



Understanding price discovery in interconnected markets: Generalized Langevin process approach and simulation



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ABSTRACT

While the literature on price discovery process and information flow between dominant and satellite market is exhaustive, most studies have applied an approach that can be traced back to Hasbrouck (1995) or Gonzalo and Granger (1995). In this paper, however, we propose a Generalized Langevin process with asymmetric double-well potential function, with co-integrated time series and interconnected diffusion processes to model the information flow and price discovery process in two, a dominant and a satellite, interconnected markets. A simulated illustration of the model is also provided.

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1. Introduction

Price discovery process and reaction to the arrival of external shock plays an important role in understanding asset pricing and intrinsic unobserved asset value (Easley and O'Hara, [1]). Such processes have been extensively studied in the market microstructure literature using various time series tools and techniques [2–6]. The price discovery process of securities bought and sold on different markets has also been studied [7,8]. This paper contributes to the literature as we introduce an alternative approach to understanding of the price movement in interconnected markets. Our model is inspired by two seemingly unrelated results: (a) simulations of the Langevin process and its application to model the currents and paths of the particles in a reservoir with the asymmetric double well potential following a sudden change in temperature (Chen [9]), and (b) patterns of cumulative impulse response functions describing the price movements of co-integrated securities (Hasbrouck, [4]).

The applications of the laws of thermodynamics and Brownian motion to describe the behavior of financial assets are far from unique. After Bachelier [10] connected stock price movements with the arithmetic Brownian motion, his idea was furthered in the 1950s and 1960s (Smith, [11]). The genre of Black–Scholes (Black and Scholes, [12]) option price models and their further development assumes that asset prices follow geometric Brownian motion. These earlier models were predominantly linear and used a Gaussian distribution assumption for the asset prices. Ray [13] while pointing out that the 1990s saw the development and popularity of research methodology that included non-linear models, scaling laws, statistical mechanics, concludes further application of the tools of econophysics (Chakrabarti [14] attributes physicist H. Eugene Stanley to have first coined the term) to understand economics and finance concepts. Accordingly, this paper contributes to the growing literature in econophysics as it applies the generalized Langevin process to describe price

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discovery in interconnected markets. The general model of price discovery in a closed system of two interconnected sub-systems can be extended to understanding the price discovery process in international markets as well as pricing of the one security traded in several markets.

The rest of the paper is organized as follows: Section 2 presents an overview of the existing price discovery studies and Langevin process. Our model is introduced in Section 3, an example and simulation results are presented in Section 4. Section 5 concludes with the summary and discussion of the model and direction for the future research.

2. Literature review

2.1. Price discovery in the interconnected markets

The price discovery studies focusing on multiple trading in equities originated in the 1970s (Garbade and Lieber [15]). Garbade and Silber [16] develop a model for dominant and satellite markets and empirically study transactions for commonly traded securities on NYSE and regional exchanges. Ross [17] finds that in arbitrage free economy the rate of information flow is directly related to the volatility of prices. Low and Muthuswamy [18] examine joint dynamics of futures prices between two competing single fixed-price auction markets, and find a lack of co-integration in the futures prices on two exchanges. Their finding is explained by the non-stationarity of cost of carry, and trading cost differentials. Horvath and Scott [19] model plunging and dumping behavior using an expected utility model. Goodhart [20] looks at the foreign exchange market reactions to exogenous news announcements and their perceived tendency to “overshoot” and then adjust towards the equilibrium. Peiers [21] examines leadership positioning in foreign exchange trading by focusing on spot rate revisions around an exogenous news event using Granger-causality tests. He investigates Goodhart’s [20] hypothesis that short-run informational asymmetries establish prices leaders.

Hasbrouck [2] suggests the existence of the implicit unobservable efficient price common to all the markets for the closely linked securities that trade in multiple markets. He focuses on the variance of the efficient price innovation. The information share (IS) is defined as the proportional contribution of those market innovations to the innovation in the underlying common efficient price (Hasbrouck [2]). It is assumed that each price in the system contains a latent random walk component, or efficient price. The method focuses on the random walk component after the removal of transient microstructure effects. This measure can be applied to examine the stock prices on multiple exchanges. Hasbrouck [2] posits that for a single underlying security or index, the random walk component is the same for all prices in the multiple exchanges or markets. The security prices are assumed to be linked by linear arbitrage relationships and therefore represent co-integrated time series for spot and futures prices. The vector error correction model (VECM) approach is used to estimate the parameters of the reduced form econometric model. Impulse response functions are then used to interpret the system parameters. The IS measure is applied to examine the price discovery process between S&P 500, S&P 400 MidCap and Nasdaq 100 indices, ETF’s and E-Mini’s in S&P 500 and Nasdaq 100 (Hasbrouck [4]). This study concludes that E-Mini futures make a significant contribution to the price discovery for S&P 500 and Nasdaq 100 where similar patterns are observed. On the other hand, the price discovery for S&P MidCap 400 index which lacks E-Mini futures, is dominated by the ETF (Figure 3 in Hasbrouck [4]).

The modification of Hasbrouck’s IS was used by Chakravarty et al. [22] to study the price discovery in option markets. In that study, the observed stock price is assumed as a sum of the implicit efficient stock price, which serves as a state variable for the observed stock and call option prices, and white noise arising from microstructural frictions. Using the Hasbrouck’s information share methodology, Chakravarty et al. [22] find that the proportion of information revealed in the option markets depends on the characteristics of underlying stocks. Option markets transmit higher information shares when option trading volume is high and stock volume is low, when the option effective spreads are narrow and stock spreads are wide. The authors find that on average price discovery in the options markets is lower when the underlying volatility is higher.

Alternatively, Gonzalo and Granger [23] provide a new insight into common factors for economic time series that ensure co-integration. They propose another measure of the market’s contribution to price discovery as a component weight of the market in efficient price innovation formation by decomposing price series into transitory and permanent components. Gonzalo and Granger [23] provide a method to study a co-integration by using common “long-memory” factors in large economic systems. Harris et al. [24] follow that approach, and use synchronous transactions data for IBM stock from NYSE, PSE and MSE, and apply VECM to investigate which of the exchanges contributes to price discovery. They find that the prices on all three exchanges depend on price differentials relative to NYSE, and confirm prior research findings that a more informed trades are executed on NYSE. Harris, McNish and Wood [25] also use Gonzalo and Granger [23] approach to study Dow Jones Industrial Average stocks trading on three informationally linked stock exchanges.

Several papers have researched the price discovery process for stocks listed on several exchanges across different countries [6,26–36]. While these manuscripts investigate the price discovery process for securities listed in different markets, within and across countries, they do not use the Langevin process.

Our motivation for the process developed in this manuscript, is to gain insight into the price discovery process of securities listed on different markets. We assume that market prices of securities listed on different markets, share the same efficient price connected to the fundamental value of the asset and are subjected to shock, e.g. new information about the fundamental value of the asset; the price discovery process is characterized by the speed of adjustment from “old”, pre-shock, to “new”, post-shock, equilibrium prices in the interconnected markets (Yan and Zivot [37], Putnins [38]). An extension of this logic

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