Journal of Banking & Finance 33 (2009) 405–414

Contents lists available at ScienceDirect

Journal of Banking & Finance

journal homepage: www.elsevier.com/locate/jbf

Regime switching in the relationship between equity returns and short-term interest rates in the UK

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ARTICLE INFO

Article history:
Received 28 March 2008
Accepted 18 August 2008
Available online 22 August 2008

JEL classification:
G0
C5

Keywords:
Regime switching
Time-varying transition probabilities
Interest rate spreads

ABSTRACT

This paper examines the relationship between UK equity returns and short-term interest rates using a two regime Markov-Switching EGARCH model. The results suggest one high-return, low variance regime within which the conditional variance of equity returns responds persistently but symmetrically to equity return innovations. In the other, low-mean, high variance, regime equity volatility responds asymmetrically and without persistence to shocks to equity returns. There is evidence of a regime dependent relationship between shorter maturity interest rate differentials and equity return volatility. Furthermore, there is evidence that events in the money markets influence the probability of transition across regimes.

1. Introduction

Under the dividend discount approach to equity pricing of Gordon (1962), and the dynamic counterpart of Campbell and Shiller (1988), the price of a share in equilibrium is determined by the discounted value of the expected cash flows accruing to the share. Campbell and Ammer (1993) decompose the variance of unexpected excess returns implied by the dividend discount model into three factors, news about future dividends, news about future interest rates, and news about future excess returns. These models predict that fluctuations to interest rates should cause equity prices to move and may also result in changes to the variance of equity returns.

Over the last two decades there has been increased use of short-term interest rates rather than measures of the money supply as intermediate targets for monetary policy. Any potential change in the policy rate is the focus of much attention from academics and practitioners, as arbitrage will ensure that a change in the policy rate will affect all other traded interest rates in the economy. Any change in the stance of monetary policy may impact on share prices along a number of alternative channels. One possible channel is via the funding costs of a leveraged firm. Any change in the policy rate will change debt funding costs and consequently may impact on the profitability of the firm and its ability to pay dividends. Secondly, any change in the policy rate may affect the opportunity cost of equity investments, again impacting on share prices. Thirdly, changes in the policy rate may impact upon the level of real activity in the economy in the short to medium term, and this may impact upon the value of equities by influencing the value of expected future cash flows. There is substantial empirical evidence to suggest that changes in monetary policy actually affect equity markets. Bernanke and Blinder (1992), Bernanke and Kuttner (2005), Chen (2007), and Basistha and Kurov (2008) *inter alia* provide evidence that changes to monetary policy in the US impact on US equity values. Bredin et al. (2007) study the impact of domestic monetary shocks on UK stock returns.

There is also the possibility that unexpected events in the interest rate markets will impact upon equity returns. Events such as the Russian debt crisis and the subsequent collapse of Long Term Capital Management in 1998 (see Jorion, 2000 *inter alia*) or the sub-prime mortgage crisis of 2007 are good examples of such shocks. Leveraged firms that finance their activities through short-term arrangements may experience periods of high volatility when conditions in the debt markets make refinancing uncertain. This is particularly true for firms that finance long-term illiquid assets with short-term borrowing, implicitly assuming that sufficient liquidity will always be available to refinance their activities.

The aim of this paper is to seek evidence of periods of high volatility in equity returns and further to examine whether these periods are associated with events in the money markets in a statistically significant fashion. Hamilton and Susmel (1994) and

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doi:10.1016/j.jbankfin.2008.08.001

Chen (2007, 2009) *inter alia* find evidence of regime switching in equity returns. A common finding in these papers is that equity returns display two regimes, a high-mean, low variance regime and a low-mean high variance regime. However, from an econometric point of view, it is not feasible to separate the first and second aims of this paper. Standard asset pricing models tell us that the riskiness of an asset is important in determining the true value of that asset. Optimal inference about the conditional mean of the asset return, requires that the conditional second moment be correctly specified. Consequently, in seeking to determine whether equity returns are influenced by events in short-term money markets, and/or whether equity returns display infrequent intervals of high volatility, it is necessary to allow for both possibilities. Omission of the former possibility may lead to unreliable inference about the latter and vice-versa. Furthermore, given the widespread evidence of asymmetry in stock volatility, see Glosten et al. (1993) and Engle and Ng (1993) *inter alia*, a standard symmetric regime-switching GARCH may very well fail to provide an adequate conditional characteristion of equity return dynamics.

The approach followed in this paper is to allow for two regimes in asset returns. The full model characterises the within regime conditional variance as an exponential GARCH process, allowing for switching between regimes and time variation and asymmetry in the conditional variance within regime. The model also allows for regime dependence in the impact, persistence and asymmetric response to shocks to equity volatility.

The results suggest that there are two regimes in UK equity returns, a high-mean, low variance regime and a low-mean high variance regime. The evidence also suggests that shorter maturity interbank interest rate differentials are significant, regime dependent, determinants of the volatility of UK equity returns. Furthermore, there is some evidence to suggest that the probability of transition across regimes is itself a function of short-term interest rate differentials. Failure to account for either regime switching and/or dependence on short-term interest rate differentials may lead to invalid inference, biased forecasts and consequently inefficient risk management as value-at-risk (VaR) measures or volatility estimates for option pricing may be biased.

This paper contains four sections. The next section outlines the Markov-Switching EGARCH model of stock returns. The third section reports the empirical results and is divided into three sub-sections. The first sub-section outlines the results associated with the baseline models of equity return. The second and third sub-sections outline the results for the extended Markov-Switching EGARCH models with fixed- and time-varying transition probabilities, respectively. The final section provides a summary and some concluding comments.

2. The Markov-Switching EGARCH model

There is a substantial literature describing the volatility of stock returns and, in particular, the asymmetry in stock volatility. Following a negative shock to equity prices, equity returns tend to display more volatility than would occur following a positive shock of equal magnitude. Nelson (1991) presents the EGARCH model designed to capture such asymmetry. The EGARCH (1,1) may be written as

$$\begin{aligned} r_t &= \mu_t + \varepsilon_t, \\ \varepsilon_t &\sim N(0, h_t), \\ \log(h_t) &= \omega + \alpha\left[\left|\frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}}\right| - \sqrt{2/\pi}\right] + \beta\log(h_{t-1}) + \delta\frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}}. \end{aligned} \tag{1}$$

The logarithmic construction of (1) ensures that the estimated conditional variance, h_t, is strictly positive avoiding the need for the non-negativity constraints typically used in the estimation of GARCH models. Moreover, since $\hat{\delta}$ is typically negative in sign, a negative innovation, $\varepsilon_t < 0$, generates more volatility than a positive innovation of equal magnitude. The innovation ε_t may be treated as a collective measure of news about equity prices arriving to the market over the period $t-1$ to t. Suppose information is held constant at time $t-2$ and before, Engle and Ng (1993) describe the relationship between ε_{t-1} and h_t as the news impact curve (NIC). The NIC for (1) may be written:

$$h_t = \begin{cases} A\cdot\exp\left[\frac{\delta+\alpha}{\sigma}\varepsilon_{t-1}\right] & \text{for } \varepsilon_{t-1} > 0, \\ A\cdot\exp\left[\frac{\delta-\alpha}{\sigma}\varepsilon_{t-1}\right] & \text{for } \varepsilon_{t-1} < 0, \end{cases} \tag{2}$$

where $A = \sigma^{2\beta}\exp\left[\omega - \alpha\sqrt{2/\pi}\right]$. Clearly given the construction of (2), $\delta < 0$ will cause the slope of the NIC in the $\varepsilon_{t-1} < 0$ segment to be steeper than corresponding slope in the $\varepsilon_{t-1} > 0$ segment; volatility therefore responds asymmetrically to the sign of the shock. A major drawback of the GARCH approach is that single regime GARCH models are prone to overestimate the persistence of a shock in the face of an unparameterised change in regime, see Lamoureaux and Lastrappes (1990); Cai (1994) and Hamilton and Susmel (1994) *inter alia*.

This paper employs a Markov-Switching EGARCH model, which, guarantees that h_t is positive without the use of non-negativity constraints and captures asymmetry in volatility. Ideally one would choose to estimate a model of the type

$$\begin{aligned} r_t &= \mu_{i,t} + \varepsilon_t, \\ \varepsilon_t &\sim N(0, h_{i,t}), \\ \log(h_{i,t}) &= \omega_i + \alpha_i\left[\left|\frac{\varepsilon_{t-1}}{\sqrt{h_{i,t-1}}}\right| - \sqrt{2/\pi}\right] + \beta_i\log(h_{i,t-1}) + \delta_i\frac{\varepsilon_{i,t-1}}{\sqrt{h_{i,t-1}}} \end{aligned} \tag{3}$$

This model allows for two states, i, indexed by an unobserved latent variable S_t which takes the value of 0 or 1 depending on the state of the markets. Following Hamilton (1989), S_t is assumed to follow a two-state Markov process with a fixed transition probability matrix P written as

$$P = \begin{bmatrix} p^{00} & 1-p^{11} \\ 1-p^{00} & p^{11} \end{bmatrix}. \tag{4}$$

Here, $p^{ii} = \Pr(S_t = i|S_{t-1} = i)$ for $i = 0,1$. Implicitly, S_t depends on past realisations of r and S only through S_{t-1}. The transition probabilities are initially assumed to be constant and are specified as

$$p^{00} = \frac{\exp\{\theta_0\}}{1+\exp\{\theta_0\}} \text{ and } p^{00} = \frac{\exp\{\gamma_0\}}{1+\exp\{\gamma_0\}}. \tag{5}$$

Cai (1994) and Hamilton and Susmel (1994) argue that MS-GARCH models are intractable. They point out that maximum likelihood estimation is impossible because the conditional variance depends on the entire past history of the data in a MS-GARCH model. Gray (1996) argues that it is possible to construct a measure of h_t that is not path dependant. Recall that $h_t = E[r_t^2|\Omega_{t-1}] - E[r_t|\Omega_{t-1}]^2$ which yields

$$\begin{aligned} h_t &= p^{00}(\mu_{0t}^2 + h_{0t}) + (1-p^{00})(\mu_{1t}^2 + h_{1t}) \\ &\quad - [p^{00}\mu_{0t} + (1-p^{00})(\mu_{1t})]^2. \end{aligned} \tag{6}$$

The measure of the conditional variance provided by (6) is conditional on available information, but aggregated across regimes and provides a path independent model of volatility. In (6) each conditional variance depends on the regime alone, and not on the entire history of the process. Using (6) in place of $h_{i,t-1}$ in (3) yields