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Portfolio management under sudden changes in volatility and heterogeneous investment horizons

Viviana Fernandez[a,*], Brian M. Lucey[b]

[a]*Center for Applied Economics (CEA), Department of Industrial Engineering of the University of Chile, Santiago, Chile*
[b]*Institute for International Integration Studies, Trinity College Dublin, Ireland*

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Abstract

We analyze the implications for portfolio management of accounting for conditional heteroskedasticity and sudden changes in volatility, based on a sample of weekly data of the Dow Jones Country Titans, the CBT-municipal bond, spot and futures prices of commodities for the period 1992–2005. To that end, we first proceed to utilize the ICSS algorithm to detect long-term volatility shifts, and incorporate that information into PGARCH models fitted to the returns series. At the next stage, we simulate returns series and compute a wavelet-based value at risk, which takes into consideration the investor's time horizon. We repeat the same procedure for artificial data generated from semi-parametric estimates of the distribution functions of returns, which account for fat tails. Our estimation results show that neglecting GARCH effects and volatility shifts may lead to an overestimation of financial risk at different time horizons. In addition, we conclude that investors benefit from holding commodities as their low or even negative correlation with stock and bond indices contribute to portfolio diversification.

Keywords: Structural volatility shifts; Heterogeneous investors; Wavelets; Value at risk

1. Introduction

To date, there is an extensive literature on the behavior of volatility of assets returns and the effect of this on both the value and composition of investors portfolios. Indeed, the GARCH model and its numerous extensions have been widely used to account for the existence of conditional heteroskedasticity in financial time series (see, for instance, the survey by Poon and Granger [1]).[1] However, less attention has been paid to the detection of multiple shifts in unconditional variance over time. For example Ref. [2] et seq. conclude that persistence in variance may be overstated by not accounting for deterministic structural breakpoints in the variance model.

*Corresponding author. Tel.: +56 2 978 4072; fax: +56 2 689 7895.
E-mail addresses: vfernand@dii.uchile.cl (V. Fernandez), blucey@tcd.ie (B.M. Lucey).

[1]Conditional heteroskedasticity means that the variance of a return series changes over time, conditional on past information. GARCH models are designed to capture the time-series dynamics of returns, in which we observe persistence or serial correlation in volatility.

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A relatively recent approach to testing for volatility shifts is the Iterative Cumulative Sums of Squares (ICSS) approach of Ref. [3]. This algorithm allows for detecting multiple breakpoints in variance in a time series. Examples of this approach to equity markets include [4–6]. Another subject, which has received attention in recent research and that also has important implications for portfolio management, is the existence of heterogeneous investors. Ref. [7] points out that, for the specific case of commodity markets, long-horizon traders will essentially focus on price fundamentals that drive overall trends, whereas short-term traders react to incoming information within a short-term horizon. Hence, market dynamics in the aggregate will be the result of the interaction of agents with heterogeneous time horizons. In order to model the behavior of financial series at different time spans, researchers have resorted to wavelet analysis. Wavelet analysis is a refinement of Fourier analysis that allows for decomposing a time series into its high frequency or noisy components and its low frequency or trend components, among many other applications. See Refs. [7–9] for commodity and derivative markets, for interest and foreign exchange rates see Refs. [10,11], and for equity markets see Refs. [12–18]. Finally, one of the main issues in the analysis of portfolios is that of what the likelihood is of a loss of a particular magnitude. This Value at Risk (VaR) analysis has attracted very significant attention in the economics and finance literature (see for example Refs. [19–21]) but relatively little in econophysics (see Refs. [22–24] as exceptions). In essence the VaR approach provides an integrated approach to examine and assess the probability of a given percentage loss of wealth over a given time period.

The aim of this article is two-fold. First, we analyze whether accounting for conditional heteroskedasticity and long-term volatility shifts in asset returns really matters when comes to quantifying the potential market risk an investor faces. In doing so, we consider different time horizons by resorting to a wavelet-based decomposition of VaR. Second, we look at the potential diversification gains in terms of the VaR decrease obtained by adding commodities to a portfolio.

This article is organized as follows. Section 2 presents the main methodological tools utilized in the empirical section of the article. Section 3 presents some descriptive statistics of the data used in the simulations carried out later on. Section 4 presents the simulation exercises involving a portfolio primarily composed of stock indices and a portfolio that also include spot and futures positions in commodities. We discuss the implications of not accounting for correlated volatility and volatility shifts for risk quantification. In addition, we focus on the benefits of holding commodities for portfolio diversification. Section 5 concludes.

2. Methodology

2.1. The ICSS algorithm

The derivation of the ICSS algorithm is based on the assumption that a time series has a stationary unconditional variance over an initial time period until a sudden break takes place. The unconditional variance is then stationary until the next sudden change occurs. This process repeats through time, giving a time series of observations with M breakpoints in the unconditional variance along the sample:

$$\sigma_t^2 = \begin{cases} \tau_0^2, 1 < t < \iota_1, \\ \tau_1^2, \iota_1 < t < \iota_2, \\ \quad .... \\ \tau_M^2, \iota_M < t < n. \end{cases} \tag{1}$$

In order to estimate the number of variance shifts and the point in time at which they occur, a cumulative sum of squares is computed, $C_k = \sum_{t=1}^{k} z_t^2,\ k = 1,\ 2,\ldots,n$, where $\{z_t\}$ is a series of uncorrelated random variables with zero mean and unconditional variance σ_t^2, as in (1). Define the statistic

$$Đ_\mathrm{k} = \frac{C_k}{C_n} - \frac{k}{n}, \quad k = 1, 2, \ldots, n, \quad Đ_0 = Đ_n = 0 \tag{2}$$

as the centered and normalized sum of squares.

If no variance shifts are observed under the time period under consideration, $Đ_k$ will oscillate around zero. Otherwise, if there is one or more sudden changes in variance, $Đ_k$ will breach given boundaries with high