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Exposing volatility spillovers: A comparative analysis based on vector autoregressive models

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ABSTRACT

We present a comparative analysis of two empirical methods grounded on a common vector autoregressive framework. In this setting, we investigate the time-varying nature and direction of volatility spillovers between some major stock indexes spanning across Europe, China and US. We find evidence that drawing on partial Granger causality brings more robust results than relying on the information provided by generalized impulse responses, especially when there is uncertainty about what other relevant factors need to be modelled.

1. Introduction

This letter presents a comparative analysis of two empirical methods grounded on a common vector autoregressive (VAR) framework. We are looking to expose the time-varying nature and direction of volatility spillovers between some major international stock indexes, and to evaluate their robustness with respect to model misspecification and/or exclusion of relevant factors. It is important to state from the beginning that all our estimated models are specified directly in (daily) volatility terms to provide a more straightforward discussion and interpretation of the empirical results.

Firstly, we draw on the information provided by generalized impulse response functions (GIRFs), introduced by Koop et al. (1996). Order invariant GIRFs are better able to track the dynamics of shocks through a system of simultaneous equations, and therefore commonly used as a basis for evaluating volatility spillovers in the finance literature (see Diebold and Yilmaz, 2012). In order to characterize the direction of volatility spillovers, we only take into account the statistical significance of GIRFs *after* the initial impact, e.g. during the second and the third days of the simulation horizon. In this way, we avoid emphasizing the same-day effects, mostly because global stock markets trade during different time intervals (thus potentially biasing the direction of intraday volatility spillovers). Moreover, the existence of such a lag would offer a more intuitive link with the second empirical approach.

Secondly, we uncover the causal relationships between our stock indexes by employing the less-common *partial Granger causality* (partial GC) framework introduced by Guo et al. (2008) with applications to neural networks. Although standard GC (including partial GC) tests are not specifically designed to reveal the dynamics of a system, they provide similar insights

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as impulse responses in indicating the direction of interactions or spillovers between pairs of endogenous variables in a VAR setting. The main advantage of partial GC, however, is that it can remove (almost) all traces of common exogenous (measured) factors and latent (unmeasured) variables, assuming they have simultaneous effects on all the observed components of the system. While this assumption might be debatable in some other domains, it is less so in a highly interconnected global financial market.

Despite some expected overlapping in the two sets of results, our comparative analysis provides some initial evidence that the partial GC approach could be more robust in exposing the underlying volatility spillovers, especially when there is uncertainty about what other relevant factors need to be included in the model specification. We believe our insights might be useful to a larger body of research in economics, and particularly in finance.

2. Data and methods

Our data comes from Bloomberg and spans from April 1st to December 31st 2015. The sample includes daily high/low price levels for three major European stock indexes, i.e. CAC40 (henceforth CAC), DAX30 (DAX) and FTSE100 (UKX); one US index, i.e. Dow Jones Industrial Average (INDU); and one Chinese index - the Shanghai composite (SHCOMP). Since each index is denominated in a given currency, we also include EUR/USD, EUR/GBP, USD/GBP and USD/CNY currency-crosses. We approximate daily *volatility* based on intraday *high* and *low* price levels, as $volatility = 100 * \sqrt{0.361 * (\ln(high/low))^2}$.

Our sample covers some potentially important market stress events observed during the year 2015: the Greek referendum, the Chinese stock market rout, the Volkswagen emission scandal, the Paris terrorist attacks, and the FED rate hike (see Table 1 for more details). Within a highly connected financial system, locally-determined stress events can have global consequences. To grasp the time-varying profile of the volatility spillovers, we use a rolling-sample estimation technique, with the length of the window set at about two months of trading.[1]

We use (the log of) *volatility* measures for the five stock indexes and the four currency-crosses above to specify three vector autoregressive models with exogenous variables, or VARXs (Alter and Beyer, 2014). Specification labelled VARX1, which focuses on Europe, includes as endogenous volatility time-series for DAX, CAC, UKX and EUR/GBP, while both US and Chinese related factors (stock indexes and currency-crosses) are kept as exogenous. Specification VARX2 extends VARX1 by including two more endogenous variables, i.e. volatility time-series for EUR/USD exchange and INDU, both used here as proxies for influences arising from global capital markets; consequently, only Chinese related factors are kept as exogenous. Finally, specification VARX3 expands VARX2 by including two more variables as endogenous, i.e. volatility measures for USD/CNY exchange and SHCOMP to account for policy uncertainties arising in relation to a significant stock market rout in China.

All time-series are stationary within the windows used in the rolling-sample estimation (results not provided here to save space). Lag length selection is based on standard information criteria and residual tests (LM autocorrelation and White heteroskedasticity). Two lags are found to be appropriate in most cases (a minimum of one and a maximum of five lags is allowed for in some specifications or samples).

Within our first approach, we characterize the direction of volatility spillovers conditional on observing statistically significant GIRFs *after* the initial impact.[2] With a daily frequency data, we focus on the GIRFs on the second and third days of the simulation horizon. This is a convenient way to avoid dealing with differences in trading hours between Chinese, European and US stock markets, although adding currency-crosses (which trade mostly on a continuous basis) to our VARXs should be more effective in incorporating new information arrivals after the stock markets close.[3]

As a second method within our comparative analysis, we implement the partial GC approach (Guo et al., 2008; Seth, 2010) building on the VARX framework described above. Following a standard definition, a variable Y has a Granger casual influence on X, if Y reduces the variance of the prediction error of$X$, conditional on explicitly accounting for all exogenous (measured) factors and latent (unmeasured) variables (Granger, 1969; Geweke, 1982). This later assumption, however, is hardly fulfilled in empirical studies. Accordingly, failing to accurately capture all relevant factors can confound the underlying causal influences. Instead, partial GC draws on *conditional variance* and a convenient partitioning of the covariance matrix that effectively eliminates the influence of exogenous and latent factors. Focusing the discussion on stock indexes only (thus, disregarding currency-crosses), we use specification VARX1 to illustrate the partial GC between a given pair of European indexes, assuming that common exogenous influences can be well represented by US and/or Chinese related factors (both stock indexes and currency-crosses); for European and US indexes in specification VARX2, we assume exogenous influences are mainly Chinese-related; specification VARX3 is consistent with the existence of other latent or unmeasured factors (e.g. economic, social or political factors that might significantly affect stock markets worldwide during certain periods of time, but are not particularly accounted for in our specifications).

[1] We use a window size of 51 observations, allowing us sufficient degrees of freedom in the estimation. As robustness checks, we use window sizes of 46 and 56, but the main findings were qualitatively similar with the ones reported.

[2] The confidence interval is set as +/- 2 standard errors.

[3] Focusing exclusively on the same-day effects could bear the risk of *concluding* that Chinese stocks have volatility consequences on US stocks, but not vice-versa.