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Capturing common components in high-frequency financial time series: A multivariate stochastic multiplicative error model

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ABSTRACT

We model high-frequency trading processes by a multivariate multiplicative error model that is driven by component-specific observation driven dynamics as well as a common latent autoregressive factor. The model is estimated using efficient importance sampling techniques. Applying the model to 5 min return volatilities, trade sizes and trading intensities from four liquid stocks traded at the NYSE, we show that a subordinated common process drives the individual components and captures a substantial part of the dynamics and cross-dependencies of the variables. Common shocks mainly affect the return volatility and the trade size. Moreover, we identify effects that capture rather genuine relationships between the individual trading variables.

1. Introduction

Numerous empirical studies have documented a strong positive contemporaneous relationship between daily volume and volatility. This observation is consistent with the mixture-of-distribution hypothesis (MDH) pioneered by Clark (1973). The MDH relies on central limit arguments based on the assumption that daily returns consist of the sum of 'large' amounts of intra-daily logarithmic price changes associated with 'pseudo' intra-day equilibria. The assumption that these intra-day

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price changes are also accompanied by an increased trading volume leads to an extension of Clark's model and implies a positive contemporaneous correlation between daily volume and volatility.[2]

Whereas the employed central limit arguments provide a sensible framework for aggregated (daily) data, they are not applicable on a high-frequency level since the number of underlying 'pseudo' equilibria cannot be large, but converge to zero when we approach the transaction level. Nevertheless, under the assumption that daily volumes and returns, both consisting of intra-day aggregates, are driven by a subordinated common process, the latter should be identifiable also on an intra-day level. Actually, the idea of an underlying (unobservable) information process is consistent with typical asymmetric information-based market microstructure models such as, e.g., those introduced by Glosten and Milgrom (1985) and Easley and O'Hara (1992). In these settings, positive mutual correlations between trading volumes and volatilities arise through interaction among asymmetrically informed market participants. However, market microstructure theory is typically relatively vague, if not silent, regarding the underlying time horizon and thus the frequency on which common information-induced effects should be observable. On the other hand, several empirical studies provide evidence for common movements and strong interdependencies in high-frequency volatilities and trading intensities, supporting the notion of an underlying common component jointly driving trading activity and volatility.[3]

In this study, we aim to analyze whether a common component in volatilities and trading volume is identifiable based not only on daily data but also on higher sampling frequencies. We associate this hypothesis with a 'micro-foundation' of the volume–volatility relationship. In this context, we will answer the following research questions: (i) To what extent do the interdependencies between volume and volatility reflect ('true') causal relationships, or rather spurious correlations due to the subordination to the same latent (information arrival) process? (ii) How strongly does the latent factor affect the individual trading components? In particular, are potential common movements with volatilities reflected in trade sizes, in trading intensities, or both? (iii) To what extent can we identify effects that are not driven by a common subordinated process but that reflect genuine trading-specific effects?

To address these questions, we propose modeling the return volatility, the average trade size, and the number of trades per time interval in terms of a new type of multiplicative error model (MEM) that is driven by two different dynamic processes: a common autoregressive latent factor with component-specific sensitivity and an observation-driven (VARMA type) dynamic capturing idiosyncratic effects given the latent factor. The resulting model is called a *stochastic multiplicative error model* (SMEM) and extends the multiplicative error structures proposed by Engle (2002) and Manganelli (2005) by a latent factor dynamic.

The proposed approach is motivated by two major aspects: First, a well-known result in the literature on tests of the MDH is that a single latent component is typically not sufficient to fully capture the short-run dynamic dependencies in both volume and volatility. As argued in Andersen (1996) and Bollerslev and Jubinski (1999), it is likely that different types of 'news', such as scheduled macroeconomic announcements, option expiration days or company-specific earnings announcements, affect volatility and volume processes differently. For instance, macroeconomic announcements lead to relatively short-lived jumps in volatility but to longer-lasting increases in trading volume. In contrast, earnings announcements are typically accompanied by strong price shifts combined with relatively little trading activity. Including such idiosyncratic effects requires accounting for additional factors. However, instead of allowing for multiple latent factors (e.g., in Liesenfeld, 2001), the SMEM captures these effects in terms of *observation-driven* dynamics. This idea has been suggested by Bauwens and Hautsch (2006) and leads to a still flexible, but computationally less burdensome specification, since only one factor is assumed to be unobservable and must be integrated out.

[2] See, e.g., Epps and Epps (1976), Tauchen and Pitts (1983), Lamoureux and Lastrapes (1990), Andersen (1996) or Liesenfeld (2001).

[3] See, e.g., Ané and Geman (2000), Engle (2000), Grammig and Wellner (2002), Renault and Werker (2003), Manganelli (2005), Meddahi et al. (2006) or Bowsher (2007).