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A GARCH model for testing market efficiency

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ABSTRACT

In this paper we propose a generalised autoregressive conditional heteroskedasticity (GARCH) model-based test for a unit root. The model allows for two endogenous structural breaks. We test for unit roots in 156 US stocks listed on the NYSE over the period 1980 to 2007. We find that the unit root null hypothesis is rejected in 40% of the stocks, and only in four out of the nine sectors the null is rejected for over 50% of stocks. We conclude with an economic significance analysis, showing that mostly stocks with mean reverting prices tend to outperform stocks with non-stationary prices.

1. Introduction

The efficient market hypothesis (EMH) is one of the traditional hypotheses in financial economics, owing to the work of Samuelson (1965) who proposed that stock prices should follow a random walk. The implication of Samuelson's proposal was that stock returns should be entirely unpredictable due to investors' arbitrage motives.

Three forms of the EMH are popularly tested in the literature. The weak form version of the EMH is based on an information set that uses current or past asset prices (see Fama, 1970). Fama (1991) argued that the weak form EMH should also include in the information set those predictor variables, such as dividend yields and interest rates, which forecast returns. When this information set is expanded to include all public information, the EMH takes a semi-strong form. Finally, if all public and private information is contained in the information set, the EMH takes the strong form (see Fama, 1970, 1991). Our test for the EMH is based on the weak form version as it is based on the idea that current price of stocks is the best predictor of the future price of stocks, and the price change (return) is expected to be zero. This implies a random walk model where increments are identically and independently distributed. When errors from a predictive model are heteroskedastic, a martingale allows for uncorrelated increments. A martingale can be considered as a generalised form of a random walk model. Therefore, a martingale model is ideal when data on hand, such as stock price data, is best characterised by heteroskedasticity (see Kim and Shamsuddin, 2008).[1]

The EMH has attracted a substantial interest, with voluminous empirical applications. Our interest on the EMH is based on two specific reasons. The first reason is that despite the plethora of studies on the EMH, none of the studies have examined

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[1] See also Tiwari and Kyophilavong (2014), Narayan et al. (2014), and Gozbasi et al. (2014).

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the hypothesis at the micro level; that is, for time series of stock prices at the firm level. In other words, all empirical applications are either on aggregate stock prices (indices) or on cross-section of stocks. This is the main research gap in the extant literature. The motivation for a micro-level test of the EMH is explained in the next section. The second reason is methodological, in that, in financial economics, it has been shown that financial data suffers from heteroskedasticity. It is, therefore, important to account for heteroskedasticity. A second issue with time series data, well established in the time series applied econometrics literature, is that data tends to be characterized by structural breaks.[2] Hence, we model both heteroskedasticity and structural breaks simultaneously.

To test for the unit root null hypothesis, following the Nelson and Plosser (1982) findings, a wide range of structural break unit root tests have been developed. These tests can be categorized into those that treat the structural breaks as exogenous and those that treat the structural breaks as endogenous. The exogenous break tests include those proposed by Perron (1989), while the endogenous class of tests include those from Lumsdaine and Papell (1997), Lee and Strazicich (2003), Sen (2003), Perron and Vogelsang (1992), and more recently Narayan and Popp (2010). A key feature of these tests is that they are based on linear models, i.e. they assume independent and identically distributed (iid) errors. Fittingly, Kim and Schmidt (1993a) show that the Dickey–Fuller type tests tend to reject the unit root null hypothesis too often in the presence of conditional heteroskedasticity[3].

The aim of this paper is to examine the EMH for US stocks. We consider, from the New York Stock Exchange, no fewer than 156 stocks. The data series are monthly and cover the period January 1980 to December 2007. Such a historical time series analysis of the efficient market hypothesis for a large number of stocks has not been previously undertaken. The second contribution, motivated by the limiting theory for unit root processes with GARCH disturbances developed by Ling and Li (1998, 2003), Seo (1999) and Gospodinov (2008), is that we propose a GARCH (1,1) unit root model that is flexible to accommodate two endogenous structural breaks.

We also undertake an economic significance analysis through which we demonstrate the relative importance of unit root properties for investors. Generally speaking, there is limited knowledge on how beneficial the knowledge on unit roots is for investors.

The remainder of the paper is organized as follows. In Section 2, we describe the literature on the EMH and derive the main motivations for our study. In Section 3, we present the econometric model and discuss the results. In Section 4, we undertake an economic significance analysis followed by a robustness test. In the final section, we provide some concluding remarks.

2. Literature and motivation

There are two motivations for the current paper. The first motivation is empirical and has roots in the literature that has tested the EMH. The literature on the EMH has followed two strands. The first strand (see, *inter alia*, DeBondt and Thaler, 1985, 1987; Zarowin, 1990) relates to the early literature on this subject and is based on a panel data – a cross-section of stocks – analysis. These studies essentially test the return reversal behaviour of stock prices. This amounts to testing whether the prior period's worst stock return performers (losers) outperformed the prior period's best return performers (winners) in the subsequent period. These studies can be considered as short-horizon based analysis of the EMH. The second strand of the literature considers the EMH over long horizons based on time series data (see, *inter alia*, Fama and French, 1988; Poterba and Summers, 1988; Richards, 1995, 1997; Chaudhuri and Wu, 2003; Zhong et al., 2003) or panel data (see Balvers et al., 2000); for a nonlinear mean reversion of stock prices, see Bali et al. (2008).

There are three distinctive features of this literature. First, there is no consensus on mean reversion. Some studies have found mean reversion, while others have rejected the mean reversion hypothesis. The more recent studies on mean reversion in stock prices, such as Balvers et al. (2000) based on panel data and Chaudhuri and Wu (2003) based on time series structural break unit root tests, find overwhelming evidence of mean reversion, however. The second feature is that, while a range of applications on mean reversion in stock prices are available, none of the studies have considered mean reversion in individual firm stock prices based on time series data. The third feature is that a wide range of econometric estimation techniques, ranging from simple cross-sectional regression models to sophisticated structural break unit root testing procedures have been applied, but none of the studies have considered a GARCH-based model. This is particularly important in light of the fact that daily and monthly data suffer from heteroskedasticity and a GARCH model solves this statistical problem, which if unsolved can potentially bias the results on mean reversion; see Engle (1982) and Bollerslev (1986).

From these features of the literature, the one gap that is obvious is: there are no studies that examine the EMH at the firm-level using time series data. In other words, no studies examine the validity or otherwise of the EMH for firm-level stock price. Why is this investigation important? The aggregate stock price based studies on the EMH assume that firms comprising the aggregate stock market are homogenous. It is, however, not the case. Firms are heterogeneous (see Narayan and Sharma, 2011). Firms are of different sizes and cost structures. Hence, some firms, or the heterogeneity of firms, may be

[2] A recent study by Narayan et al. (2013) shows that structural breaks have slowed down the growth rate of the US, UK and Japanese stock markets.

[3] The relevance of unit roots in financial time series and panel data have been demonstrated by many studies; one influential study that motivates us is Geppert et al. (2002).