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Time-varying international stock market interaction and the identification of volatility signals ☆

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ABSTRACT

This paper investigates the dependency of international stock market interaction on financial volatility. We show in a stylized economic model that volatility-dependent cross-market spillovers can be interpreted in two different ways, as indicating *information* flow or *uncertainty*. If higher volatility in one market leads to higher (lower) reactions in another market, volatility reflects information (uncertainty). We apply a simultaneous time-varying coefficient model, where structural ARCH-type variances serve two purposes: governing the time variation of spillovers and ensuring statistical identification. We analyze data of US and further stock markets. Indeed, we find strong nonlinear, volatility-dependent spillovers.

1. Introduction

The present study investigates international stock market interaction and its dependency on financial volatility. We apply a flexible econometric approach to estimate and to interpret volatility-dependent cross-market spillover. Considering the public and academic discussion, we argue that two basic understandings of volatility could be distilled. On the one hand, the fact that prices vary can be interpreted as a sign of *information* flow. On the other hand, high variability is often seen as a mirror image of pronounced *uncertainty* in the market. Both views suggest volatility-dependent stock market interaction, albeit in different directions. We aim at empirically testing whether such a relation exists and to shed light on the role of volatility. We use a simple economic framework to motivate that higher volatility in one market should lead to higher (lower) reactions in another market if volatility reflects information (uncertainty). Secondly, we propose a strategy to infer the role of return variability from the data: we analyze different reactions of investors to observed returns, depending on the prevailing level of volatility. As our econometric framework, we apply a simultaneous time-varying coefficient model, where time variation is a function of ARCH-type variances. The analysis is based on daily data of major stock indexes from the Americas, Australia and the Asian region.

Let us first provide some background concerning the two interpretations of volatility we put up for discussion and review some literature we see connected to our line of reasoning. From one point of view, volatility is often associated with uncertainty or risk. Considering the global financial crisis for instance, future market developments are highly uncertain. In the public discussion, the image of fragile and disoriented financial markets prevails. Intuitively, the extensive stock market volatility is often interpreted as the reflection of this uncertainty. In the present study

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this concept of volatility shall be summarized as the *uncertainty hypothesis*.

Regarding the pricing of assets, it seems natural that investors expect to be compensated for bearing uncertainty in their portfolios. In fact, in academia the understanding of volatility as risk long plays an important role with a prominent example given by the μ-σ-utility function and the CAPM. Originating from Engle et al. (1987), financial econometricians translated this idea into the variance-in-mean model (see also French et al., 1987, Bali and Engle, 2010 and the references therein). Another example for volatility proxying uncertainty is given by interactions between output or inflation uncertainty and the conditional means of these variables (e.g. Grier and Perry, 2000). In a further strand of literature, numerous studies analyze how uncertainty about exchange rate movements affects trade volume and foreign direct investment, e.g. Cushman (1985), Chowdhury (1993) and Kiyota and Urata (2004). For instance, volatility might negatively impact the size of trade flows if exchange rate uncertainty renders trade less profitable for risk averse agents.

On the contrary, a second view interprets volatility as a measure of information flow intensity. We refer to this perception as the *information hypothesis*. Some representatives of the literature who elaborate on the volatility-information link are Clark (1973), Epps and Epps (1976), Ross (1989) and Fleming et al. (1998). Overall, as in the mixture-of-distribution hypothesis, the idea is that no motivation for further trading would exist in a situation where all prices have settled at their equilibrium values. Thus, volatility would be zero in absence of relevant news. If, however, additional information becomes available, price adjustments will generate fluctuations until a new equilibrium is reached. Of course, in reality, shocks are too frequent to allow conventional asset prices to ever settle at some constant consensus value, and perception and handling of information both represent more complicated processes than assumed in stylized economic models. Nonetheless, the line of reasoning exemplifies how volatility is connected to information arrival.

The information content of price movements is normally not observable. This is likely to be one of the main reasons why information flow was connected to volatility in the first place. By the same token, a strand of literature examined trading volume as an observable variable that is at least partly driven by the information arrival process; see Tauchen and Pitts (1983), Harris (1987), Lamoureux and Lastrapes (1990), Foster and Viswanathan (1993, 1995), Gagnon and Karolyi (2009). Certainly, volume cannot *explain* volatility, in the sense of an exogenous variable. Instead, both are affected simultaneously by the latent information process. Moreover, many trades are unlikely to be linked to information arrival, such as in the cases of liquidity management (e.g. Andersen, 1996), strategic trading under asymmetric information (e.g. Kyle, 1985) or differences of opinions on the interpretation of signals (e.g. Kim and Verrecchia, 1991). Attempts have been made to proxy information arrival directly by, for example, central bank decisions, macroeconomic news or firm-specific announcements. For studies of corresponding volatility effects, see e.g. Andersen and Bollerslev (1998), Kalev et al. (2004) or de Goeij and Marquering (2006). Nonetheless, even if important insights into news effects could be gained, such direct observable measures cannot represent more than a fraction of the universe of information arriving in financial markets. Above all, they hardly capture private information, which is a major factor behind volatility (French and Roll, 1986).

Our distinct hypotheses help to fix ideas concerning the character of volatility. Naturally, they are not mutually exclusive. Rather, exploring how volatility affects stock market interaction amounts to asking which effect predominates. In fact, this calls for a mechanism connecting the latent variables information and uncertainty to a measure that is estimable from the data. In the present approach, we propose letting the reaction of market participants decide the character of volatility instead of leaving this task up to the econometrician. Specifically, we make use of the intensity by which shocks feed into actual market prices, thereby connecting a high intensity to high information content, as further explained below.

In the empirical analysis, we will also allow for leverage effects, i.e. positive (good news) and negative shocks (bad news) may have different effects on volatility. The distinction we make between the *information hypothesis* and the *uncertainty hypothesis* is, however, different from asymmetric volatility reactions. While accounting for possible leverage effects, we analyze how the level of volatility influences the spillover of shocks between markets. Thereby, for instance information can equally result from both good and bad news.

Logically, while shocks can be identified in the "source" market, transmission intensity is measured in the "target" market. In case observed price changes in the source market are interpreted as highly informative (uncertain) signals by the target market, the latter will incorporate a relatively large (small) fraction of the innovation into its own price. We illustrate this principle in a stylized economic model, based on signal extraction by rational agents. Overall, high volatility in the target market associated with high spillover intensity would support the information hypothesis, while evidence for the uncertainty hypothesis would follow from an inverse linkage.

Econometrically, we measure this nonlinear effect in a time-varying coefficient model governed by the (autoregressive) conditional variance of the source market, i.e., we utilize time variation in volatility to identify its impact on transmission intensity. Such an empirical strategy has not yet been considered in the literature. Our concept does not aim at explaining the mere fact that markets are interconnected, e.g. by trade, policy coordination or common shocks. Rather, we exploit the existing interaction for estimating the spillover intensity and its link to volatility. Furthermore, the a priori division into "source" and "target" markets is an artificial one. In reality, once one introduces spillover effects, one must take a stance on how to resolve endogeneity. Our model set-up to analyze international stock market interaction will generally allow for bi-directional transmission between the US and the second country of interest. Identification is achieved by making use of the heteroskedasticity in the data, which can be exploited to uniquely pin down the structure of simultaneous systems; compare Sentana and Fiorentini (2001) or Rigobon (2003). Therefore, both the direction and the size of spillovers can be determined empirically. These considerations on simultaneity apply to markets with overlapping trading hours, like in the Americas. For models of the US and the major Asian or Australian stock indexes, the spillover direction is given by the sequence of time, since these markets trade with substantial time shifts. Consequently, identification problems are alleviated in this setting.

Our first major result is that in all countries under investigation spillover intensity significantly depends on volatility. As regards the information content of volatility, our results tell that it crucially depends on the combination of "sender" and "receiver" of volatility signals. For industrial countries, the information hypothesis holds. As for most emerging economies, however, the uncertainty hypothesis prevails in their relations to the US.

The rest of the paper proceeds as follows. The next section presents a stylized model of stock market returns and derives the testable hypotheses. Section 3 introduces the econometric model and discusses identification issues and the estimation procedure. Section 4 applies the methodology to daily returns of major stock indexes from the Americas, Australia and the Asian region. The last section concludes.