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Measuring stock market resiliency with Discrete Fourier Transform for high frequency data

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HIGHLIGHTS

- Stock market resiliency as one of market liquidity dimensions is investigated.
- A new methodology for resiliency estimation is introduced.
- Discrete Fourier Transform for high-frequency intraday data is utilized.
- A modified formula for resiliency proxy with a window function is yielded.
- Real-data analysis of market resiliency on the Polish stock market is provided.

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ABSTRACT

In this paper, we investigate market resiliency as one of the stock market liquidity dimensions. A new methodology for stock resiliency measurement based on Discrete Fourier Transform (DFT) for high-frequency intraday data is introduced. The known disadvantage of DFT is signal leakage. Therefore, the modified formula for resiliency proxy that decreases the signal leakage impact by filtering is utilized. Three alternative window functions are employed: (1) the Hamming window, (2) the Kaiser window, and (3) the SR785 Flat-Top window. Furthermore, there is provided statistical analysis of the results, including its significance and some additional properties. The findings of empirical experiments for real-data from the Warsaw Stock Exchange reveal that the results rather turn out to be robust to the choice of the window filter. Thus, the DFT approach might be considered an auspicious resiliency proxy with an intuitive base.

1. Introduction

According to the literature, the majority of researchers follow Kyle [1] and they distinguish between three dimensions of market liquidity: depth, tightness, and resiliency. Wong and Fung [2] pointed out that another commonly used concept is immediacy, but it incorporates elements of all three dimensions, and therefore it do not have to be considered as a separate dimension. Bernstein [3] mentioned the following three dimensions: depth, breadth, and resiliency. He stressed that these three attributes are generally accepted as the basic requirements for good markets. Harris [4] emphasized that what people think about liquidity, is trading quickly, about trading large size, or about trading at low cost. However, people rarely distinguish among three dimensions when discussing liquidity. Luo et al. [5] highlight that liquidity can be defined as market resiliency in terms of dynamism. Foucault et al. [6] also stress that resiliency is a dynamic dimension of market liquidity and they specify resiliency as the speed at which liquidity returns to a "normal" level after a trade. In practice, if

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the resiliency of a market is high, an investor can accelerate the execution of a large order. If resiliency is low, an investor should trade more slowly.

It is important to note, that although there is a growing body of empirical literature concerning direct measurement of liquidity, relatively little empirical research has been conducted directly on the liquidity dimensions of equity markets in the world. Market depth has been investigated more extensively than other dimensions of liquidity. Moreover, there has been quite extensive research on bid/ask spread, which may be treated as a measure of market tightness. However, the least empirical investigation has been conducted on the stock market resiliency, as this dimension of liquidity is especially difficult to estimate. Ranaldo stresses that since resiliency is a measure of price elasticity, it is difficult to formulate straightforward indicator to gauge it [7].

The main goal of the paper is to introduce and employ a new methodology for estimation of stock market resiliency with Discrete Fourier Transform (DFT) for high-frequency intraday data. The additional aim is a real-data investigation of the dimension for the Warsaw Stock Exchange (WSE). An analysis of robustness of the empirical results to the choice of the window function that is used in the DFT formula is conducted. We can assert that the obtained results turn out to be robust to the choice of the window filter. Moreover, we provide an analysis of the obtained results with respect to the whole sample period from January 2005 to December 2016 and three consecutive subsamples, each of equal size: pre-crisis, crisis, and post-crisis periods. The Global Financial Crisis (GFC) on the Polish financial market is formally established based on the paper by Olbrys and Majewska [8], in which the Pagan and Sossounov [9] method for statistical identification of market states is employed. We assess whether the empirical results of market resiliency during the GFC period significantly differ compared to the other investigated periods.

It is worthwhile to note, that other dimensions of market liquidity have been analysed for intraday WSE data. For example, Olbrys and Mursztyn [10] have investigated two dimensions of Polish stock market liquidity: market depth and market tightness. Olbrys [11] has conducted the study of interaction between market depth and market tightness on the WSE. However, to the best of the authors knowledge, some results regarding measurement of market resiliency using DFT for high-frequency intraday WSE data are novel and have not been reported in the literature thus far.

The remainder of the study is organized as follows. Section 2 presents a brief literature review concerning stock market resiliency. Section 3 specifies a methodological background. Section 4 contains real-data description as well as presentation and discussion on the results of empirical experiments for the WSE data. The last section encompasses the conducted research with a summary.

2. Resiliency as one of dimensions of market liquidity

A resilient market is a one in which prices recover from random liquidity shocks quickly. As Kyle [1] emphasizes, market resiliency measures the rate at which prices bounce back from an uninformative shock. In a highly liquid market, with respect to resiliency, prices bounce back immediately to their unmitigated level [12]. Therefore, some researchers argue that an estimation of price reversal can be a natural measure of market resiliency [13].

As mentioned in Introduction, since resiliency is a measure of price elasticity, it is difficult to define straightforward indicator to estimate it. Moreover, as Rosu [14] stresses, assessing market resiliency is difficult since it would involve having access to information that is not public. Therefore, there is no unanimity in measuring market resiliency. Empirical studies have adopted various procedures. For example, some researchers examine market resiliency using VAR based approaches, e.g. [15–19]. Dong et al. [20] utilize a Kalman-filter methodology to estimate resiliency. Huang and Stoll [21,22] propose a procedure to decompose the effective bid/ask spread into information and immediacy-related (price reversal) components. The authors estimate the realized spread as the price reversal component of the effective bid/ask spread. Hence, the realized spread may be treated as a measure of market resiliency. Ranaldo [7] applies similar approach. He approximates market resiliency for intraday data from the Swiss Stock Exchange, with ultra-short rate of return over a period of 10 min. Muranaga and Shimizu [23,24] argue that the restoration speed of a coil (which is an indicator of resiliency in physics) can be used as a measure of stock market resiliency. They investigate tick-by-tick data from the Tokyo Stock Exchange. Degryse et al. [25] analyse resiliency for 20 selected companies from the Paris Bourse. They carry on an event study in the context of aggressive orders. Gomber et al. [26] also employ event study methodology. There is used data from the Frankfurt Stock Exchange and the authors disclose resiliency after large transactions high, i.e., liquidity quickly reverts to "normal" levels. Weber and Rosenow [27] study time-dependent correlations between order flow and returns and they reveal strong evidence for resiliency. The Island ECN order book (coming from NASDAQ) was utilized in their research.

Some researchers conduct theoretical studies of market resiliency. For example, Foucault et al. [28] and Large [29] propose theoretical models of order book resiliency, and models are supported by numerical simulations. Following the dynamic model developed by Foucault et al. [28], Kempf, Mayston and Yadav [30] carry on an empirical study concerning market resiliency on the Frankfurt Stock Exchange.

Kim and Kim [31] employ a spectral analysis in frequency domain and they construct a resiliency measure using Discrete Fourier Transform (DFT) for daily data. Resiliency is defined as quickness of price recovery from a liquidity shock. The authors measure resiliency for individual equities as the speed of mean reversion of the transitory price component. The higher price reversal speed is, the lesser impact of random price changes is observed on an asset valuation process. Hence, the faster a reversal move is, the more resilient an asset becomes. On the contrary, decreasing reversal speed intensifies investment risk. An asset time series transformation to spectral domain is utilized to acquire value of reversal speed. Then, higher speed will be shown with lower frequency peaks.