THE PRICE-DIVIDEND RELATIONSHIP IN INFLATIONARY AND DEFLATIONARY REGIMES[1]

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Abstract. This paper argues that the linear price-dividend relationship as predicted in the Gordon model breaks down in regimes of high inflation and deflation. Using data for the US and the UK over the period from 1871 to 2002, nonlinear estimates support the prediction of the model.

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1. Introduction

This paper argues that the linear stock price/dividend relationship as implied by the Gordon growth model breaks down in deflationary and high inflationary regimes. In periods of deflation managers are reluctant to lower nominal dividends by the rate of deflation even if they consider the real earnings capacity of the firm to be unaltered because it may lead to an adverse reaction by the stock market. In periods of high inflation, by contrast, shareholders and managers are unlikely to hold the same expectations about inflation due to the signal extraction problem that has been stressed by Lucas (1973), thus blurring the price-dividend relationship. Hence, since it becomes more difficult to predict inflation at high rates of inflation, inflationary expectations of shareholders and managers are likely to diverge to such an extent that Gordon's model breaks down.

As a consequence the price-dividend relationship will differ in the regimes of deflation, moderate inflation, and high inflation. Using data over the period from 1871 to 2002 for the US and the UK, this paper shows that the price-dividend relationship differs substantially in the three regimes. The estimation results, which are based on nonlinear estimation techniques, show that the

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positive relationship between nominal stock prices and dividends disappears entirely in high inflation and deflationary regimes, but remains much stronger than predicted by the Gordon model, in periods of moderate inflation.[3]

2. The price-dividend relationship and inflationary regimes

The Gordon growth model, which predicts a linear price-dividend relationship, is likely to break down in deflationary and high inflation regimes. In periods of deflation firms need to increase the real value of dividends to keep the nominal value of dividends unaltered, even if the real earnings capacity of firms remains unaltered, to prevent adverse reactions in the stock markets. Empirical studies find severe adverse share market reactions to nominal dividend reductions (see for example DeAngelo *et al*, 1992, Michaely *et al*, 1995). Hence, to prevent a negative share market reaction firms seek to keep nominal dividends unaltered and the resulting increase in the real value of dividends is likely to overstate the change in the permanent earnings of the company. Rational investors will, of course, be aware of this problem, but the management wants to avoid a negative reaction in the share market from uninformed investors. Thus changes in nominal dividends in the deflationary spells in the US and the UK over the periods from 1870 to 1900, from 1921 to 1922, and from 1927 to 1933, may have weakened the linear relationship between dividends and stock prices as predicted by the Gordon model.

In periods of high inflation a linear price-dividend relationship is also likely to break down because of information extraction problems. Friedman (1977) argues that there is a positive relationship between inflation and the dispersion of relative price changes, and several empirical studies have found evidence for Friedman's hypothesis (see Silver and Ioannidis, 2001, for references). For the price-dividend relationship, this implies that, in periods of high inflation, managers and shareholders are likely to hold different expectations about the prices of a company's products. The shareholder has information about the general price level but little information about the product prices that are relevant for the company's earnings potential. This leads to the famous information extraction problem suggested by Lucas (1973). Lucas (1973) argued that shareholders, among other agents outside the firm, are unaware of the price changes between the period of the actual price change and the publication of the annual report. A price increase is, therefore, likely to lead to a discrepancy between actual and expected profits, which may in turn result in a break-down in the linear dividend-price relationship.

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[3] Ackert and Hunter (1999, 2001) have theoretically and empirically also shown that the dividend-share price relationship is nonlinear because managers place upper and lower bounds on dividends.

3. Model specification

The discussion in the previous section suggests that the relationship between stock prices and dividends depends on the inflationary regime. However, in the long run the dividend-price ratio tends towards a constant provided that the retention ratio and the discount rate are constant. Based on a general equilibrium model, Madsen and Davis (2006) show that the price-dividend ratio converges to $[\rho(1-\kappa)]^{-1}$ in steady state, where κ is the retention ratio and ρ is the required stock returns. It follows that the log of stock price and the log of dividends are cointegrated.

To accommodate these features into the price-dividend relationship the following error-correction model is estimated:

$$\Delta p_t = \lambda_0 + \lambda_1 \Delta d_t + \lambda_2 (p_{t-1} - d_{t-1}) + v_t , \qquad (1)$$

where p is the log of nominal stock prices, d is the log of nominal dividends per share, v_t is a stochastic error-term and lowercase letters are logs of uppercase letters. The error correction terms are included in the models to allow for the possibility of a constant price-dividend ratio in the long run as predicted by the Madsen-Davis model.

Equation (1) is formulated in nominal as opposed to real terms because estimates in real terms gave unsatisfactory results both in statistical and economic terms. While the theory presented in the previous section does not sharply distinguish between real and nominal returns, returns are usually reported in nominal terms in annual reports. Even when inflation adjusted returns are calculated, it is nominal returns that are given prominence in most annual reports. Furthermore, several empirical studies show that real stock returns are adversely affected by inflation although real earnings per unit of capital are unaffected by inflation under complete indexation rules (see for instance Fama, 1981). This implies that inflation drives a wedge between real dividends and real stock returns for reasons that are unrelated to the arguments that are presented in the previous section.

In the nonlinear estimates the price-dividend relationship is subdivided into three inflationary regimes referred to as *M*1, *M*2, and *M*3. In regime *M*1 the rate of price change is below the boundary τ^L; in regime *M*2 the rate of change in prices is within the boundaries of τ^L and τ^U; and in regime *M*3 the rate of change in prices is above the boundary of τ^U. For convenience, below τ^L is referred to as deflationary, between τ^L and τ^U is referred to as moderately inflationary and above τ^U, as high inflationary regimes although the boundaries are endogenously determined.

The following nonlinear model is estimated:

$$\Delta p_t = \theta_{1t} M_{1t} + \theta_{2t} M_{2t} + (1 - \theta_{1t} - \theta_{2t}) M_{3t} + \varepsilon_t \qquad (2)$$

$$M_{1t} = \beta_{10} + \beta_{11} \Delta d_t + \beta_{12} (p_{t-1} - d_{t-1}) \qquad (3)$$

$$M_{2t} = \beta_{20} + \beta_{21} \Delta d_t + \beta_{22} (p_{t-1} - d_{t-1}) \qquad (4)$$

$$M_{3t} = \beta_{30} + \beta_{31} \Delta d_t + \beta_{32} (p_{t-1} - d_{t-1}) \qquad (5)$$

$$\theta_{1t} = 1 - [1 + \exp\{-\gamma_1 (\pi_t - \tau^L)\}]^{-1} \qquad (6)$$

$$\theta_{2t} = 1 - [1 + \exp\{-\gamma_2 (\pi_t - \tau^L)(\pi_t - \tau^U)\}]^{-1}, \qquad (7)$$

where π_t is the rate of change in prices approximated by the log first-differences in consumer prices, τ^U is the upper bound of inflation, τ^L is the lower bound of inflation/deflation, and ε_t is a disturbance term. In (2) the proportional change in share prices, Δp_t, is a weighted average of M_{1t}, M_{2t} and M_{3t}. M_{1t}, M_{2t} and M_{3t} are, in turn, linear functions of the dividend growth rate, Δd_t, augmented by the error correction terms. The θs are transition functions among regimes governed by inflation values within or outside the regime boundaries τ^L and τ^U.

Equation (6) determines θ_{1t} as the transition function that inflation π_t is below the lower regime boundary of τ^L, whereas Equation (7) determines θ_{2t} as the transition function that π_t is within the regime boundaries at τ^L and τ^U.[4] The term (1- θ_{1t} - θ_{2t}) denotes the transition function that π_t is higher than the upper regime boundary at τ^U. The smoothness parameters γ_1, $\gamma_2 > 0$ determine the smoothness of the three transition regimes. The model belongs to the class of multiple-regime Smooth Transition Auto-Regressive (MRSTAR) models in which inflation drives the transition amongst regimes.[5] The model collapses to a linear model if $\beta_{1i} = \beta_{2i} = \beta_{3i}$, for i=0,..,2. The model generalizes the quadratic logistic STAR model where only two regimes are allowed for (see e.g. van Dijk *et al*, 2002). Following Granger and Teräsvirta (1993), γ_1 and γ_2 are made dimension-free by dividing them by the standard deviation and the variance of π_t, respectively.

For comparison the following Gordon model, where cointegration between the log of stock prices and dividends are allowed for, is also estimated:

$$\Delta p_t = \alpha_0 + \alpha_1 \Delta d_t + \alpha_2 (p_{t-1} - d_{t-1}) + v_{1t}. \qquad (8)$$

4. Empirical estimates

[4] Equation (7) has the properties that 1) θ_{2t} becomes constant as $\gamma_2 \to 0$; and 2) as $\gamma_2 \to \infty$, $\theta_{2t}=0$ if $\pi_t < \tau^L$ or $\pi_t > \tau^U$ and $\theta_{2t}=1$ if $\tau^L < \pi_t < \tau^U$ (Jansen and Teräsvirta, 1996).

[5] See van Dijk *et al* (2002) for more details about multiple STAR models.

The results of estimating the models using annual data for the US and the UK over the period from 1871 to 2002 are shown in Table 1.[6] The ADF tests in the notes to Table 1 show that Δp_t, Δd_t and π_t are stationary at conventional significance levels, where Akaike's Information Criterion is used for selection of the lag length of the ADF tests. The estimations of the error-correcting augmented log-linear Gordon model (Equation (8)), are shown in columns (i) and (ii). The standard errors for the UK are based on White's heteroscedasticity consistent covariance matrix because the residuals exhibited heteroscedasticity. The estimated coefficient of dividends is significantly different from zero at the 5% significance level for the US but not for the UK. Conversely, the estimated coefficient of the error-correction term is significantly negative for the UK but not the US. Overall, the estimates suggest that there is some relationship between share prices and dividends, but that the relationship is weak.

Table 1. Estimates of linear and non-linear Δp_t models, 1871-2002.

	(i) US linear	(ii) UK linear	(iii) US 3-regime	(iv) UK 3-regime	(v) US 2-regime	(vi) UK 2-regime
			M_{1t} regime:	**M_{1t} regime:**	**M_{1t} = M_{3t} regime:**	**M_{1t} = M_{3t} regime:**
Constant	0.033 [0.039]	0.039 [0.002]	0.025 [0.631]	0.015 [0.505]	-0.027 [0.353]	-0.029 [0.418]
Δd_t	0.269 [0.022]	0.090 [0.252]	0.454 [0.064]	0.111 [0.651]	0.264 [0.147]	0.122 [0.341]
$(p_{t-1} - d_{t-1})$	-0.096 [0.077]	-0.250 [0.004]	-0.206 [0.115]	-0.059 [0.695]	-0.220 [0.003]	-0.451 [0.000]
			M_{2t} regime:	**M_{2t} regime:**	**M_{2t} regime:**	**M_{2t} regime:**
Constant			0.034 [0.044]	0.032 [0.035]	0.086 [0.000]	0.075 [0.000]
Δd_t			0.631 [0.000]	0.294 [0.014]	0.402 [0.001]	0.187 [0.087]
$(p_{t-1} - d_{t-1})$			-0.033 [0.649]	-0.087 [0.351]	-0.080 [0.251]	-0.104 [0.258]
			M_{3t} regime:	**M_{3t} regime:**		
Constant			0.014 [0.201]	0.020 [0.120]		
Δd_t			-0.416 [0.086]	-0.002 [0.979]		
$(p_{t-1} - d_{t-1})$			-0.164 [0.016]	-0.495 [0.000]		
τ^L			-0.133 [0.579]	-1.202 [0.304]	-0.101 [0.560]	-1.101 [0.271]
τ^U			3.196 [0.000]	6.356 [0.000]	3.251 [0.000]	6.401 [0.000]
γ_1 [a]			123.0 [0.551]	15.019 [0.579]	32.24 [0.273]	4.321 [0.074]
γ_2			35.34 [0.851]	4.416 [0.114]		

[6] Dividends and stock prices for the UK are from Grossman (2002) from 1871 to 1913 and from Barclays Capital (2001) from 1914 to 2000. The US stock market index and dividends are from Global Financial data over the period from 1871 to 1999. Consumer prices are from Mitchell (1975, 1983). All data are updated using data from DataStream and IMF, *International Financial Statistics*.

s_L	0.178	0.157				
s_{NL}			0.173	0.151	0.172	0.152
s^2_{NL}/ s^2_L			0.944	0.925	0.933	0.937
AIC	-0.587	-0.839	-0.601	-0.880	-0.634	-0.885
Durbin-Watson	1.970	1.900	1.941	1.911	1.970	1.887
AR(2)	2.985 [0.054]	0.517 [0.597]	3.436 [0.035]	0.507 [0.603]	5.487 [0.005]	0.914 [0.403]
HET	0.806 [0.523]	2.939 [0.023]	1.477 [0.110]	1.887 [0.090]	2.294 [0.030]	1.998 [0.070]
ARCH(1)	1.374 [0.243]	28.115 [0.000]	1.429 [0.234]	4.829 [0.030]	0.675 [0.412]	8.937 [0.003]
Ho: β_{1i}=β_{2i}=β_{3i} [b]			2.907 [0.016]	4.219 [0.001]	1.531 [0.220]	3.123 [0.047]
Ho: β_{11}=β_{21}=β_{31} [c]			5.672 [0.004]	1.422 [0.245]	0.375 [0.541]	0.105 [0.746]
Ho: β_{12}=β_{22}=β_{32} [d]			0.929 [0.397]	3.560 [0.031]	1.896 [0.171]	2.839 [0.094]

Notes: p-values are given in square brackets. For the UK, p-values are based on White's heteroscedasticity consistent standard errors. s_L (s_{NL}) is the standard error of the linear (non-linear) regression. AR(2): F-test for up to 2nd order serial correlation. ARCH(1): 1st order Autoregressive Conditional Heteroscedasticity F-test. HET: F-test for Heteroscedasticity. Numbers in square brackets are the p-values of the test statistics. AIC: Akaike Information Criterion. The tests on betas are F-tests.

[a] Only one smoothness parameter is estimated for the 2-regimes models.

[b] F-test of equal effects across regimes. This involves 3-regimes for columns (iii) and (iv). It involves 2-regimes for columns (v) and (vi).

[c] F-test of equal Δd_t effects across regimes. This involves 3-regimes for columns (iii) and (iv). It involves 2-regimes for columns (v) and (vi).

[d] F-test of equal ($p_{t-1} - d_{t-1}$) effects across regimes. This involves 3-regimes for columns (iii) and (iv). It involves 2-regimes for columns (v) and (vi).

ADF tests on US data: p_t: -1.706; d_t: 1.220; ($p_{t-1} - d_{t-1}$): -2.390; Δp_t: -9.355**; Δd_t: -6.906**; π_t: -3.117*.
ADF tests on UK data: p_t: 1.924; d_t: 1.559; ($p_{t-1} - d_{t-1}$): -5.708**; Δp_t: -8.261**; Δd_t: -5.674**; π_t: -4.790**.
** Indicates rejection of the unit root hypothesis at 1 percent. * Indicates rejection at 5 percent. Lag lengths for the ADF tests are chosen by the AIC.

The results of estimating the three-regime nonlinear models are presented in columns (iii) and (iv) of Table 1. These are preferred to the log-linear models based on the Akaike Information Criterion (AIC). The ratio of error variances, s^2_{NL}/s^2_L, is less than one, which gives further support to the suggestion that the nonlinear models are preferred to the log-linear models. Finally, F-tests for log-linearity in Table 1 reject the null hypothesis of log-linearity (the model collapses to a linear model if $\beta_{1i}= \beta_{2i} = \beta_{3i}$, for i =0,..,2). Note that γ_1 and γ_2 are imprecisely estimated. However, this should not be interpreted as evidence of weak nonlinearity as pointed out by Teräsvirta (1994) and van Dijk *et al* (2002). Accurate estimation of γ_1 and γ_2 is difficult because it requires many observations in the immediate neighbourhood of the thresholds. Furthermore, large changes in γ_1 and γ_2 have only small effects on the shape of the transition function, which implies that estimates of γ_1 and γ_2 need not be precise (van Dijk *et al*, 2002).

The estimated lower price change regime boundaries are –0.1% for the US and –1.2% for the UK. These estimates are both very close to zero, which suggests that a shift from inflation to deflation changes the price-dividend relationship, as predicted by the theory in Section 2. The upper price change regime boundary is estimated to be 3.2% for the US and 6.4% for the UK. These boundaries are again consistent with the hypothesis of this paper that information asymmetries are likely to increase above a certain inflation threshold. The upper bound is higher for the UK than the US, which may, to some extent, reflect that the average level of inflation for the UK is almost 1-percentage point higher than for the US. As suggested by Lucas (1973), agents are likely to be more susceptible to the consequences of inflationary shocks as the rate of inflation grows higher.

To get an impression of the estimated values of the transition functions and their dependence on inflation, Figure 1 plots the fitted θ_t-functions against the rate of inflation. The transition function θ_{1t} starts with the value of 1 below the lower boundary, τ^L, where the rate of inflation is negative for both the UK and the US. In the interval between τ^L and τ^U, θ_{1t} takes the value of 0 whereas θ_{2t} takes values close to 1. As inflation increases above the upper boundary τ^U, (1- θ_{1t} - θ_{2t}) rises to the value of 1. Note that the θ_t functions change values quite abruptly in the neighborhood of the estimated inflation boundaries because the estimates of the smoothness parameters (i.e. the γ's) are quite large.

The empirical estimates indicate a substantial dividend effect within the moderately inflationary bounds (M_2 regime) and that the estimated coefficients of dividends double on average in comparison with the simple log-linear models (Equation (8)). Furthermore, the estimated coefficient of dividends for the US is not significantly different from one at the 1-percentage level (F-test =6.313; p-value=0.013), as predicted by the Gordon model. That the estimated coefficients of dividends are below one is likely to reflect an errors-in-variables bias. The estimated coefficient of dividends is only one to the extent that dividends reflect the permanent earnings potential of the firm under the null hypothesis that the Gordon growth model is true.

The dividend effects are insignificant at the 5% level in the deflationary (M_1) and high inflationary (M_3) regimes for both countries. The positive dividend effect, as predicted by the Gordon model, disappears entirely in the high inflationary regime. In other words, dividends do not convey any information about permanent earnings, as perceived by shareholders, in high inflationary periods. There is, however, a strong error-correction effect in the high inflationary regime, which suggests that share prices will eventually converge to the long-run equilibrium as defined by the Gordon growth model, but that short-term changes in dividends do not give reliable signals to share holders about the earnings capacity of the firm. This is exactly what the signal extraction model of Lucas, as discussed in the previous section, predicts.

Although the estimates indicate that the error-correction augmented Gordon model performs relatively poorly compared to the three-regime model, the last two rows in Table 1 test the null hypothesis of equality of the coefficients of dividends in the three different regimes (H_o: $\beta_{11}=\beta_{21}=\beta_{31}$) and whether the estimated coefficients of the error-correction terms are equal (H_o: $\beta_{12}=\beta_{22}=\beta_{32}$). The null hypothesis of equality of coefficients of dividends is rejected at the 5% level for the US and the null hypothesis of equality of the coefficients of the error-correction terms is rejected for the UK at the 5% level. These results give further support for the hypothesis that the price-dividend relationship differs across inflationary regimes.

5. Robustness check

To check the robustness of the parameter estimates, this section estimates a two-regime model and the three-regime non-linear models separately over in the periods from 1871 to 1944 and from 1945 to 2002. First, the estimates of the two-regime models, where $M_{1t} = M_{3t}$, are presented in the last two columns of Table 1. In terms of second-order serial correlation, and heteroscedasticity, the three-regime model performs better than the three-regime model. However, in terms of the Akaike information criterion, the two-regime model performs better than the three-regime model. The estimated boundaries are almost identical for the three-regime and two-regime models, which suggest that the estimated estimates of the boundaries are robust. For the two-regime model the estimated lower boundaries are -0.1% (US) and -1.1% (UK), whereas the upper boundaries are 3.3% (US) and 6.4% (UK).

Table 2. Estimates of non-linear 3-regime Δp_t models, 1871-1944 and 1945-2002.

	(i) US 1871-1944	(ii) US 1945-2002	(iii) UK 1871-1944	(iv) UK 1945-2002
	M_{1t} regime	**M_{1t} regime**	**M_{1t} regime**	**M_{1t} regime**
Δd_t	0.500 [0.133]	0.399 [0.999]	0.128 [0.409]	0.352 [0.925]
$(p_{t-1} - d_{t-1})$	-0.254 [0.394]	-0.152 [0.534]	-0.056 [0.563]	-0.762 [0.196]
	M_{2t} regime	**M_{2t} regime**	**M_{2t} regime**	**M_{2t} regime**
Δd_t	0.501 [0.031]	1.814 [0.001]	0.510 [0.075]	0.542 [0.270]
$(p_{t-1} - d_{t-1})$	0.041 [0.861]	-0.007 [0. 942]	-0.056 [0.582]	-0.166 [0.390]
	M_{3t} regime:	**M_{3t} regime:**	**M_{3t} regime:**	**M_{3t} regime:**
Δd_t	-0.673 [0.139]	-0.918 [0.035]	-0.104 [0.274]	-0.416 [0.086]
$(p_{t-1} - d_{t-1})$	0.015 [0.933]	-0.294 [0.006]	-0.219 [0.066]	-0.634 [0.000]
τ^L	-0.137 [0.677]	-0.901 [0.100]	-0.930 [0.579]	-0.100 [0.669]

τ^U	3.202 [0.000]	4.528 [0.001]	6.434 [0.000]	5.227 [0.000]
γ_1	122.9 [0.669]	142.1 [0.000]	267.7 [0.824]	4.765 [0.375]
γ_2	53.48 [0.546]	3.433 [0.144]	18.28 [0.615]	20.93 [0.304]

Notes: See the notes of Table 1. All models include intercept terms (not reported).

Turning to parameter stability, Table 2 reports prewar and postwar estimates. Only the key parameter estimates are reported in Table 2 to preserve space. For the US, the dividend effects are broadly in line with those of Table 1. For the UK, the dividend effects are less well determined, particularly for the post World War II period, which is not surprising given that there has hardly been any deflation in postwar UK. The estimated boundaries are again remarkably similar for both estimation periods and comparable to the estimates in Table 1. These results give further support to the hypothesis that the price-dividend relationship differs in inflationary regimes and that the regime boundaries are robust to estimation period and model specification.

6. Conclusions

This paper has argued that the linear price-dividend relationship as predicted by Gordon's model breaks down in deflationary and high inflationary regimes. Using long data for the US and the UK the non-linear estimates showed that the price-dividend relationship and the adjustment of stock prices towards their long-run equilibriums, are significantly different in deflationary, moderately inflationary and high inflation regimes. Furthermore, it was shown that the results were robust to estimation period and to the choice of the number of regimes.

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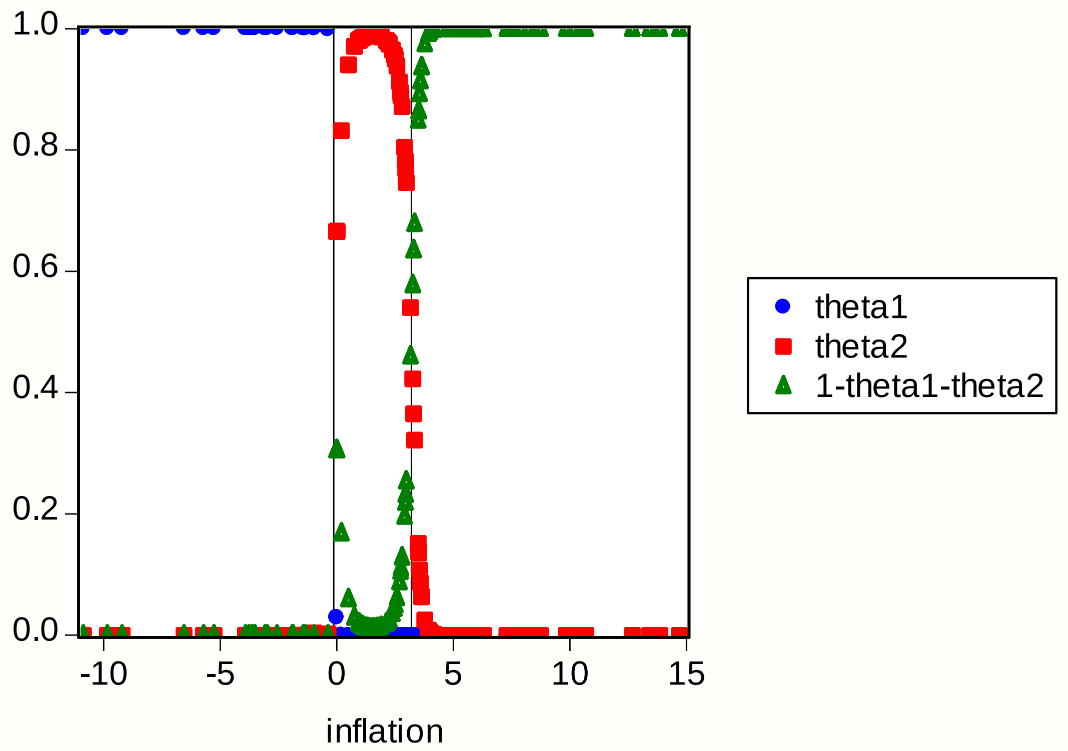
Figure 1: Plot of fitted θ_t functions against inflation π_t and the estimated boundaries τ^L and τ^U

a) US data: τ^L =-0.133%, τ^U =3.196%



b) UK data: τ^L =-1.202%, τ^U =6.356%