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Are there threshold effects in the stock price–dividend relation? The case of the US stock market, 1871–2004

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We use recent developments on threshold autoregressive models that allow deriving endogenously threshold effects to analyse the evolution of the US stock price–dividend relation over the period 1871 to 2004. More specifically, a mean-reverting dynamic behaviour of the stock price–dividend ratio should be expected once such threshold is reached. Our empirical results showed that significant adjustments would occur when, in a particular year, the stock price–dividend ratio had shown a decrease of more than 8.0% between the previous year and the fourth year before, which implies nonlinearities in the dynamic behaviour of the US stock price–dividend relation.

I. Introduction

Over the last decades, the influence of the linear Present Value (PV) model to explain the behaviour of aggregate US stock prices has been actively investigated. In particular, and according to several empirical studies, the linear PV model fails to explain the behaviour of stock prices in the long run; see, e.g. Bohl and Siklos (2004) and Kanas (2005), and the references therein. This article examines whether this failure of the linear PV model can be attributed to nonlinearities in the stock price–dividend relation.

As discussed in Campbell *et al*. (1997), when expected stock returns are time varying, the correct theoretical framework for the analysis of the PV model is nonlinear. In addition, several recent theoretical models have explicitly introduced nonlinearities in the relationship between stock prices and dividends. A possible reason for such nonlinear effects has been pointed out in an important paper by Krugman (1987). More specifically, this author suggests that trigger-price sell strategies are followed by private investors participating in portfolio insurance schemes who commit themselves to buying or selling when the stock price reaches a pre-determined threshold level. Cecchetti *et al*. (1990) show that nonlinearity in the stock price–dividend relation may arise within an equilibrium model of asset price determination which combines a nonlinear endowment process of dividends (a Markov switching model), and investors that attempt to smooth their consumption. Finally, Froot and Obstfeld (1991) proposed a standard PV model with intrinsic bubbles where speculation by rational investors would create threshold effects in the stock price–dividend relation.

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On the other hand, some empirical studies that investigate the presence of nonlinearities in the stock price–dividend relation have recently appeared. For instance, Kanas (2003) provides some empirical evidence of nonlinearities in the PV model using US annual data for 1871–1999, and following the procedure for nonlinear cointegration suggested by Granger and Hallman (1991). More recently, Kanas (2005) has used three nonlinear nonparametric techniques (i.e. nonlinear cointegration, locally weighted regression and nonlinear Granger causality tests), also obtaining evidence on the existence of nonlinearities in the stock price–dividend relation for the United Kingdom, the United States, Japan and Germany, using monthly data for the period 1978:1 to 2002:5.

This article tests empirically whether there have been nonlinearities in the stock price–dividend relation for the US market. The data are annual, cover the years 1871–2004. We use recent developments on Threshold AutoRegressive (TAR) models that allow deriving endogenously threshold effects in the evolution of the US stock price–dividend ratio. Nonlinearity is tested by means of the technique developed by Hansen (1990, 1996, 1997) and Caner and Hansen (2001), to test for a threshold whose location is unknown *a priori*. In this way, a mean-reverting dynamic behaviour of the US stock price–dividend ratio should be expected once such threshold is reached.

The rest of the article is organized as follows: The econometric methodology is outlined in Section II, the empirical results are presented in Section III and the main conclusions are summarized in Section IV.

II. Econometric Methodology

Recent work by Hansen (1996, 1997, 2000) and Caner and Hansen (2001) presents some new results on the TAR model introduced by Tong (1978, 1983, 1990). In particular, they develop new tests for threshold effects, estimate the threshold parameter and construct asymptotic confidence intervals for the threshold parameter.

More specifically, consider a two-regime TAR(k) model with an autoregressive unit root, and two regimes θ_1 and θ_2:

$$\Delta y_t = \theta_1' x_{t-1} 1\{Z_{t-1} < \lambda\} + \theta_2' x_{t-1} 1\{Z_{t-1} \geq \lambda\} + e_t \tag{1}$$

for $t = 1, \ldots, T$, where $x_{t-1} = (y_{t-1} r_t' \, \Delta y_{t-1} \ldots \Delta y_{t-k})'$, $1_{\{\cdot\}}$ is the indicator function, e_t is an i.i.d. error, $Z_{t-1} = y_{t-1} - y_{t-m}$ for some $m \geq 1$ is the threshold variable, r_t is a vector of deterministic components including an intercept and possibly a linear time trend, and $k \geq 1$ is the autoregressive order. The threshold parameter, λ, is unknown and represents the level of the variable y_t that triggers a 'regime change'.

Since Equation 1 is a regression equation (although nonlinear in parameters), Least Squares (LS) would be an appropriate method of estimation. Caner and Hansen (2001) show that, under the auxiliary assumption that e_t is $N(0, \sigma^2)$, LS is equivalent to maximum likelihood, in which case, the estimates can be used to conduct inference on the parameters of Equation 1 using standard Wald test statistics.

The main question in model (1) is whether there is a threshold effect. In order to test the null hypothesis of linearity (i.e. no threshold effect and $\theta_1 = \theta_2$), against the alternative of threshold effect (i.e. the process is nonlinear), Caner and Hansen (2001) propose a standard heteroskedastic-consistent Wald or Lagrange multiplier test, $\sup W_T(\lambda)$, where the threshold point, λ, and the corresponding vectors θ_1 and θ_2, are estimated by LS. They show that $\sup W_T(\lambda)$ has a nonstandard asymptotic null distribution, which is due partially to the presence of a parameter that is not identified under the null, and partially to the assumption of a nonstationary autoregression. As a result, critical values cannot be tabulated, so that the authors suggest a bootstrap method to compute asymptotic critical values and p-values.

III. Empirical Results

In this section, we analyse the possible presence of nonlinearities in the US stock price–dividend ratio, pdr_t, over the period 1871 to 2004, using the methodology presented in the previous section. The series on real stock prices and dividends are taken from Robert Shiller's website (http://www.econ.yale.edu/~shiller/data/). The stock price index is the January values of the Standard & Poor's 500 Composite Stock Price index; the evolution of the real stock price–dividend ratio is shown in Fig. 1.

As a first step of the analysis, we have tested for the order of integration of the stock price–dividend ratio. To this end, we have used a modified version of the Dickey–Fuller and Phillips–Perron tests proposed by Ng and Perron (2001), which try to solve the main problems present in these conventional tests for unit roots.

In general, the majority of the conventional unit root tests suffer from three problems. First, many tests have low power when the root of the autoregressive polynomial is close to, but less than, unit (DeJong *et al.*, 1992). Second, the majority of the tests suffer from severe size distortions when the moving average polynomial of the first-differenced series has a large negative autoregressive root (Schwert, 1989; Perron and Ng, 1996). Third, the implementation of unit root tests often needs the selection of an autoregressive truncation lag, k; however, as discussed in Ng and Perron (1995) there is a strong association between k and the severity of size distortions and/or the extend of power loss.

Recently, Ng and Perron (2001) have proposed a methodology that solves these three problems. This method consists of a class of modified tests, called $\bar{M}^{\text{GLS}}_{\text{MAIC}}$ originally developed in Stock (1999) as M tests, with Generalized Least Squares (GLS) detrending of the data as proposed in Elliot *et al.* (1996), and using the Modified Akaike Information Criteria (MAIC).[1] Also, Ng and Perron (2001) have proposed a similar procedure to correct for the problems of the standard Augmented Dickey–Fuller (ADF) test, $\text{ADF}^{\text{GLS}}_{\text{MAIC}}$.[2]

In Table 1 we report the results of the $\bar{M}^{\text{GLS}}_{\text{MAIC}}$ tests and the $\text{ADF}^{\text{GLS}}_{\text{MAIC}}$ test. In all these tests the null hypothesis is that a series is $I(1)$ against the alternative that it is $I(0)$.[3] The null hypothesis of nonstationarity for the series in levels cannot be rejected, independently of the test, whereas the existence of two unit roots is clearly rejected at the usual significance levels. Therefore, according to the results of these tests, the US stock price–dividend ratio would be $I(1)$, so we work with the variable in first differences to ensure stationarity.

In the TAR(k) model, the threshold variable is $Z_{t-1} = y_{t-1} - y_{t-m}$ for some integer $m \in [1, M]$ called the delay lag, which is unknown *a priori* so it has to be estimated. For the threshold variable, we use a long difference for some $m \leq 8$, as suggested by Hansen (1997). Following Franses and van Dijk (2000), we use both the minimization of Akaike's (1973) information criteria and Hannan and Quinn (1979) (HQ) statistics to choose the appropriate lag order k. Both criteria lead to $k = 8$.

Table 2 reports the Sum of Squared Errors (SSE) from the various TAR models from $m = 1$ to $m = 8$, and the bootstrap-calculated asymptotic p-value

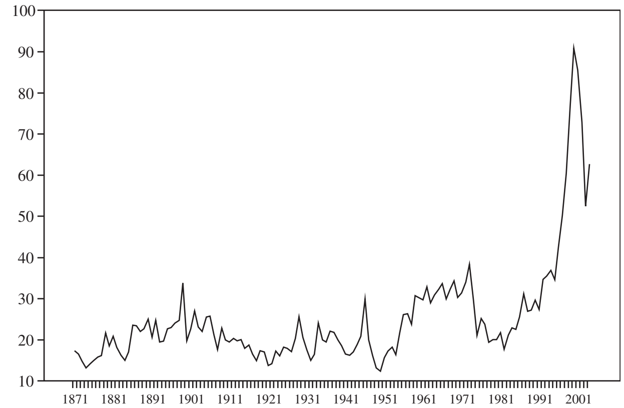

Fig. 1. Annual data on US stock market, 1871–2004 (Real stock price–dividend ratio)

(using 5000 replications) for the Wald test statistic, $\sup W_T(\lambda)$, on the null of linearity against a particular threshold model. Hansen (1997, 2000) suggests to select the delay lag through the minimization of the SSE, so in this case $m = 5$. The model is highly statistically significant.

Next, Table 3 presents the parameter estimates for the TAR model selected. Setting $m = 5$, the LS estimate of the threshold parameter (or trigger point) would be -8.0. The estimate $\hat{\lambda} = -8.0$ means that the estimated TAR model splits the regression into two regimes, depending on whether, in a particular year, the US stock price–dividend ratio, has shown an decrease of more than 8.0% between the previous year and the fourth year before. Of the 134 observations in the fitted sample, 34 observations lie in regime 1 where $y_{t-1} - y_{t-5} \leq -8.0$ and 86 observations lie in regime 2 where $y_{t-1} - y_{t-5} > -8.0$.

Figure 2 depicts the threshold variable, $Z_{t-1} = y_{t-1} - y_{t-5}$, together with the estimated threshold parameter, -8.0, for the case of the US stock price–dividend ratio over the period 1876 to 2004. As can be seen, four trigger points, according to Krugman's (1987) model, would appear: 1884, 1904, 1951 and 1978, which can be mainly related to recessions and/or wartime. The two shifts in 1884 and 1904 were caused by two short-lived recessions. A major shift in the evolution of the stock price–dividend ratio occurs in 1951, coinciding with the Korean War. Finally, the figure shows another major shift in 1978, in the aftermath of the 1973 oil crisis, which plunged the US economy into a deep recession.

[1] These tests are the $\bar{\text{MZ}}^{\text{GLS}}_{\alpha}$, $\bar{\text{MSB}}^{\text{GLS}}$ and $\bar{\text{MZ}}^{\text{GLS}}_{t}$.
[2] See Ng and Perron (2001) and Perron and Ng (1996) for a detailed description of these tests.
[3] Note that for the $\bar{\text{MSB}}^{\text{GLS}}$ test, the null hypothesis is rejected in favour of stationarity when the estimated value is smaller than the critical value.

Table 1. Ng and Perron tests for a unit root

$I(2)$ versus $I(1)$	Case: $p=0$, $\bar{c}=-7.0$					
	M^{GLS}_{MAIC} tests					
Variable	MZ^{GLS}_{α}	MZ^{GLS}_{t}	MSB^{GLS}	ADF^{GLS}		
Δpdr_t	−63.69***	−5.64***	0.088	−13.83***		
$I(1)$ versus $I(0)$	Case: $p=1$, $\bar{c}=-13.0$					
	$\bar{M}^{GLS}_{MAIC}$ tests					
Variable	MZ^{GLS}_{α}	MZ^{GLS}_{t}	MSB^{GLS}	ADF^{GLS}		
pdr_t	−10.14	−2.06	0.203***	−2.15		
Critical values:	Case: $p=0$, $\bar{c}=-7.0$			Case: $p=1$, $\bar{c}=-13.0$		
	10%	5%	1%	10%	5%	1%
$\bar{M}Z^{GLS}_{\alpha}$	−5.7	−8.1	−13.8	−14.2	−17.3	−23.8
$\bar{M}SB^{GLS}$	0.275	0.233	0.174	0.185	0.168	0.143
$\bar{M}Z^{GLS}_{t}$, ADF^{GLS}	−1.62	−1.98	−2.58	−2.62	−2.91	−3.42

Notes: *, ** and *** denote significance at the 10, 5 and 1% levels, respectively.
The MAIC is used to select the autoregressive truncation lag, k, as proposed in Perron and Ng (1996). The critical values are taken from Ng and Perron (2001).

Table 2. TAR models for the US stock price–dividend ratio

$Z_{t-1}=y_{t-1}-y_{t-m}$								
M	1	2	3	4	5	6	7	8
SSE	2.43	2.33	2.55	2.38	**2.30**	2.36	2.54	2.48
p-value[a]	0.31	0.98	0.35	0.98	**0.01**	0.92	0.73	0.68

Notes: [a]From the Wald or Lagrange multiplier test, $\sup W_T(\lambda)$, that tests the null hypothesis of linearity (i.e., the threshold effect disappears and $\theta_1=\theta_2$) against the alternative of a threshold effect (i.e. the process is nonlinear), as proposed in Hansen (1997) and Caner and Hansen (2001).
The bold font indicates the model selected.

Table 3. TAR estimates for the US stock price–dividend ratio

Variable	Intercept	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}	Δy_{t-5}	Δy_{t-6}	Δy_{t-7}	Δy_{t-8}
Regime 1: $y_{t-1}-y_{t-5}\leq -8.0$									
$\hat{\theta}_1$	0.04	0.07	−0.23	0.19	−0.03	0.25	0.10	0.52	0.23
SE	(0.03)	(0.17)	(0.14)	(0.18)	(0.13)	(0.14)	(0.13)	(0.13)	(0.13)
Regime 2: $y_{t-1}-y_{t-5}> -8.0$									
$\hat{\theta}_2$	0.01	−0.09	−0.05	−0.002	−0.01	−0.27	−0.10	−0.05	−0.30
SE	(0.02)	(0.18)	(0.13)	(0.12)	(0.11)	(0.12)	(0.13)	(0.09)	(0.11)

IV. Conclusions

In this article we contribute to the debate on the ability of the PV model to explain the behaviour of stock prices. Specifically, we examine whether this failure of the linear PV model can be attributed to nonlinearities in the stock price–dividend relation. To this end, we use recent developments on TAR models that have allowed us to derive endogenously threshold effects in the evolution of the US stock price–dividend relation, which could explain the changes in the trigger stock prices selling strategies followed by private investors participating in portfolio insurance schemes. More specifically, we should expect a mean-reverting dynamic behaviour of the US stock price–dividend ratio once such threshold is reached, according to the theoretical model of Krugman (1987).

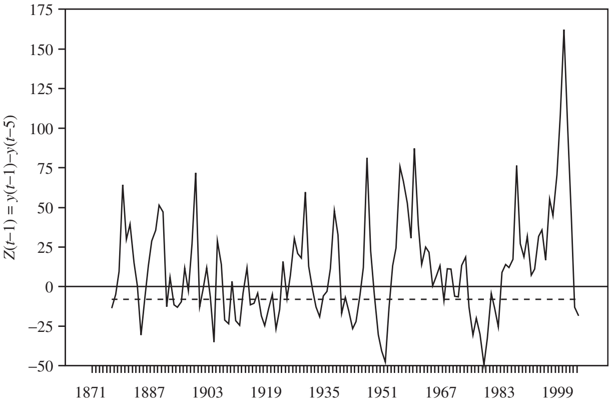

Fig. 2. Threshold regimes for the US stock price-dividend ratio, 1876–2004

Our empirical results showed that significant adjustments would occur when, in a particular year, the stock price–dividend ratio had shown a decrease of more than 8.0% between the previous year and the fourth year before, which implies nonlinearities in the dynamic behaviour of the US stock price–dividend relation. There is also evidence of four trigger points, according to the theoretical model of Krugman (1987), which can be mainly related to recessions and/or wartime. The first and second one would occur at 1884 and 1904, following two short-lived recessions. In turn, a third trigger point would emerge at 1951, coinciding with the Korean War. Finally, a major shift appears in the aftermath of the 1973 oil crisis.

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