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How well does the weighted price contribution measure price discovery? ☆

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ABSTRACT

The weighted price contribution (WPC) is a popular measure for price discovery. This paper examines the theoretical properties and empirical performance of the WPC in sequential markets. The benchmark used to judge the WPC is the information share (IS) measure based on the variation of the efficient price. We derive the asymptotic value of the WPC, which is a complex combination of the unconditional means and variances of the returns of sequential markets, under the assumption of normality. We show that the WPC correctly converges to the IS only when the returns are uncorrelated with zero means. Our theoretical predictions based on normality hold well in simulations and in empirical analyses of the overnight price discovery for the S&P 100 index and its constituent stocks. As the correlation between overnight and daytime returns increases, the WPC deviates from the IS substantially.

1. Introduction

A core function of financial markets is price discovery, the process that incorporates new information into asset prices. How well a trading venue performs the price discovery function has a significant impact on the valuation (e.g. Lee, 2001), the liquidity (e.g. O'Hara, 2003), and the volatility (e.g. Andersen, 1996) of the traded assets. It also plays an important role in determining the cross-market correlations in price, liquidity, and volatility (e.g. Andersen et al., 2003; Domowitz et al., 2005; Karolyi et al., 2012). As argued by Mishkin (2009), the effectiveness of price discovery in asset markets has a direct impact on the effectiveness of monetary policies during financial crises. As new technologies and trading venues replace the

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traditional exchange-based market structure, their impact on price discovery and market efficiency will be an important issue for investors, regulators, as well as researchers.

A key issue in the study of the price discovery process is the measurement for the effectiveness of price discovery at a given trading venue. Early studies of price discovery measures focus on parallel markets where the same asset (or highly correlated assets) is traded simultaneously in different venues, e.g. NYSE versus NASDAQ. Hasbrouck (1995) and Harris et al. (2002) are the two dominant models for parallel markets and have been adopted by numerous studies. They are analysed and compared in a special issue of the Journal of Financial Markets in 2002. Yan and Zivot (2010) use a structural cointegration model to bring new insights to the comparison. Lien and Shrestha (2009) and De Jong and Schotman (2010) introduce additional structures to improve the Hasbrouck model. Note that these models are designed for parallel markets and are inappropriate for non-overlapping markets (e.g. Tokyo and New York) or time periods (e.g. the pre-opening period and exchange trading hours). This limitation is addressed in Wang and Yang (2011), which proposes a model for measuring price discovery in non-overlapping sequential markets in the spirit of Hasbrouck (1995).

The current study examines a popular non-parametric measure of price discovery in sequential markets, known as the weighted price contribution (WPC). It was originally proposed by Barclay and Warner (1993) to measure price movements associated with different transaction sizes. Cao et al. (2000) is the first to adopt it as a price discovery measure for sequential time periods and gives it the current name. The WPC has been used to measure price discovery during the pre-opening period (Cao et al., 2000), during overnight trading (Barclay and Hendershott, 2003, 2008), and during opening and closing call auctions (Ellul et al., 2005). The need to empirically measure price discovery in sequential periods and the simplicity of the WPC greatly enhances its popularity, particularly for supplementing and supporting the core methodology and findings (e.g. Owens and Steigerwald, 2005; Agarwal et al., 2007; O'Hara et al., 2014).

Although the WPC is used in many studies, few have explored its validity as a price discovery measure.[1] Consider a trading day t that is divided into n consecutive periods. Let $p_{i,t}$ be the log price of an asset at the end period i on day t. Let $r_{i,t}=p_{i,t}-p_{i-1,t}$ be the return in the ith period and $r_t=\Sigma_{i=1}^{n} r_{i,t}$ be the daily return. The WPC of the ith period is defined as

$$WPC_i=\sum_{t=1}^{T}\frac{r_{i,t}}{r_t}\left(\frac{|r_t|}{\sum_{s=1}^{T}|r_s|}\right),\ i=1,\dots,n. \tag{1}$$

The perceived validity of the WPC as a price discovery measure seems to come from its definition: the contribution of the ith period to price discovery is measured by the cross-day weighted average return ratio $r_{i,t}/r_t$, with the weight for day t being $|r_t|/\Sigma_{s=1}^{T}|r_s|$. Is $r_{i,t}/r_t$ a valid measure for price discovery in the ith period? Is the WPC consistent with the definition of price discovery as the process of incorporating new information into asset prices? This paper aims to explore the economic underpinning and the empirical performance of the WPC. We derive the asymptotic expression for the WPC in (1) under the assumption of normality. We show that it is primarily a measure of the volatility ratio across periods, not the return ratio as it appears. We explore the theoretical relationship between the WPC and the characteristics of the return series: its mean, variance, and serial correlation. We then draw theoretical comparison between the WPC in (1) and a benchmark measure of price discovery. Our benchmark is the information share (IS) measure proposed by Wang and Yang (2011), which is based on the variation in the efficient price as in Hasbrouck (1995). We show that the WPC becomes a consistent estimator of the IS only when returns are uncorrelated and have zero means. The difference between the IS and the WPC crucially depends on return characteristics, especially return serial correlations. Our theoretical results are confirmed by simulation experiments, where non-normality does not have noticeable effects.

We support our theoretical findings by drawing empirical comparisons between the WPC and the IS in the context of estimating the overnight and daytime price discovery for the S&P 100 index and its current constituent stocks. Several studies have documented significant overnight or pre-opening price discovery when the organised exchanges are closed (e.g. Cao et al., 2000; Barclay and Hendershott, 2003, 2004, 2008; Moulton and Wei, 2005). Tompkins and Wiener (2008) and Cliff et al. (2008) document positive overnight returns and negative daytime returns across major international markets. The overnight price discovery is reflected in the price change between today's market close and next day's market open. We use the WPC and the IS measure of Wang and Yang (2011) to estimate overnight price discovery. The main empirical findings are the following:

- For the S&P 100 index, the annual time-series analyses indicate that the overnight WPC is indeed largely determined by the ratio of overnight and daytime return standard deviations, consistent with the theoretical analyses. The asymptotic values of the overnight WPC are very close to the estimated WPC. The difference between WPC and IS is mainly driven by the correlation between overnight and daytime returns and the standard deviation ratio.
- The cross-sectional analyses based on the S&P 100 stocks confirm that the ratio of overnight and daytime return standard deviations is an important determinant of the overnight WPC. Furthermore, the correlation between overnight and daytime returns has strong effects on the overnight WPC and its deviation from the overnight IS. Both effects are consistent with the theoretical predictions. Other return characteristics (such as skewness and kurtosis) do not have strong effect on the WPC and its deviation from the IS.
- In recent years, the high correlations between the overnight and daytime returns of the S&P 100 Index have resulted large deviations between the estimated WPC and IS.

[1] We are aware of only Van Bommel (2011), which explores the statistical properties of the WPC. We relate our study to that of van Bommel in Section 2.