

# MARKET MICROSTRUCTURE – A HIGH FREQUENCY ANALYSIS OF VOLUME AND VOLATILITY INTRADAY PATTERNS ACROSS THE BRAZILIAN STOCK MARKET

## *MICROESTRUTURA DE MERCADO - UMA ANÁLISE DE ALTA FREQUÊNCIA DO VOLUME E DOS PADRÕES DE VOLATILIDADE EM TODO O MERCADO DE AÇÕES BRASILEIRO*

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Alexandre Silva da Costa<sup>1</sup>

Paulo Sergio Ceretta<sup>2</sup>

Fernanda Maria Müller<sup>3</sup>

### ABSTRACT

*We investigate market microstructure with high frequency data for all stocks that participate in the Ibovespa index, traditional and influential Latin American index. Market microstructure has been widely investigated in developed markets however not many studies focus on developing countries such as Brazil. We modeled volatility with a straightforward method using standard deviation as proxy, and classified the volume traded of all Ibovespa stocks in every 10 minutes interval of the trading days sampled. In the end, we found similarities of previous investigations documented in financial literature such as the stylized facts L-shape pattern for volatility and the U-shape for volume. One interesting finding is that during the most active trading time, the interval that comprises the closing call, volatility slumps; on the other hand, the second most active trading time, the opening, displays extreme volatility.*

**Keywords:** *Intraday, Volatility, Volume, Market Microstructure.*

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<sup>1</sup> Possui graduação em Administração de Empresas pela Universidade Federal de Santa Maria, UFSM e mestrado em andamento em Administração pela Universidade Federal de Santa Maria, UFSM. Santa Maria. Rio Grande do Sul. Brasil. E-mail: xandicosta@gmail.com

<sup>2</sup> Possui graduação em Administração pela Universidade Federal de Santa Maria, UFSM, mestrado em Engenharia de Produção pela Universidade Federal de Santa Maria, UFSM e doutorado em Engenharia de Produção pela Universidade Federal de Santa Catarina, UFSC. Atualmente é Professor Associado da Universidade Federal de Santa Maria, Revisor de periódico da REAd, Revisor de periódico da Revista Brasileira de Finanças, Revisor de periódico da Revista de Ciências da Administração (CAD/UFSC), Revisor de periódico da Latin American Business Review (Binghamton), Revisor de periódico da Redes (Santa Cruz do Sul), Revisor de periódico da Custos e Agronegócio Online, Membro de corpo editorial da Sociais e Humanas, Revisor de periódico da RAM, Revisor de periódico da Ciência Rural, Revisor de periódico da The Quarterly Review of Economics and Finance, Revisor de projeto de fomento da The United Arab Emirates University, Membro de corpo editorial da Revista de Administração da UFSM e Membro de corpo editorial da RAM. Santa Maria. Rio Grande do Sul. Brasil. E-mail: ceretta10@gmail.com

<sup>3</sup> Possui graduação em Administração pela Universidade Federal de Santa Maria, UFSM e mestrado em andamento em PG Engenharia de Produção pela Universidade Federal de Santa Maria, UFSM. Santa Maria. Rio Grande do Sul. Brasil. E-mail: fernandamaria.muller@yahoo.com.br

## RESUMO

Neste estudo, investigamos a microestrutura de mercado, com dados de alta frequência, para todas as ações que participam do Ibovespa, tradicional e influente índice da América Latina. Embora a microestrutura de mercado tenha sido amplamente investigada em mercados desenvolvidos, não há muitos estudos acerca de países em desenvolvimento, como o Brasil. Tendo isso em vista, modelamos a volatilidade por meio de um método simples, usando o desvio padrão como *proxy*, e classificamos o volume de negociação de todas as ações do Ibovespa, em cada intervalo de 10 minutos dos pregões amostrados. Encontramos resultados semelhantes aos de investigações anteriores documentados na literatura financeira, como o padrão em forma de L para a volatilidade e o em forma de U para o volume. Outro achado interessante é que, durante o tempo de negociação mais ativa (o intervalo que compreende o fechamento), há quedas de volatilidade, enquanto que, no segundo momento de negociação mais ativo (a abertura), há uma alta volatilidade.

**Palavras-chave:** Intraday, Volatilidade, Volume, Microestrutura de Mercado.

## 1 INTRODUCTION

Understanding patterns of volatility and trading volume seasonality can add edge to arbitrage and speculation as well as risk management. Knowing the past behavior can add to traders and market professionals to get in or out positions to maximize returns and minimize risk. Moreover market regulators can design new policies to evolve to a more efficient trading system based on market microstructure<sup>4</sup>. This investigation has been done several times in developed markets but this approach is new to the Brazilian main exchange.

This type of study goes back to Wood, McInish and Ord (1985) where they investigate behavior of returns and characteristics of trades at micro level of NYSE (New York Stock Exchange) finding higher returns and higher standard deviation during the first 30 minutes of trading. Then Jain and Joh (1988) find that average returns differ across trading hours and some hours of the day present higher volume. More recently Tilak *et al.*, (2013) found the same U-shaped pattern investigating intraday data the main index in France<sup>5</sup>.

The variables investigated were volume and volatility, seeking out for patterns during the trading session of Brazilian stock market, the BM&FBovespa trying to match up results of stock markets around the world that display a similar behavior, a U or L shaped pattern. The time frame of this work comprises the first trading session of 2013 to the last trading session of March of the same year. This horizon was used due to data availability. These patterns can be considered a stylized fact in finance. Stylized facts are observations that have been made in so many contexts that they are widely understood to be empirical truths. Being the opening, the more volatile time of the trading day and easing along the day and bumping up in the end in the U-shaped. Or either opening high and simmering down along the day, until closing as the L-shaped suggests. As to volume, we point some peculiar characteristics when analyzing 10 minutes tick intervals for the most traded stocks in Brazil.

It has been utilized a simple approach to model volatility, mean of squared standard deviation for four distinct periods throughout the trading day. We grouped the 10-min ticks in 4 distinct trading times: opening, lunch, midafternoon and closing. Anticipating some of the results found, volatility follows more a L-shaped pattern with daily highs in the opening easing along the day, with a bit of a bump after lunch time as found by Tina and Guo (2007) when analyzing securities of the Shanghai

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<sup>4</sup> In 1874 the first reference was made regarding Market microstructure, in the Paris Stock Market (BIAIS; GLOSTEN; SPATT, 2005). Market microstructure can be referred as anomalies and specific local rules in a given Market, reflecting patterns in price, volume, volatility and more data that are relevant.

<sup>5</sup> CAC40 - *Cotation Assistée en Continu*, is the index that represented the French Market with the most active 40 companies.

Stock Exchange. As per volume the pattern found is U-shaped with high activity in the beginning and at the end of the trading day; with a little bump in midafternoon perhaps caused by the closing in Europe or traders coming back from lunch here in Brazil, similarly as found when Andersen and Bollerslev (1998) found investigating the Deutsche mark-dollar volatility; plus McInish and Wood (1992) investigating bid-ask patterns of NYSE (New York Stock Exchange) stocks found the same U pattern.

This study is justified by the absence of this sort of investigation in Brazil, leader in trading volume in Latin and South America. Even though the topic has received a great deal of attention in developed markets such as the NYSE, London Stock Exchange and Tokyo there is a lack of similar studies to smaller financial markets.

Another importance of this study is that it utilizes high-frequency data, so very important to analyze questions related to the negotiation process and trading patterns, seldom used in the Brazilian market (see Wood (200) for a historic perspective of high frequency data) (TSAY, 2010).

## 2 REVIEW OF PREVIOUS EMPIRICAL WORK

The Brazilian Market has been widely studied (see Neto, Galli and Decourt (2008), De Oliveira, Lopes and Abbade (2010) and Neto and De Medeiros (2011)), however most of them focus in low-frequency data and little has been aimed market microstructure.

This investigation has been done several times for developed markets, in many forms and methods. Different patterns of volatility have been found in several works in financial literature such the work of Lockwood and Linn (1990) where they examine the variance of hourly market returns on the Nasdaq, indicating that return volatility falls from the opening hour until early afternoon and rises thereafter and is significantly greater for intraday versus overnight periods.

Andersen and Bollerslev (1997) study and find evidence of strong intraday periodicity and seasonality of two different asset classes, foreign exchange and securities, traded under widely different market structures. Again Andersen and Bollerslev (1998) studying the Deutsche mark-dollar intraday activity found behavioral patterns and long run dependencies. Buckle *et al.*, (1998) find the L-shape pattern and other significant patterns when analyzing Short Sterling interest rate and FTSE 100 stock index futures contracts traded on the London International Financial Futures and Options Exchange (LIFFE).

Jain and Joh (1988) provide evidence on joint characteristics of hourly common stock trading volume and returns on the New York Stock Exchange. Average volume traded shows significant differences across trading hours of the day and across days of the week. Average returns differ across hours of the day, and, to some extent, across days of the week. Andersen, Bollerslev and Cai (2000) analyzing intraday volatility of 5-min Nikkei 225 returns, found a doubly U-shaped pattern associated with the opening and the closing in alternate sessions of the Tokyo Stock Exchange.

Eaves and Williams (2010) study intraday patterns on the Tokyo Grain Exchange (TGE) and announcements of public information, finding that intraday volume is U-shaped and intraday volatility is closer to L-shaped, the same results this paper produces. After accounting for the public information in immediately preceding auctions for the same commodity, for earlier trading in other commodities, and for trading on overseas markets open overnight in Tokyo, the intraday patterns are effectively flat.

Nishimura, Tsutsui and Hirayama (2012) investigating spillover effects between China and Japan using 5-min high frequency data, finds that the volatility pattern is U-shaped in Shanghai and W-shaped in Tokyo. Agarwalla and Pandey (2013), another study that focus on a developing market, investigate the expiration day effect on intraday volatility and find that the volatility of the stocks increases in the last half-an-hour trade on the expiry day but not during the other time intervals, in the Bombay stock exchange.

### 3 THE IBOVESPA

The Ibovespa is the main indicator of the Brazilian stock market's average performance. The Ibovespa reflects the variation of the main stock market in Brazil and its most traded stocks. There have been no methodological changes to the index since its inception in 1968, when it has been attributed a base value of 100 points as of a hypothetical investment. The participation of each stock in the portfolio has a straight relation with its representativity in the cash market, measured in terms of number of trades and financial value, adjusted to the sample size. From time to time less traded stocks give place to others that obtained greater numbers in a set time frame. In this work, the stocks that pertain to the index in the beginning of the sample size will be evaluated, if there were changes in the period, these changes will not affect the results of this work.

The index main objective is to be an average indicator of the market performance. For that purpose, its composition aims at reflecting as close as possible the real configuration of the cash market operations on BM&FBOVESPA. In terms of liquidity, stocks that integrate its theoretical portfolio represent more than 80% of the number of trades. In terms of market capitalization, the issuing companies of the stocks that compose the BM&FBOVESPA index theoretical portfolio are responsible, in average, for approximately 70% of the sum of all BM&FBOVESPA overall market cap. For our calculation we did not include all listed stocks, only the ones that participate in the Index (BM&FBOVESPA, 2013).

### 4 METHODOLOGY

Intraday data of returns and volume in a 10 minutes interval is the base for the dataset. The trading days chosen span from January to March 2013, in a total of 1870 observations per stock<sup>6</sup>. In order to perform this study 69, of the 71 total that make up for the index were studied. Data referred to BRPR3 and BBDC3 were not used due to data inconsistency.

After collecting all data, a test for unit root was applied and for that the ADF (Dickey-Fuller Augmented) was applied. Based on the results, was identified that the volume of negotiation does not present unit root, being stationary in the level of (p-value>0.05). Therefore, calculus of the first logarithmic difference was carried out, as  $r_{i,t} = \ln P_{i,t} - \ln P_{i,t-1}$ , where  $r_{i,t}$  is the log-return of the series in the period analyzed  $t$ , and  $\ln P_{i,t}$  and  $\ln P_{i,t-1}$  is the logarithm of the price in  $t$  and  $t-1$ . To assure that the series become stationary the ADF was again taken; the KPSS was also used.

Whenever intraday data is in usage some major drawbacks come to life, for an example when compiling 10 minutes interval of less liquid stocks, there are times that that particular stock have not been traded in a few of the 10 minutes along the entire trading day, but the index was. So what is seen is a long record of index data but not so long of the less liquid stocks. To correct and unsettle that, all blank spaces were filled with the last traded value and zero volume. In this way, all stocks have equal number of observations and more importantly, the stock is set at its real price in time, and appropriated volume level, considering the same 10 minutes interval. A 10-minute interval is commonly used in finance; many works utilize this time frame when analyzing stock market returns, Harvey and Whaley (1991).

The methodology is simple and straightforward; to measure volatility we averaged the squared standard per each of the four periods studied: opening, lunch, midafternoon and closing.

<sup>6</sup> The source of this data was the Thompson Reuters Eikon Software® which is extremely reliable and one of the most trustworthy trading software in the market today.

Then we summed up all the averages of each of the periods for all days of the sample. This is done considering the volatility of all stocks in the index. The first period comprises the opening bell, which starts at 10:00, but the first tick is only at 10:10, all the way to lunchtime at noon. Obviously the market opens at 10:00 however the first tick is only at 10:10 therefore is the first tick of the day. So the first period goes from 10:10 am when the first 10 minutes tick is up to 11:50 am. The second period comprehends lunchtime from 12:00 to 13:40. The third period is midafternoon from 13:50 to 16:40. And the last is closing time from 16:40 to 17:30.

Volume is the total in Real R\$ (Brazilian Currency) of all stocks traded in each of all 10 minutes interval during the entire trading day for all days of the sample. It would be very much easier to use the total of the market volume, although we opted to use only stocks participant in the index because of their supposedly more efficiency. Even in some stocks that belong to the index portfolio, there is lack of liquidity, volume and interest. For penny shares, and there are many listed, their inclusion in any study may scramble results, due to abnormal variance/volatility and volume, originated from the issues that lack of liquidity results, plus illicit trading activities such as bump and dump strategies, very much common to the Brazilian market.

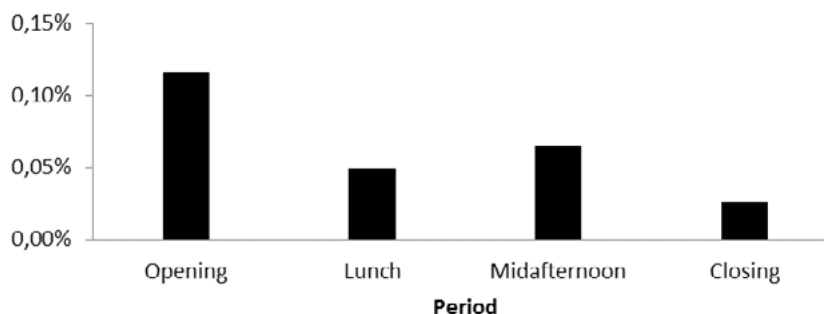
## 5 RESULTS

High frequency analysis is extremely relevant to understand how returns and volume react to information. As pointed out by Taylor (2005) given a higher number of inputs, data is subject to noises such as temporal asymmetry in the trading volume, changes in volatility throughout the day and other characteristics of their microstructure. Therefore, the main purpose here is to identify if volume and volatility in the Brazilian Market present some sort of pattern or variation along the day.

To estimate volatility, every stock during a trading day was considered, the standard deviation of returns for the periods of opening, lunch, midafternoon and closing. They were all averaged up during those periods to form one figure of standard deviation per each period.

The empirical results, Chart 1, confirm that the period which displayed higher volatility is the opening with 0.1161%. As the runner up, is the midafternoon period with 0.0648%. In third place, lunch time, with 0.0482%. And surprisingly, at last the closing call with 0.0260%. This result can be related to the occurrences in the currency market: many players, low spreads and therefore high efficiency and very low volatility. This pattern is called in literature as L shaped because it spikes in the beginning and eases along the day.

Chart 1 - Sum of the averaged intraday volatility for Ibovespa per period

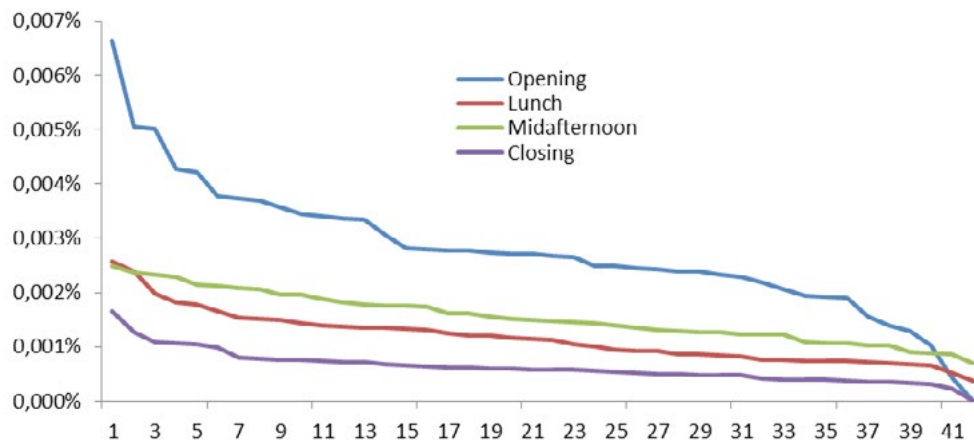


Source: Elaborated by the authors.

Chart 1 displays the L-shape with a little bump after lunch. And Chart 2 brings a more detailed display of this phenomenon, with extremely high volatility in the beginning of the trad-

ing session and coming down until reach bottom in the end of the daily session. For easier notation we divided the volatility percentage by a thousand and noted under the percentage form.

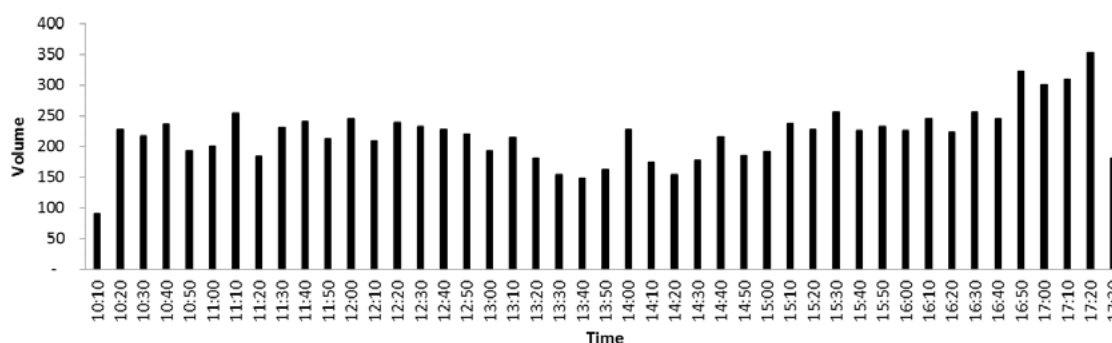
Chart 2 – Averaged observations of intraday volatility, segmented by trading period



Source: Elaborated by the authors.

Chart 2 displays all the averaged volatility in every trading period. The observations are arranged by descending order to facilitate display. It shows that by far the opening call brings the most volatility, whereas the closing is far less volatile. This fact brings some controversy on the volume/volatility relationships much studied in finance such as Bollerslev and Dubinsky (1999), Darrat, Rahman and Zhong (2003), Baum and Caglayan (2010) and Frank and Garcia (2011). It contradicts from one side and agrees from other because the opening is very high in volume also very volatile, the closing also high in volume but the least volatile.

Chart 3 – Total volume traded for every 10-min tick – in millions of R\$



Source: Elaborated by the authors.

Chart 3 brings the total volume of all Ibovespa stocks summed up per 10 minutes interval during the entire sample period. Is important to frizz that during the opening tick (10:10) the volume is the lowest but there is a cause for this fact. Opening auction of the most traded companies commonly take more than 10 minutes, therefore the order for buy or sell even if orders were placed before the opening bell, will only take place when the initial auctions is closed and will be accounted in the second tick (10:20) which displays high activity, as the chart above shows.

There is a spike around 14:00 perhaps caused by traders coming back from lunch or the closing in Europe, but this is just one assumption, after that activity settles and around 15:00 and grows steadily until the closing bell. The closing tick (17:30) also does not display very high volume, but for the same fact as the opening, auction that starts during the tick before. The 17:20 tick presents the higher volume and this is hedge funds, pension funds, market makers and institutional investor adjusting positions.

## 6 CONCLUDING REMARKS

This work proposed to analyze if volume and volatility of Ibovespa stocks present a pattern previously found in financial literature, as similar to an L or to a U shape. For that intraday return data extracted in a 10 minute interval of 69 companies were taken from January to March 2013. As a proxy for volatility, standard deviation has been chosen.

The analysis allows indicating that volatility presents an L shape pattern. In the beginning of the trading day, stocks are more volatile easing up along the day, as displayed in Chart 1. As per volume, activity presents a U shape pattern, with spikes in the beginning and in the end of the trading day, easing along mid afternoon.

In that way, to contribute to it, at the end of this research we point out the same patterns as presented in the findings of Eaves and Williams (2010), a L-shape distribution for volatility and U-shape for volume.

As the main contribution of this work is the utilization of intraday high-frequency data in a developing country, such as the Brazilian Market. As for future research the suggestion is to opt for a different volatility proxy, such as a Multiplicative-GARCH.

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