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Who moves first? An intensity-based measure for information flows across stock exchanges

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ABSTRACT

In this paper we propose an innovative measure for information flows between stock exchanges. We develop an intensity-based information share using Russell's (1999) autoregressive conditional intensity model. Thereby we maintain the irregular nature of financial high frequency data and use durations and timing of price changes to determine the informationally dominant market. From our empirical application to US-listed Canadian stocks we conclude that the home market mostly reflects information first. On the basis of a cross-sectional analysis we find a positive correlation between the intensity-based information share and liquidity.

1. Introduction

The last decade has seen increasing globalization and improved technology concerning the trading of financial assets. This development has sharpened competition among stock exchanges around the world, in particular where exchanges compete for the same crowd of investors, as in the case of cross-listed stocks. In order to attract investors, exchanges have to provide an efficient trading environment, where information is incorporated into prices as quickly as possible. This renders the contributions of each trading venue to the price discovery process of the common stock a quality feature.

This paper contributes to the current literature by proposing an alternative price discovery measure (*information share*). Our information share is based on Russell's (1999) autoregressive conditional intensity model (ACI). This bivariate intensity approach accounts for the informational content of time between consecutive quoted price changes within a market as well as the timing interdependencies between the price processes on both markets. In contrast to the commonly applied Hasbrouck (1995) methodology, we exploit the irregular occurrence of price changes and deliver a unique information share. We apply our new measure to Canadian stocks that are traded on the Toronto Stock Exchange (TSX) and cross-listed on the New York Stock Exchange (NYSE). Furthermore, we examine potential determinants of information shares in a cross-sectional analysis.

Evidence from previous studies suggests that price discovery for cross-listed stocks mainly takes place in the home market. Eun and Sabherwal (2003) examine a sample of US-listed Canadian stocks based on the relative adjustment of prices in a market to deviations from the equilibrium price. They conclude that the contribution of the US market cannot be neglected, but that the home market clearly dominates price discovery. Adjustment coefficients as a measure of price discovery, however, have been criticized, since they do not account for the contemporaneous correlations and variances of markets' price innovation (see De Jong, 2002; Baillie et al., 2002). The majority of empirical studies apply Hasbrouck's (1995) method, in which the information share is defined as the contribution of a market's price innovation to the variance of the efficient underlying price innovations. Grammig et al. (2005), Hupperets and Menkveld (2002) and Korczak and Phylaktis (2010) use the Hasbrouck (1995) methodology to estimate the home and foreign market share in price discovery for US-listed stocks from various countries. They conclude that trading on the home market stock exchanges contributes most to price discovery, while trading on the NYSE primarily takes place to offset arbitrage opportunities.

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The main drawback of the Hasbrouck (1995) approach is that it merely delivers upper and lower bounds for an information share. The method requires equidistant sampled quotes and, depending on the chosen sampling frequency, the information share bounds can diverge considerably. Consequently, the conclusions concerning the leading market are rather vague (see Hupperets and Menkveld (2002) and Korczak and Phylaktis (2010)).[1] We take an alternative view on how to quantify the informational linkage between different exchanges trading the same underlying asset which is motivated by the following considerations. First, as acknowledged in the financial markets literature (e.g. Dufour and Engle, 2000; Engle, 2000; Engle and Lunde, 2003; Frijns and Schotman, 2009), the irregular occurrence of trades and quotes and the time between consecutive financial market events reveal the dynamics of price responses to new information in the market. Hence, arbitrary sampling schemes used to obtain regularly spaced data neglect this aspect of the price dynamics and induce an undesirable loss of information. Second, as pointed out by Hasbrouck (1995), "... the information share measures *who moves first* in the process of price adjustment." If price discovery is indeed understood as which market "moves first", an information share measure that is derived from a model that directly accounts for the irregular sequence and timing of the price process seems to be a straightforward approach. We exploit the irregularity of high frequency stock market data and propose an alternative information share by modeling the arrival rates (intensities) of the price processes using Russell's (1999) ACI model. Within this framework the dynamics of the intensity functions are driven by innovations that allow for a flexible interaction and simultaneously affect the conditional intensities in both markets.

In the case of cross-listed securities the law of one price applies and deviations from the equilibrium price can only be transitory. Consequently, when prices in both markets deviate, adjustment has to take place to restore the equilibrium. The main question is which market moves first and which markets adjust to restore the equilibrium price? If the market event that caused the deviation was due to new information, the arbitrage relation between prices in parallel markets forces an immediate incorporation of new information into the other market's price thereby increasing its intensity. This translates into positive spillover effects due to the innovations. We argue that the larger the effect of an innovation in one market on the other market's intensity, the greater is its intensity-based information share, i.e. the information flow that originates from this trading venue.

We empirically analyze the price discovery process of Canadian stocks traded on the TSX and cross-listed on the NYSE. Our results show the TSX to be a clear leader in the price discovery process. With an average information share of 73%, the contribution of the TSX is more pronounced than indicated by Eun and Sabherwal (2003).

We also examine potential determinants of a market's contribution to price discovery by conducting a cross-sectional regression of the intensity-based information share on stock-specific factors and liquidity-related variables.

Eun and Sabherwal (2003), Korczak and Phylaktis (2010), Grammig et al. (2005) and Frijns et al. (2010) among others analyze the determinants of price discovery in the home and foreign market and find a positive relation between the contributions to price discovery and liquidity. In line with this research, our results show that liquidity proxies are the only variables that are related to a market's price determination. This implies that providing an efficient and liquid trading environment is of particular interest for small national stock exchanges that seek to maintain their dominance in the price discovery process of cross-listed stocks.

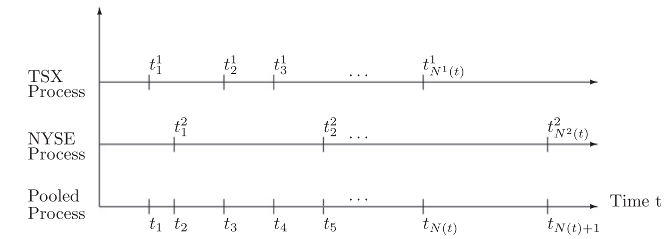

Fig. 1. Pooled point process illustration. The figure gives an illustration of a simple point process $N(t)$ that consists of two individual counting processes, $N^1(t)$ and $N^2(t)$. $\{t_i^1\}_{i=1}^{n^1}$ denotes the arrival times of events on the TSX and $\{t_i^2\}_{i=1}^{n^2}$ corresponds to price event times on the NYSE. A time sequence $\{t_i\}_{i=1}^{n}$ containing both event time series is obtained by pooling and ordering the individual event times. As a consequence, an event occurring on the TSX not only depends on its own history, but depends on the history of the NYSE process as well, and vice versa.

The remainder of the paper is organized as follows. Section 2 outlines the methodological details of the ACI model, describes the data and introduces the intensity-based information share. In Section 3 we present estimation results and discuss the estimated information shares. A cross-sectional regression analysis is provided in Section 4. Section 5 concludes.

2. A new measure for contributions to price discovery

2.1. The autoregressive conditional intensity model

In our empirical application we consider stocks that are simultaneously traded on the TSX and the NYSE. This section introduces a bivariate autoregressive conditional intensity (ACI) model that is applied to the price events[2] of a stock listed on both markets. We start by defining the point process $\{t_i^s\}_{i=1}^{n^s}$ as the stochastic sequence of price changes on the market s in calendar time t, where $s = 1$ corresponds to a price event on the TSX and $s = 2$ refers to a price event on the NYSE. The associated counting functions that establish the number of s-type events over t are indexed by $N^s(t)$. Pooling and ordering of the arrival times, t_i^1 and t_i^2, yields a simple point process $\{t_i\}_{i=1}^{n}$ with counting function $N(t)$. We assume that the arrival times are strictly distinct, $0 < t_1 < t_2 < \ldots < t_n$. Based on this assumption, the individual point processes are strictly orderly, too. Fig. 1 gives an illustration of a pooled point process $N(t)$ consisting of two individual processes $N^1(t)$ and $N^2(t)$.

The internal filtration denoted by $\Im_t$ consists of the complete information path of the left continuous counting process $N(t)$. The $\Im_t$-intensity process that characterizes the evolution of $N^s(t)$ is then

$$\lambda^s(t;\Im_t) = \lim_{\Delta\to 0}\frac{1}{\Delta}\mathbb{P}[N^s(t+\Delta) - N^s(t) > 0, N^{s'}(t+\Delta) - N^{s'}(t) = 0|\Im_t] \quad (1)$$

$\forall s \neq s'$, where $s' = 1, 2$. Eq. (1) gives an instantaneous probability of observing an s-type price event conditional on the information set available at t.

Russell's (1999) ACI model defines the s-type conditional intensity function as

$$\lambda^s(t;\Im_t) = \lambda_0^s \psi^s(t)\phi^s(t). \quad (2)$$

The baseline intensity function that defines the deterministic evolution of the intensity function of the price events in the s^{th} market is

[1] Grammig and Peter (forthcoming) propose a methodology to uniquely determine Hasbrouck information shares. They use distributional assumptions to identify unique information shares using daily data. Generally, the assumptions on which they base their identification, are rather suited for middle and low frequency data and often are not supported by the high frequency data, such as the data used in our empirical application.

[2] We define informative price events as cumulated absolute midquote changes. A detailed description follows in Section 2.2.