	0.819	0.786
Corr(PD,PD*)	-0.081	-0.135	-0.187	-0.292	-0.525	-0.960
(s.e.)	(0.391)	(0.442)	(0.500)	(0.634)	(0.836)	(0.235)
Contribution (std)						
r_{t+1} :	0.73 (2.94)	0.74 (3.48)	0.55 (5.11)	0.77 (8.02)	-1.47 (12.9)	-4.25 (6.36)
Δd_{t+1} :	-0.05 (0.87)	-0.004 (0.98)	0.04 (1.33)	0.001 (2.14)	0.59 (0.26)	1.32 (1.66)
V_{t+1} :	0.02 (0.08)	0.02 (0.034)	0.02 (0.05)	0.02 (0.07)	0.03 (0.10)	0.05 (0.052)
$C_{\pi,t+1}$:	0.31 (2.33)	0.24 (2.58)	0.39 (3.84)	0.21 (5.90)	1.86 (9.50)	3.88 (4.65)
PD_{t+N} :	-0.01 (0.19)	0.002 (0.09)	-0.002 (0.09)	0.001 (0.08)	-0.01 (0.06)	-
Euro Area (α=2,ϕ=0.2)						
Wald	18.48	14.25	11.77	10.12	8.99	18.38
(*p*-value)	(0.030)	(0.134)	(0.227)	(0.341)	(0.438)	(0.031)
Mean error	-0.66	-0.86	-0.92	-0.94	-0.96	-0.98
MAE	10.34	13.66	14.93	16.81	21.15	27.52
RMSE	13.35	17.68	19.33	21.28	25.40	32.40
Granger ratio	0.775	0.773	0.772	0.790	0.833	0.849
Corr(PD,PD*)	0.124	0.225	0.322	0.475	0.661	0.797
(s.e.)	(0.322)	(0.473)	(0.622)	(0.791)	(0.816)	(0.694)
Contribution (std)						
r_{t+1} :	2.75 (3.45)	0.36 (2.62)	-0.16 (6.85)	-0.01 (9.25)	2.65 (4.25)	3.23 (3.72)
Δd_{t+1} :	0.61 (0.61)	0.31 (0.46)	0.47 (1.62)	0.25 (1.09)	0.66 (0.95)	0.69 (0.52)
V_{t+1} :	-0.09 (0.15)	0.01 (0.14)	0.07 (0.40)	0.03 (0.44)	-0.08 (0.19)	-0.11 (0.16)
$C_{\pi,t+1}$:	-2.27 (3.85)	0.32 (2.90)	0.63 (7.18)	0.74 (9.88)	-2.24 (4.86)	-2.81 (4.06)
PD_{t+N} :	0.005 (.007)	0.003 (0.09)	-0.006 (0.11)	-0.003 (0.10)	0.013 (0.02)	-

Notes
See Table 1. V denotes market return volatility (measured as squared nominal returns) and C_π denotes the covariance between CPI-inflation and (nominal) market return.

Finally, concentrating on the contributions of the different components, for the U.S., Table 4 shows a major impact of the risk free rate (r_{t+1}) and the inflation covariance risk ($C_{\pi,t+1}$), with shares of between 0.55-0.70 and 0.20-0.40, respectively, for maturities up to 5 years. For longer maturities, these shares are larger than the price dividend ratio itself, forcing positive and negative offsetting contributions larger than 1 (in absolute values). They also have large amplitudes as shown by the high standard deviation. The other factors –dividend growth (Δd_{t+1}), market return variance (V_{t+1}) and final-horizon price dividend (PD_{t+N}), have a negligible impact. Only in the long run, the dividend factor seems to be a bit more significant. For the euro area, contributions at the short end and at the long end give most weight to the risk free rate and the covariance risk term, but with high standard deviations, as for the U.S. At the intermediate horizons, 2 to 5 years, the dividend growth factor also contributes importantly. In any case, the final maturity price dividend is not a major factor. Across all models in Table 1 to 3, the main contribution derives from the risk free rate, while the dividend growth factor is generally one third of the former, and matches the size of the variance (V_{t+1}) or consumption risk (ΔC_{t+1}) factors in Table 2 and 3.

Figure 1 Constant risk, U.S. (in-sample)

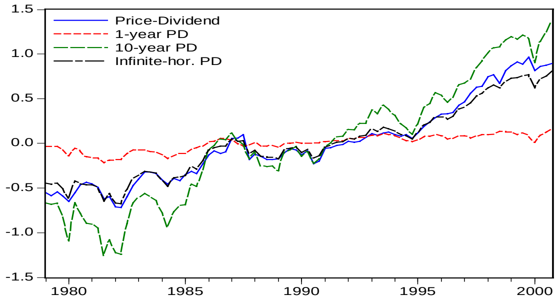


Figure 2 CCAPM risk, U.S. (in-sample)

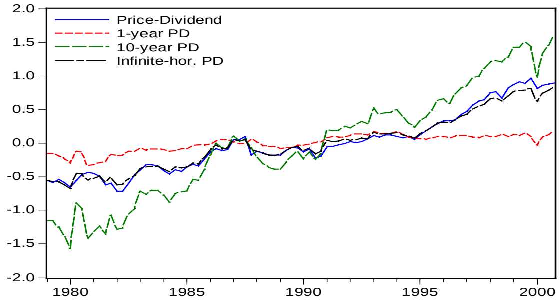


Figure 3 Volatility risk, U.S. (in-sample)

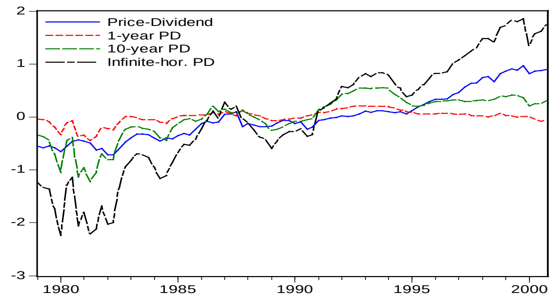


Figure 4 Variance-covariance risk, U.S. (in-sample)

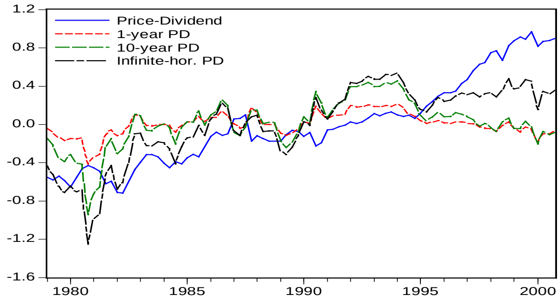


Figure 5 Constant risk, Euro Area (in-sample)

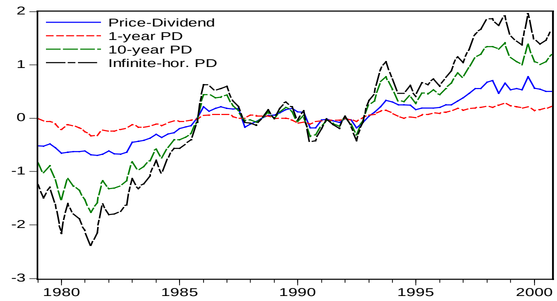


Figure 6 CCAPM risk, Euro Area (in-sample)

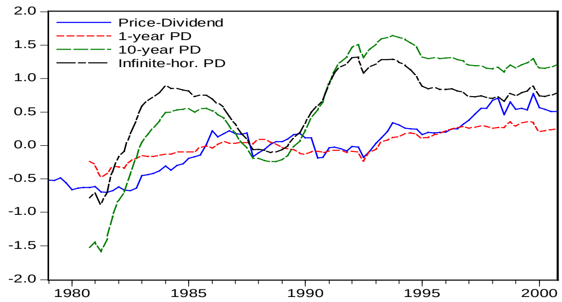


Figure 7 Volatility risk, Euro Area (in-sample)

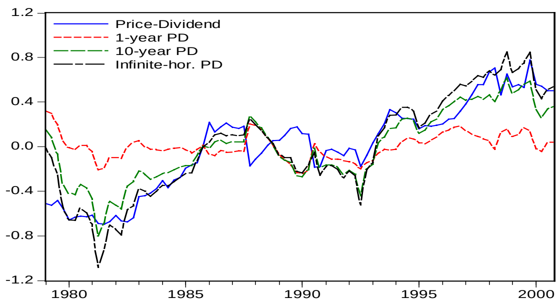
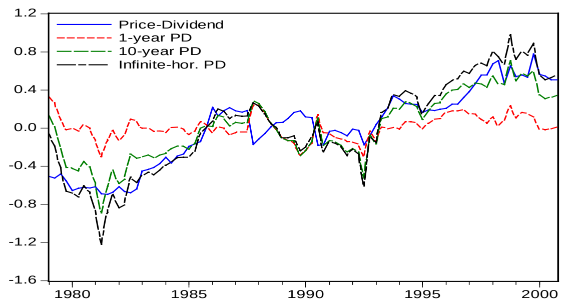


Figure 8 Variance-covariance risk, Euro Area (in-sample)



Returning to the Figures 1-8, there are several additional interesting points to note. First, across all models, the 1-year price dividend rate forecast is virtually flat, implying that short run expectations are very constant. Second, the longer the investment horizon, the more volatile and trending the price dividend forecast becomes. Third, in the period from mid 1980s-early 1990s, all model estimates across all maturities closely tracked the actual price dividend ratio. Fourth, a 10-year maturity forecast is still not close to the infinite horizon forecast of the price dividend ratio, given the differences between the two series. For the U.S., the constant risk and CCAPM risk model seem to display a close relation between the actual ratio and the infinite horizon forecast (yet merely apparent since the scale is larger in Figures 1 and 2 than in Figure 4) and with a 10-year maturity exceeding the infinite horizon forecast in the latter part of the sample. Figures 3 and 4 seem to indicate that after 1994, a large volatility risk is priced into market expectations of the price dividend ratio (cf. the wide divergence and different direction of the forecast-based series vis-à-vis the actual price dividend ratio –especially so for the 10-year forecast). For the Euro Area, the 10-year is closer to the infinite horizon forecast than for the U.S., and the actual price dividend ratio seems to move inside a corridor marked by the 10-year and infinite horizon forecasts. Another difference lies with the CCAPM risk model (Figure 6), which seems to be more cyclical in its long term expectations than the other models or its U.S. counterpart (Figure 3).

When comparing the above findings with earlier literature, one should bear in mind that the current study applies to the period 1979-2000, while most other research has been concerned with larger annual data sets and abstract from the most recent years. Nevertheless, there are some interesting common threads and differences. For example, the finding by Cuthbertson et al. (1997) for the U.K., and Black and Fraser (1999) of short-termism for the UK and U.S. seems to be reflected by the presence of bubbles in our estimates for the U.S. through volatility risk models. In contrast with Campbell and Shiller (1988), several models do seem helpful to explain stock price movements. And opposite to Black and Fraser (2000), the variance-covariance risk model for the U.S. seems to indicate that the price dividend ratio is too high and that the recent overvaluation is in fact well-founded (in their research, Black and Fraser did not include the years after 1997 though). Moreover, results for intermediate investment horizons, between one year and infinity, have been examined here in some detail and gave additional useful insights.

3.3 Out of Sample Evidence

In this section, the baseline VAR estimates for the period 1979/1-2000/4 are maintained and combined with the most recent information over 2001/1-2002/3 on dividend growth, market volatility, inflation, etc., to yield out of sample forecasts of the price-dividend ratio under the given equilibrium return models. Summary evidence on out of sample performance is given in Table 5 and Figures 9-16.

Table 5 : Out-of-sample statistics (2001-2002) for model-based price-dividend ratios

	U.S.						**Euro Area**					
Horizon	**1**	**2**	**3**	**5**	**10**	**∞**	**1**	**2**	**3**	**5**	**10**	**∞**
Constant Risk												
ME	0.6312	0.4943	0.3621	0.1075	-0.4865	0.0627	0.2907	0.1247	-0.0190	-0.2548	-0.6350	-1.0539
MAE	0.6312	0.4943	0.3621	0.1382	0.4865	0.0716	0.4639	0.2998	0.1467	0.2677	0.7759	1.3359
RMSE	0.6368	0.4986	0.3691	0.1619	0.5605	0.0855	0.5423	0.3578	0.1903	0.2979	0.8693	1.5252
Granger	0.9913	0.9913	0.9811	0.8537	0.8680	0.8378	0.8554	0.8378	0.7709	0.8984	0.8926	0.8758
CCAPM Risk												
ME	0.3531	0.0126	-0.3034	-0.8984	-2.2596	0.0174	0.1952	-0.0439	-0.2505	-0.5684	-0.8197	-0.3966
MAE	0.3531	0.1788	0.3084	0.8984	2.2596	0.0485	0.3539	0.2671	0.3074	0.5684	0.8197	0.3966
RMSE	0.3742	0.1950	0.4017	0.9821	2.3707	0.0514	0.4034	0.3174	0.3824	0.6240	0.8451	0.4369
Granger	0.9438	0.9171	0.7678	0.9147	0.9531	0.9434	0.8772	0.8416	0.8037	0.9110	0.9700	0.9077
Volatility Risk												
ME	0.6878	0.5834	0.4994	0.3710	0.1299	-1.2632	0.3427	0.2627	0.2022	0.1066	-0.0509	-0.2460
MAE	0.6878	0.5834	0.4994	0.3710	0.1778	1.2632	0.4817	0.4815	0.4275	0.3145	0.1688	0.2954
RMSE	0.7237	0.6249	0.5460	0.4288	0.2406	1.3364	0.5650	0.5576	0.4994	0.3733	0.2127	0.3320
Granger	0.9504	0.9336	0.9148	0.8652	0.7391	0.9453	0.8526	0.8635	0.8560	0.8424	0.7937	0.8897
Variance-Covariance Risk												
ME	0.6722	0.6456	0.6230	0.5906	0.5310	0.1084	0.3435	0.2692	0.2092	0.1115	-0.0550	-0.2833
MAE	0.6722	0.6456	0.6230	0.5906	0.5310	0.2285	0.6078	0.5835	0.5289	0.4504	0.3043	0.3008
RMSE	0.6941	0.6830	0.6708	0.6485	0.5968	0.2985	0.7154	0.6940	0.6362	0.5176	0.3500	0.3764
Granger	0.9685	0.9452	0.9288	0.9107	0.8898	0.7655	0.8496	0.8407	0.8314	0.8702	0.8693	0.7991

Notes

This Table reports out of sample statistics (2001/1-2002/3) for models of the price dividend ratio, over various horizons, computed using VAR estimates over 1979/1-2000/4. ME: mean error, MAE: mean absolute error, RMSE: root mean square error, Granger: MAE/RMSE. Lower numbers denote a more accurate fit

The numbers in Table 5 indicate that for the U.S., across all models, the out of sample performance improves along with the investment horizon. The best fit appears to be for the CCAPM risk model at 1 to 3 years and infinite maturity, and at intermediate horizons, the constant risk and volatility risk models do better. The variance-covariance risk model does not outperform any of the other models, nor does it perform any worse. For the Euro Area, the models seem to perform best at intermediate horizons, i.e., the 3 to 5 years horizons. At a 3-year horizon, the constant risk model performs best. At shorter maturities, both the constant risk and CCAPM risk models do well, while at long term horizons, the volatility and variance-covariance risk models do best. Overall, Table 5's results suggest that there was an important macro (downside) risk, as captured by the CCAPM risk model, that helped to track the price dividend ratio best over the quarterly period 2001-2002, out of sample. For longer investment horizons, the volatility risk model seems to have had a better track record.

Similar conclusions follow from an inspection of Figures 9-16. The 1-year prospective price dividend ratio remains very flat across all models, both for the U.S. and Euro Area. In fact, the actual price dividend ratio in the U.S. declined from its high end-2000 level until 2001/4, then stagnated before it again started to rise in 2002/3. This behaviour was closest mimicked by the infinite maturity CCAPM and constant risk models and by the 10-year horizon volatility risk model. The variance-covariance risk model ratios increased to become more aligned with the actual price dividend ratio toward the end of 2002. For the Euro Area, the price dividend ratio was characterised by two large swings, starting with a decline until 2001/3, then a sharp recovery for one quarter, before falling again for two quarters and again recovering in 2002/3. This cyclical pattern seems ultimately best tracked by the volatility and variance-covariance risk models, given the narrower scaling in Figures 15-16 compared to Figures 13-14.

Figure 9 Constant risk, U.S. (out-sample)

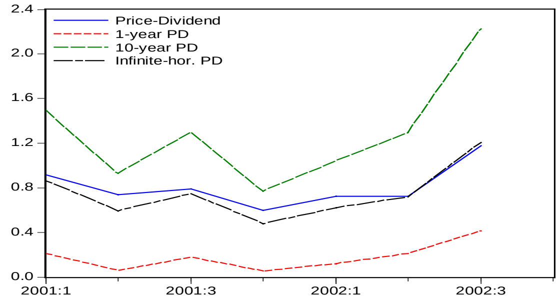


Figure 10 CCAPM risk, U.S. (out-sample)

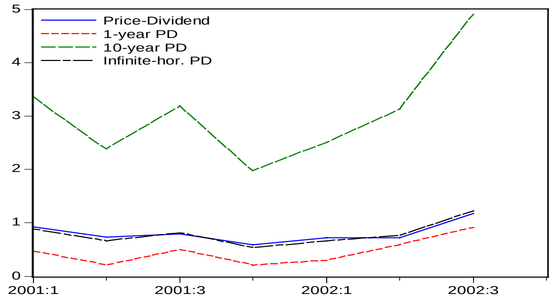


Figure 11 Volatility risk, U.S. (out-sample)

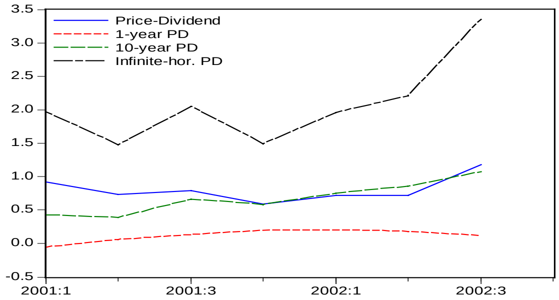


Figure 12 Variance-Covar. risk, U.S. (out-sample)

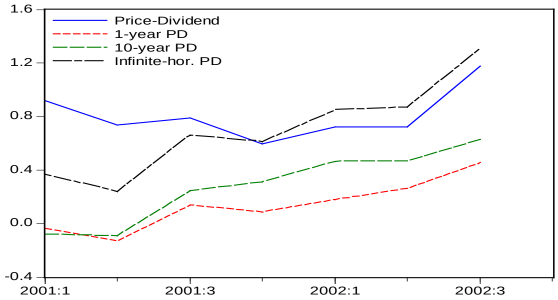


Figure 13 Constant risk, Euro Area (out-sample)

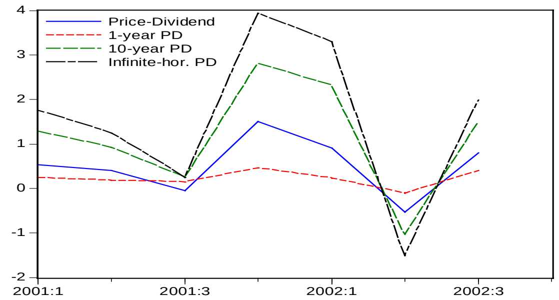


Figure 14 CCAPM risk, Euro Area (out-sample)

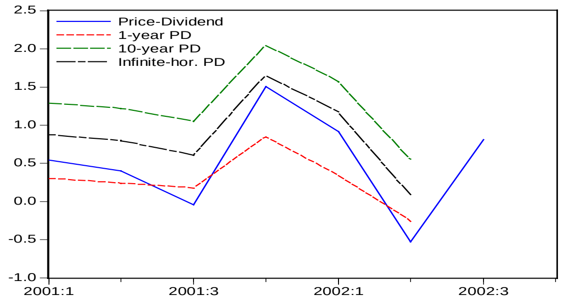


Figure 15 Volatility risk, Euro Area (out-sample)

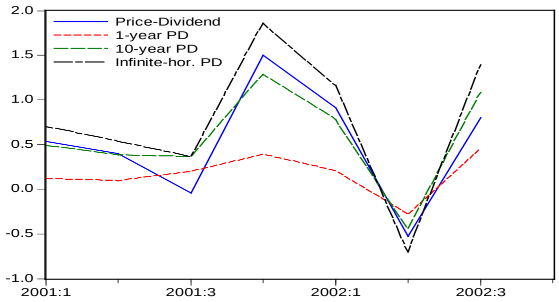
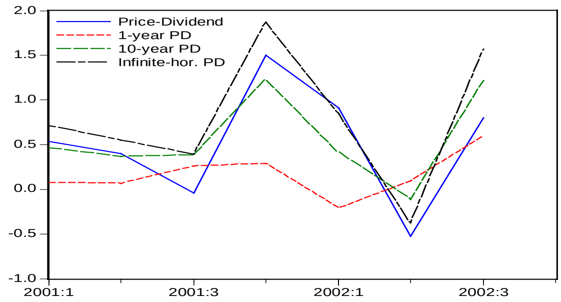


Figure 16 Variance-Covar. risk, Euro Area (out-sample)



3.4 Price Dividend Bubbles? A Tentative Decomposition.

This section lays out an analytical framework and graphical evidence on a decomposition of the price dividend ratio into a fundamental and bubble component. The idea is that the price dividend ratio consists of a fundamental component and a bubble component, which can be derived from an accounting decomposition (ignoring time subscripts):

$$PD = PD^* + B \tag{3.1}$$

where PD is the actual price dividend ratio, PD^* the fundamental component and B the bubble component, for a given pricing model. Recalling from section 2 the infinite and limited-investment horizon representation of the price dividend ratio, equations (2.3) and (2.4), it is straightforward to identify the fundamental component as the difference between the infinite and finite investment horizon representation, the rationale being to filter out short-run erratic movements:

$$PD^* = PD^\infty - PD^K \tag{3.2}$$

where PD^∞ is the infinite-life price dividend and PD^K is the finite, K-period price dividend ratio. Consequently, the bubble part is identified as the remainder:

$$B = PD - PD^* = PD - (PD^\infty - PD^K) \tag{3.3}$$

This decomposition is illustrated using the variance-covariance risk model. Evidence for the other models is similar and therefore is not reported.[5] Figures 17-18 and 19-20 show the fundamental and the bubble components, respectively, for the U.S. and Euro Area. The figures report both on the in-sample and out of sample period, as reported in sections 3.2 and 3.3. As for K, both a short 1-year and long 10-year horizon are tried to check the sensitivity of the decomposition to the choice of the maturity (specifications for other horizons (not reported) are situated in between these two). From Figure 17, it can be seen that in the U.S. the 1-year and 10-year fundamental behaved very similar, except perhaps for the fact that the 1-year fundamental is more volatile –as could reasonably be expected. Figure 18 shows clearly that a bubble developed in the U.S. stock market, for both 1-year and 10-year bubble proxies, starting in 1994 and ending in 2001. However, the latest figure seems to suggest a return to extreme overvaluation. For the Euro Area, the results are more sensitive to the choice of the investment horizon. The 1-year fundamental moves very close to the actual price dividend and hence, from Figure 20, there is no noticeable sign of a bubble (or overvaluation). The 10-year specification, however, shows signs of some overvaluation during the 1990s, as it shows signs of undervaluation in the early part of the sample period (until 1985). Out of sample, it shows a very erratic pattern. Hence, it would be too rash to conclude that a bubble developed in the Euro Area the same way as it did in the U.S. Probably the reason why the 10-year component looks like a bubble is

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[5] More detailed results are available on request from the author.

that the 10-year fundamental component is very flat, hence allowing for bigger excessive movements in the bubble part.

Figure 17 Fundamentals, U.S.

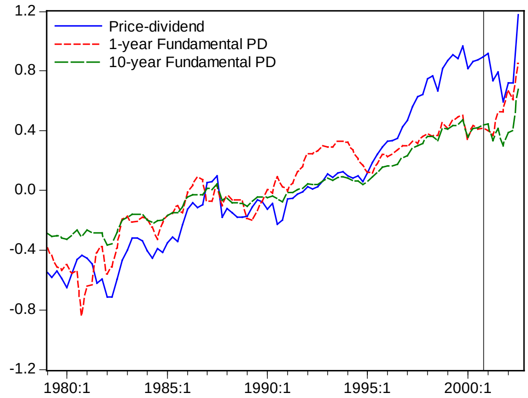


Figure 18 Bubbles, US

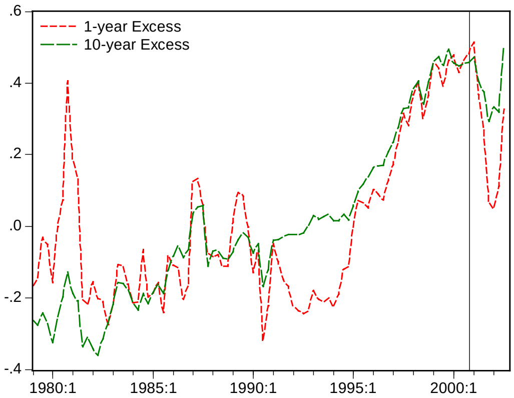


Figure 19 Fundamentals, Euro Area

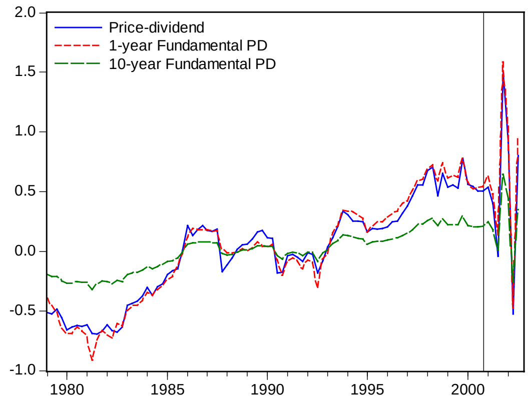
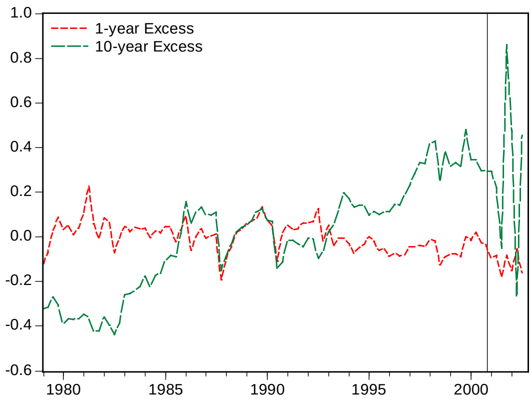


Figure 20 Bubbles, Euro Area



To summarize, a careful inspection of the above tables and figures has shown that for the Euro Area the proposed – and more sophisticated – variance-covariance model is not rejected by the data, while for the U.S., more care must be taken since this model is either out of line with the actual price dividend path or suggests the presence of a serious bubble. The latter view seems to be supported by the price decomposition as discussed above and by a recent study of Shiller (2000) who also attributed the rise in U.S. stock prices to a bubble driven by psychological factors.

4 DOES MONETARY POLICY REACT TO THE PRICE DIVIDEND RATIO?

The correct valuation of the stock market and the identification of bubbles may have serious implications for investors but may also concern monetary authorities for reasons of financial stability and prudential supervision of major market participants. As such, it may be interesting for market participants to know whether monetary policy reacts systematically to asset prices and price dividend metrics in particular. In this respect, Hayford and Malliaris (2001) find that the Fed has contributed to the stock market overvaluation and subsequent decline, for the period 1987-2000, using a price earnings ratio to extend the Taylor rule:

$$i_t = \pi_t + r^* + \alpha_1\left(\pi_t - \pi^*\right) + \alpha_2 y_t + \alpha_3\left(PE_t - PE^*\right) \tag{4.1}$$

where i denotes the policy-controlled interest rate (Fed funds rate), π is the inflation rate, y is the output gap, PE is the price earnings ratio on the S&P 500 index, r^* is the real interest rate and π^* and PE^* are the target level of inflation and fundamental price earnings ratio, respectively; α_i (i =1, 2, 3) are coefficients, with α_1>0 in order to have stable policy (i.e., the central bank must react to increases in inflation by increasing the real interest rate). For PE, α_3>0 implies that the central bank aims at reducing an estimated bubble while α_3<0 implies monetary policy is accommodating a stock market overvaluation. Hayford and Malliaris estimated equation (4.1) as

$$i_t = a_0 + a_1\pi_t + a_2 y_t + a_3 PE_t \tag{4.2}$$

where a_i (i = 0,…,3) are coefficient estimates; $a_0 = r^* - \alpha_1\pi^* - \alpha_3 PE^*$, $a_1 = 1+\alpha_1$, $a_2 = \alpha_2$ and $a_3 = \alpha_3$. Acknowledging serial correlation in these results, they also estimated a dynamic version of the model based on a partial adjustment mechanism, $\Delta i_t = \gamma_1\left(i_t^* - i_{t-1}\right) + \gamma_2\Delta i_{t-1}$, which was given by

$$\Delta i_t = g_0 + g_1\Delta i_{t-1} + g_2\left(g_3\pi_t + g_4 y_t + g_5 PE_t - i_{t-1}\right) \tag{4.3}$$

with g_i (i = 0,…,5) denoting coefficient estimates, $g_0 = \gamma_1(r^* - \alpha_1\pi^* - \alpha_3 PE^*)$, $g_1 = \gamma_2$, $g_2 = \gamma_1$, $g_3 = 1+\alpha_1$, $g_3 > 1$ if monetary policy is stable, $g_4 = \alpha_2$, $g_5 = \alpha_3$. The coefficient for g_5 was estimated to be significantly negative, supporting the view that the Fed has accommodated the overvaluation in the 1990s.

In the present context, it is interesting to investigate whether the results hold when using a price dividend instead of price earnings measure, and whether a time varying value for the fundamental price dividend ratio as computed in section 3, over various horizons, has any relevance for the results.

To this end, the upper part of Table 6 reports the estimates of equation (4.3) without price dividend information, and the lower part gives summary results of including a variable $PD\text{-}PD^*$, in fact corresponding to a measure of *B* (bubble) as derived in section 3.4, equation (3.3), for various finite investment horizons. The lower part of Table 6 gives a description of whether monetary policy is stable under the specified dividend price model (yes/no: yes if $g_3>1$), the coefficient and *t*-statistic (Newey-West corrected for heteroskedasticity and serial correlation, HAC) for *B*, and the adjusted R^2 of the extended model. The estimates for the Euro Area are given for illustrative purposes only, since one cannot expect a Taylor rule to hold over the given period as there was no single monetary policy in place. Rather, it expresses the dynamic behaviour of the synthetic fundamentals over the given reference period.

Inspecting the upper panel of Table 6, one can see that the basic reaction function yields a stable monetary policy as mentioned above, with an inflation response coefficient larger than one and with a significant response to the output gap as well in the U.S. (but not for the Euro Area). The lagged interest rate change is not significant, suggesting the absence of interest rate smoothing over the given period. Extending the function with price dividend (bubble) information causes monetary policy to be unstable[6] – at least when policy responds systematically to asset price bubbles, especially in the U.S. and less so for the Euro Area.[7] This could be interpreted in line with Miller et al. (2002) who show that one-sided intervention policy on the part of the Federal Reserve may lead investors into the *erroneous* belief that they are insured against downside risk. However, in case that U.S. monetary policy remained stable, there is no significant reaction to asset price bubbles. So the message is more subtle than in Hayford and Malliaris (2001), who found that the Fed *has been* accommodating towards asset price bubbles. As such, their evidence could be interpreted in line with experimental results by Filardo (2001) who found that monetary authorities should respond to changes in asset prices (to reduce output and inflation variability) only if they play a role in determining output and inflation. For the Euro Area, statistics do not attribute an important role to asset price bubbles in interest rate setting, although, as mentioned, this evidence cannot be given a structural interpretation since there was no single monetary policy in place over the period considered.

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6 In the U.S., three out of four models imply that the Fed took an accommodating stance towards asset price bubbles, given the negative and significant coefficients. The volatility risk model suggests the opposite. For the Euro Area, for most specifications of bubbles, monetary policy seems to have been relatively unresponsive to asset price bubbles.

7 In one but all cases for the constant risk model, for the CCAPM risk model starting at the 5-year horizon and at the extremes for the volatility and variance-covariance risk model, Euro Area policy responded significantly to asset bubbles (8 out of the 20 cases depicted). In all instances, monetary policy would become unstable.

Table 6 Has monetary policy reacted to stock market fads?

	U.S.					Euro Area				
Base reaction function	$\Delta i_t = 0.004 + 0.11\Delta i_{t-1} + 0.17\,(1.59\pi_t + 0.90 y_t - i_{t-1})$ (1.28) (0.86) (2.20)[b] (3.30)[a] (3.45)[a] $R^2 = 0.206$ Ljung-Box Q(3)=0.274					$\Delta i_t = 0.0014 + 0.08\Delta i_{t-1} + 0.06(1.21\pi_t + 2.39 y_t - i_{t-1})$ (0.91) (0.62) (1.70)[c] (2.56)[b] (1.26) $R^2 = 0.144$ Ljung-Box Q(3)=0.958				
Horizon	**1**	**2**	**3**	**5**	**10**	**1**	**2**	**3**	**5**	**10**
Constant risk										
Policy Stable?	*N*	*N*	*N*	*N*	*N*	*N*	*N*	*N*	*N*	*Y*
B-coefficient	-0.118	-0.093	-0.071	-0.048	-0.027	0.055	0.069	0.090	0.175	0.145
(*t*-statistic)	(-3.70)[a]	(-4.76)[a]	(-4.97)[a]	(-5.04)[a]	(-4.99)[a]	(2.85)[a]	(2.73)[a]	(2.70)[a]	(2.53)[b]	(0.37)
Adj. R^2	0.266	0.319	0.331	0.330	0.320	0.198	0.197	0.200	0.208	0.133
CCAPM risk										
Policy Stable?	*N*	*N*	*N*	*N*	*N*	*Y*	*Y*	*Y*	*N*	*N*
B-coefficient	-0.147	-0.094	-0.067	-0.042	-0.022	0.132	0.043	-0.004	-0.030	-0.037
(*t*-statistic)	(-6.82)[a]	(-6.91)[a]	(-6.42)[a]	(-5.79)[a]	(-5.16)[a]	(0.39)	(0.27)	(-0.07)	(-2.67)[a]	(-2.94)[a]
Adj. R^2	0.319	0.349	0.340	0.321	0.302	0.151	0.134	0.130	0.164	0.178
Volatility risk										
Policy Stable?	*N*	*N*	*N*	*N*	*N*	*N*	*Y*	*Y*	*Y*	*N*
B-coefficient	0.042	0.044	0.046	0.052	0.076	0.609	7.10	89.8	30.35	-0.054
(*t*-statistic)	(7.48)[a]	(6.71)[a]	(6.30)[a]	(5.96)[a]	(5.97)[a]	(2.57)[a]	(0.22)	(0.01)	(0.01)	(-0.73)
Adj. R^2	0.408	0.372	0.354	0.341	0.350	0.413	0.302	0.195	0.127	0.134
VAR-COV risk										
Policy Stable?	*Y*	*Y*	*N*	*N*	*N*	*N*	*Y*	*Y*	*Y*	*N*
B-coefficient	-0.041	-0.053	-0.061	-0.066	-0.062	0.530	1.768	7.368	0.328	-0.054
(*t*-statistic)	(-1.59)	(-2.10)[b]	(-2.55)[b]	(-3.06)[a]	(-3.42)[a]	(4.32)[a]	(1.12)	(0.15)	(0.45)	(-0.65)
Adj. R^2	0.216	0.225	0.233	0.243	0.250	0.482	0.341	0.218	0.138	0.134

Notes

The Table reports on a (dynamic) interest rate reaction function, estimated by nonlinear least squares over the period 1984/1-2000/4, with quarterly data. The upper panel displays the function without price dividend information and presents coefficients, *t*-statistics (in parentheses), adjusted R^2, and Ljung-Box Q-statistic (for serial correlation).

The lower panel displays summary statistics for the reaction function including price dividend (bubble) information $B = PD\text{-}PD^*$, as in section 3.4, using the four models from section 3 for PD^*, the fundamental price dividend with finite investment horizons from 1 to 10 years. Statistics include a description whether monetary policy is stable (*Y*/*N*: yes/no) –depending on whether the inflation coefficient g_3 is larger than one or not; the coefficient and HAC *t*-statistic for the added *B*-term, and an adjusted R^2 for the complete model.

Statistically significant at [a]: 1%, [b]: 5%, [c]: 10%.

6 CONCLUSIONS

This paper has examined various price dividend models. It was argued that the lack of a direct role for inflation risk in existing model could be a shortcoming. Accordingly, a combination of an inflation-CAPM and the price dividend model was proposed as an extension of the existing literature. The data shows that for the U.S., this model behaves differently from earlier models since the resulting price dividend ratio does not exhibit an upward trend in the 1990s shared by the other models. For the Euro Area, the estimates are closer in line with earlier models. A framework was proposed to assess the overvaluation of the stock market and uncovered visibly the existence of a bubble in the U.S. stock market, but less so for the Euro Area. Finally, interest rate reaction functions have been augmented by price dividend information, in order to see whether monetary policy has reacted to asset price bubbles. The evidence suggests the Fed may or may not have reacted to asset bubbles (in an accommodating way), depending on the view whether U.S. monetary policy remained stable or not. Euro Area monetary policy, in historical terms, was largely unresponsive to asset bubbles.

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APPENDIX: VAR METHODOLOGY

This section discusses the use of VAR and the computation of the price dividend factor models. From equation (2.3), (2.4) and (2.5), the price dividend ratio ζ_t can be written, for an infinite horizon, as

$$\zeta_t = k/(1-\rho) + \sum_{j=0}^{\infty} \rho^j E_t\big(\Delta d_{t+1+j} - (r_{t+1+j} + \alpha\,\phi\, V_{t+1+j} + (1-\alpha)C_{\pi,t+1+j})\big) \qquad \text{(a.1)}$$

and, for a finite horizon i,

$$\zeta_t = k(1-\rho^i)/(1-\rho) + \sum_{j=0}^{i-1} \rho^j E_t\big(\Delta d_{t+1+j} - (r_{t+1+j} + \alpha\,\phi\, V_{t+1+j} + (1-\alpha)C_{\pi,t+1+j})\big) - \rho^i E_t\,\delta_{t+1+i} \qquad \text{(a.2)}$$

If a VAR is estimated, consisting of a vector $X_t = [\zeta_t\,,\; r_t\,,\; V_t,\; C_t,\; \Delta d_t]$, writing the estimated system under a companion matrix form, appropriately stacking higher order lags into the companion matrix A, with u denoting the residuals, yields

$$X_{t+1} = AX_t + u_t \qquad \text{(a.3)}$$

Define e_j as a column vector whose j-th element is one and whose other elements are zero. This vector can be used to pick out the j-th element of vector X_t; for example, $e_1' X_t = \zeta_t$ and $e_5' X_t = \Delta d_t$.
The estimated VAR can be used to derive the expected value at horizon k of any of the elements in (a.1) or (a.2). For the system as a whole, the optimal forecast at time t of X_{t+k} : $E_t\, X_{t+k} = A^k X_t$, with k=1, 2, 3, … . Hence, the discounted multiperiod forecast of the vector X, for an infinite horizon, becomes

$$E_t \sum_{j=0}^{\infty} \rho^j X_{t+1+j} = A\,\big(\mathrm{I} + \rho A + \rho^2 A^2 + \rho^3 A^3 + \dots\big) X_t = A\big(\mathrm{I} - \rho A\big)^{-1} X_t \qquad \text{(a.4)}$$

and, in case of a finite horizon i,

$$E_t \sum_{j=0}^{i-1} \rho^j X_{t+1+j} = A\,\big(\mathrm{I} + \rho A + \rho^2 A^2 + \rho^3 A^3 + \dots + \rho^{i-1} A^{i-1}\big) X_t = A\big(\mathrm{I} - \rho^i A^i\big)\big(\mathrm{I} - \rho A\big)^{-1} X_t \qquad \text{(a.4)}$$

As such, the VAR provides a useful tool to compute expectations at time t of future expected values of the components of the structural price dividend model. Previous research has proven that the VAR methodology gives the most adequate estimates of future expected values (see Hodrick, 1992, for a monte carlo study on the performance of various expectations operators for dividend price models).

Tables A.1 and A.2 present GMM estimates for the variance-covariance model and the CCAPM model. Variables have been demeaned before being estimated, as a way to get rid of the constant term in (a.1) and (a.2). The set of variables in minimal, but as argued by Cuthbertson et al. (1997), price dividend ratios contain all necessary information about future expected dividends and discount rates; hence, extending the information set would never improve test results.

Table A.1 VAR(2) estimates for variance-covariance model

	PD	***r***	***V***	C_π	Δd	**PD**	***r***	***V***	C_π	Δd
	U.S.					**Euro Area**				
PD(-1)	1.15	-5.28	0.061	-13.18	-3.40	0.830	-1.856	-1.576	2.302	13.24
	(8.54)[a]	(-1.96)[b]	(0.03)	(-0.69)	(-0.66)	(5.28)[a]	(-1.47)	(-0.44)	(0.14)	(2.59)[b]
PD(-2)	-0.177	5.27	0.119	7.16	1.530	0.079	0.928	2.99	-20.50	-15.96
	(-1.29)	(1.92)[c]	(0.06)	(0.37)	(0.29)	(0.48)	(0.70)	(0.80)	(-1.17)	(-2.95)[a]
r(-1)	-0.005	0.518	0.039	-0.275	0.134	-0.026	1.146	-0.110	-3.242	0.560
	(-1.11)	(5.56)[a]	(0.55)	(-0.41)	(0.76)	(-2.04)[b]	(11.20)[a]	(-0.38)	(-2.41)[b]	(1.35)
r(-2)	0.002	0.362	0.010	-0.237	-0.193	0.016	-0.294	0.198	1.934	-1.048
	(0.41)	(3.80)[a]	(0.14)	(-0.35)	(-1.07)	(1.26)	(-2.91)[a]	(0.70)	(1.46)	(-2.56)[b]
V(-1)	0.013	-0.163	0.004	0.624	0.052	0.004	-0.034	-0.044	0.313	0.269
	(1.83)	(-1.13)	(0.03)	(0.61)	(0.19)	(0.95)	(-0.91)	(-0.41)	(0.63)	(1.76)
V(-2)	0.001	0.199	-0.046	1.266	0.368	-0.001	-0.026	0.001	0.120	0.166
	(0.11)	(1.37)	(-0.42)	(1.23)	(1.34)	(-0.29)	(-0.68)	(0.01)	(0.24)	(1.07)
C_π(-1)	-0.001	0.070	0.003	-0.024	0.019	0.001	0.018	0.029	-0.105	-0.060
	(-1.43)	(3.58)[a]	(0.21)	(-0.17)	(0.52)	(0.51)	(1.51)	(0.84)	(-0.66)	(-1.22)
C_π(-2)	0.000	0.082	-0.010	0.027	0.016	-0.001	0.001	-0.017	-0.068	0.034
	(-0.14)	(5.18)[a]	(-0.87)	(0.24)	(0.54)	(-0.89)	(0.15)	(-0.82)	(-0.68)	(1.11)
Δd(-1)	-0.001	0.025	-0.059	0.060	-0.196	-0.001	-0.008	-0.052	0.212	0.162
	(-0.39)	(0.41)	(-1.31)	(0.14)	(-1.71)[c]	(-0.27)	(-0.30)	(-0.67)	(0.58)	(1.45)
Δd(-2)	-0.001	-0.045	-0.043	-0.041	-0.158	-0.003	0.003	0.097	-0.044	-0.129
	(-0.22)	(-0.74)	(-0.96)	(-0.10)	(-1.38)	(-1.06)	(0.14)	(1.42)	(-0.14)	(-1.29)
Adj. R^2	0.978	0.844	-0.052	-0.044	0.011	0.948	0.948	-0.043	0.089	0.162
LB(3)	0.390	7.074[c]	3.804	0.289	0.060	0.218	0.318	1.121	0.155	0.867

Notes

Table A.1 displays VAR coefficients and t-statistics for the full variance-covariance model, estimated with 2 lags. PD denotes price dividend, r 10-year government bond rate, V market volatility (squared log returns), C_π covariance between (per-period product of) inflation and nominal return, Δd log dividend growth.

Adj. R^2 is the R^2 adjusted for degrees of freedom, LB(3) is the Ljung-Box (serial correlation test) statistic with 3 lags. Period of estimation is 1979/1 – 2000/4. Statistically significant at [a]: 1%, [b]: 5%, [c]: 10%.

Table A.2 VAR(2) estimates for CCAPM model

	PD	***r***	***C***	**Δ*d***	**PD**	***r***	***C***	**Δ*d***
	U.S.				**Euro Area**			
PD(-1)	1.042	0.450	1.603	-0.971	0.825	-0.478	-0.312	9.53
	(9.60)[a]	(0.19)	(1.67)[c]	(-0.24)	(7.67)[a]	(-0.57)	(-0.56)	(2.66)[a]
PD(-2)	-0.059	-0.511	-1.863	-0.700	-0.029	-0.052	-0.384	-10.78
	(-0.53)	(-0.21)	(-1.92)[c]	(-0.17)	(-0.28)	(-0.06)	(-0.71)	(-3.10)[a]
r(-1)	-0.003	0.455	-0.043	0.004	-0.019	1.015	0.149	0.126
	(-0.63)	(4.03)[a]	(-0.93)	(0.02)	(-1.43)	(9.63)[a]	(2.11)[b]	(0.28)
r(-2)	0.002	0.339	0.037	-0.107	0.004	-0.186	-0.148	-0.842
	(0.48)	(3.24)[a]	(0.88)	(-0.60)	(0.29)	(-1.74)[c]	(-2.06)[b]	(-1.84)[c]
C(-1)	-0.012	1.113	0.184	0.866	0.010	0.083	0.215	1.326
	(-0.94)	(4.04)[a]	(1.64)	(1.85)[c]	(0.48)	(0.52)	(2.01)[b]	(1.94)[c]
C(-2)	-0.010	-0.010	0.255	-0.080	-0.061	0.536	0.170	0.458
	(-0.77)	(-0.04)	(2.25)[b]	(-0.17)	(-3.01)[a]	(3.40)[a]	(1.60)	(0.68)
Δ*d*(-1)	-0.001	0.115	0.030	-0.142	0.000	-0.003	0.016	0.038
	(-0.48)	(1.81)[c]	(1.17)	(-1.31)	(0.10)	(-0.12)	(0.98)	(0.37)
Δ*d*(-2)	-0.002	0.070	0.028	-0.124	-0.004	0.004	0.006	-0.207
	(-0.58)	(1.11)	(1.09)	(-1.17)	(-1.15)	(0.16)	(0.39)	(-2.03)[b]
Adj.R^2	0.977	0.812	0.17	0.047	0.947	0.956	0.499	0.194
LB(3)	0.498	15.33[a]	2.754	0.287	0.540	1.691	2.626	1.364

Notes
Table A.2 gives coefficients and *t*-statistics for the VAR(2) with consumption growth, *C*; see Table A.1 for additional explanatory notes.