Information flow directions using Granger Causality with intraday data

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Abstract

This paper analyzes the information flow directions between the American and Brazilian stock exchanges to capture the contagion phenomenon between them, with the use of a Vector Autoregressive model followed by a Granger Causality test. The tested assumption aims to show that exists a flow from the American stock exchange to the Brazilian stock exchange using minute-by-minute intraday data, for a two-week period, which is confirmed after proceeding with the analysis. Additionally, impulse response functions are estimated to shocks in the time series, and all the results show that the flow is U.S. to Brazil and not the other way.

1 Introduction

As global financial markets gradually became highly integrated and dependent on each other, risk contagion between them became a primary characteristic of globalization, inducing uncertainty to both market agents and regulators. This financial liberalization has strengthened financial integration promoting risk diversification, reduction of cost of capital, and information efficiency, helping to create economic growth. [2] [3] The reduction in capital mobility restrictions impacts, having spillover effects, that are changes in returns or volatilities in one market due to transmission of market-specific information from another market [4].

A specific transmission mechanism connected to the spillover effect is contagion. According to the World Bank, contagion is the transmission of shocks across countries or in general inter-country spillover effects, being therefore manifested in both bad and good circumstances. A more restrictive definition is that "contagion" is the propagation of volatility from one market to another (or even within a single market) through information channels. This process is generally seen as symptomatic of the interdependence of the global market and is usually associated with financial crises when there is an increase in the correlations between financial markets compared to the relative stability periods since they can manifest as negative externalities diffused from one collapsing market to another.

From a historic perspective, the term "contagion" has been used at least since the Asian financial market crisis in the 1990s, when the depreciation of the Japanese yen in comparison with the U.S. dollar was a significant external factor contributing to the pressure in Asian markets since the five most affected countries - Thailand, Malaysia, Indonesia, Korea, and the Philippines - had substantial trade linkages with Japan and the United States. [1] Even if that's the starting point of this term, the phenomenon was evident a lot earlier, as in the Global Financial Crisis in 1929, where the effects of the collapse of the American stock market in the U.S. had spillover effects on international markets.

The direction of the risk diffusion in different periods of time and how to describe the intensity of the risk contagion effect is being addressed in this paper, which aims to study the direction of information flow between the American and Brazilian financial markets. It is utilized the methodology of linear Granger causality tests to determine if the minute-by-minute variations of external indexes are useful predictors of variations in the BOVESPA index (IBOV). The main concearn is to understand the structure of this information flow and how ordinary and daily external shocks are being transmitted to the Brazilian stock market.

The risk contagion process means that external shocks will be transmitted to the local market, which directly increases financial market risk and influences other economic risks, including liquidity risk, business bankruptcy, deceleration of trade surplus, recessions, and variations in the employment rate. This is of great importance since studying the real-time link between financial markets and exploring the characteristics of risk is crucial for local governments. The causality of financial risk contagion is commonly tested by the causality between two variables in a Granger's causality test, purposed by Granger[5]. This approach consists in determining whether the past values of one time series can help to explain the current value of the other time series.

The purpose of this study is to test the direction of the international information flow and check the interdependence between markets in a noncritical period. This is important as a representation of a non-crisis and no hazardous period potential for uncertainty caused by financial risk contagion, using linear Granger causality tests. Alongside the before mentioned reasons, the paper in questions attempt to verify the statement in [5] "... one might suggest that in many economics situations, an apparent instantaneous causality would disappear if the economic variables were recorded at more frequent time intervals".

2 Data

The time series used in this work consists of the indexes: IBovespa (IBOV) to represent the Brazilian stock market and to represent foreign markets of the USA, we use Standard Poor's 500 or S&P500 (listed as SPX) and the NASDAQ 100 Index (listed as NDX), derived from the NYSE and NASDAQ exchanges, respectively. As described, both Brazilian and American indexes have a similar meaning in assessing the stock market in their respective countries.

The BOVESPA Index is the main indicator of the stocks negotiated at B3, the Brazilian Stock Exchange. It is the result of a theoretical portfolio of stocks and is composed of the stocks and units of the listed companies in B3, corresponding to approximately 80% of the trading sessions. It is reviewed on a quarterly basis in order to maintain its representativeness in the volume traded, and, on average, the components of the Ibovespa represent 70% total value traded in shares. Because of its representativeness, it is considered the benchmark of variable income. The Ibovespa index number represents the present value of a portfolio started in 1968, with an initial value of 100 and taking into account the increases in stock prices plus the reinvestment of all dividends, and subscription rights received for the constant's bonus shares. The Ibovespa is composed of shares that must meet the criteria established by B3:

- Should have been traded on the stock market in the last 12 months;
- Should be included in the group of stocks whose added negotiability indices represent 80% of the total value of all individual negotiability indices;
- The trading portion must be greater than 0.1% of the total stock flow on the stock exchange;
- More than 80% should be traded on the stock exchange.

The Standard & Poor's 500 is a market index that measured the stock performance of the 500 leading publicly traded companies listed on stock exchanges in the United States. The index is regarded as one of the best gauges of prominent American equities' performance, and by extension, of the stock market overall. It covers approximately 80% of the available market capitalization and represents 50% of the global equity market capitalization, being designed to measure the performance of index-eligible stocks listed on the NYSE and Nasdaq, being weighted float-adjusted market capitalization and includes liquidity and tradability criteria.

To be part of the index, the companies must follow the following criteria:

- Must be U.S. companies;
- Must have positive as-reported earnings over the most recent quarter, as well as over the most recent four quarters;
- Must have an unadjusted market cap of USD 12.7 billion or greater and must have a float-adjusted market cap that is at least 50% of the unadjusted minimum market cap threshold.
- Sector balance in the relevant market capitalization range is also a selection factor;
- All eligible U.S. common equities on eligible U.S. exchanges can be included. Closed-end funds, ETFs, ADRs, ADS, and certain other types of securities are ineligible for inclusion.

The NASDAQ 100 is an index composed of 107 equity securities issued by 100 of the largest and most innovative non-financial companies listed on the Nasdaq Stock Market based on market capitalization. It's a modified weight index, such that the weight of the stocks in the index is according to the total market value of their outstanding shares, such that as a company's stock price changes, its stock index's value changes as well. It is important for describing companies outside the financial sector, being well known for including the ones that are at the forefront of innovation, in industries such as technology, retail, industrial, telecommunication, healthcare, transportation, and media. It is based on foreign exchange and is not an index of only U.S.-based companies. It differentiates from the before mentioned SP 500 by its exclusion of financial firms.

The data for the three indexes was obtained, minute by minute, during the minutes in which both markets are open, that is, with the American markets opening from 10:30 to 17:00 GMT-3 and BOVESPA itself operating from 10:00 to 16:55 or around 386 minutes of joint operation of the two markets.

The data was obtained manually through https://tradingview.com/, from 28 April to 12 May 2023. The sample consists of 10 weekdays (May 1 is a holiday in Brazil), and the return series has 3854 observations. Further characteristics of the sample can be found in the appendix of this work. Table 1 presents the descriptive statistics for the series, while Table 2 shows the results of the stationarity tests. Figure 1 shows the trajectory assumed by the three indexes during the period, normalized to 100, while Figures 2, 3 and 4 shows the histograms for the returns series, excluding zero returns.

3 Methodology

The series will be analyzed in the returns instead of the index-level series because the return information meets the interests of investors and the returns series has to move interesting statistical properties, such as stationarity, than the series of levels.

Denoting the level of the asset at the instant t for I_t we can calculate the return between the instant *t-1* and t per

$$R_t = \frac{I_t - I_{t-1}}{I_{t-1}} = \frac{I_t}{It-1} - 11 + R_t = \frac{I_t}{I_{t-1}}$$

In practice, because this time series refers to intraday minute-by-minute data, the high frequency means that the levels of assets between t and *t-1* are very close and therefore:

$$R_t \approx 0$$

It will be used *log-return* values because of *stationarity*, so statistical properties remain constant over time. Since there will be used a Vector Auto-Regressive (VAR) model, it is important to have the stability of the estimated coefficients, also removing trends and shocks in the series:

$$r_t = \ln(1 + R_t) = \ln\left(\frac{I_t}{I_{t-1}}\right) = \ln(I_t) - \ln(It - 1) \approx R_t$$

To perform Granger Causality tests on IBOV and S&P 500 and IBOV and NASDAQ, a Vector Autoregressive model was estimated with the use of Information criteria for the determination of lags. A Structural VAR model was also designed in order to capture the contemporaneous causality of the American Stock Exchange in the Brazilian stock exchange, with Cholesky decomposition.

4 Results

In Table 1 it is possible to see that all returns series present means are very close to zero. In Figure 1, as can be seen, the normalized variation of the Indexes suggests that NASDAQ and SP 500 follow a very similar trajectory, while IBOV grew more during the period, with similar returns. When analyzing the returns, we can see a small asymmetry to the right, a feature that might be attributed to the bullish market during the period, which would probably be corrected if the sample were larger and carried a larger period. The histograms show a distribution centered around zero with apparent low dispersion.

In Table 2, it was tested stationarity and the presence of a unit root for all series using the Augmented Dick-Fuller test. As expected, the series in level are non-stationary while the series of returns are stationary and don't present stochasticity. The returns series are not normally distributed and apparently follow most of the stylized facts we expected.

To conduct the Granger Causality test, was first estimated Vector Autoregression model. To choose the appropriate specification choice the lag selection approach based on the information criteria was used, minimizing a loss function that negatively depends on the fitting errors and positively depends on the number of parameters of the model. In Table 3 we can see the results for the Akaike (AIC), Hannan-Quinn (HQ), Schwarz (BIC), and Akaike Final Prediction Error (FPE), and for the two VARs, we have the ideal lag = 1 for the VAR of IBOV and NASDAQ, while for SPX and IBOV, the results were tested for both p=1 and p=2, and was preferred to maintain p=1 for the results in the paper.

The VAR is used because it can explain past and causal relationships among multiple variables over time. In this case, the R software pushes it to a Structural Vector Autoregression model, that has the ability to describe contemporaneous relationships between the analyzed variables. It is an important question, in this case, to describe the relationship between contemporaneous variables with the use of the Structural VAR model and its Cholesky decomposition to estimate Granger Causality and Impulse Response Functions to shocks.

As for the main empirical exercise of this paper, the results can be found in Table 4. Both VAR specifications, IBOV and S&P 500 and IBOV and NASDAQ, were used to perform pairwise causality tests for the returns series. For the IBOV and S&P 500 specification, it was also tested for a lag of 2, considering the findings in the information criteria table. In all cases, the results were the same: S&P 500 and NASDAQ returns are good predictors for the IBOV returns, but the contrary is not true, and this can be seen by the Probs column, which cannot reject the null hypothesis for values under 0,05

Testing for the possibility of shocks with the use of Impulse Response Functions allows us to represent the dynamic effects of structural shocks in the variables of interest. Figures 5 and 6 display the results of the impulse response function with a Structural VAR model using Cholesky decomposition, which imposes the restriction of a lower triangular matrix so the first variable is the returns of American stock markets (SPX and NDX, respectively), which is not sensitive to a contemporaneous shock of the other variable, while the Brazilian stock market return (IBOV) is sensitive to shock in the other variable. It can be seen a stronger shock in the minutes right after the information happens.

5 Conclusion

This paper performed causality tests using the log returns series of two of the most relevant indexes for the American economy and the most important index for the Brazilian economy in order to test the direction of the international information flow in financial markers.

The main results are that data from both S&P 500 and NASDAQ are helpful to predict the behavior of the Brazilian market when both markets are open. The result is intuitive and agrees with the literature that the information flow follows from developed to emergent markets, in a unilateral channel rather than a feedback one. Considering a time span without major economic crashes and without crises, there is still statistical significance that the channel exists, meaning that the contagion is even present in an everyday framework.

Considering the Granger preposition cited in the Introduction, the findings of the paper corroborate with the statement that the process, to be considered real, should be verified for more frequent observations, such as minute-by-minute data.

Acknowledging the limits of the work, such as a short time span and the limitations of the model, it is suggested to further investigate an SVAR model with exogenous variation, such as political news, and a bigger number of days. Still, the work promotes relevant features of the Granger causality and information flows.

References

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A Appendices

Table 1: Descriptive Statistics of level and return series

Variable	N	Mean	St. Dev.	Min.	Q1	Q3	Max
$IBOV$	3,854	$105,029$	$2,4458.93$	101,067	102,235	107,217	108,817
SPX	3,854	4,121	23.72549	4,048	4,114	4,133	4,166
NDX	3,854	13,211	108.7511	12,944	13,138	13,288	13,423
$RetIBOV$	3,854	0.000014	0.000569	-0.006044	-0.000235	0.000014	0.010927
$RetSPX$	3,854	-0.00000	0.000397	-0.004032	-0.000157	0.000170	0.008729
$RetNDX$	3,854	0.000003	0.000429	-0.004509	-0.000188	0.000201	0.008337

Table 2: Stationarity tests for level and return series

Variable	ADF Test Statistic	p-value
$IBOV$	-1.6572	0.7235
SPX	-2.1829	0.5009
NDX	-2.3251	0.4407
$RetIBOV$	-16.368	0.01
$RetSPX$	-16.38	0.01
$RetNDX$	-16.458	0.01

Table 3: Tests for Speficiation choice

VAR	AIC	HQ	BIC	FPE
$IBOV + SPX$	2	1	1	2
$IBOV + NDX$	1	1	1	1

Table 4: Pairwise Granger Causality Test Results

Null Hypothesis	Obs	F-Stastic	Prob.
$RetSPXdoesnotGrangerCauseRetIBOV$	3,854	56.075	0.0000000
$RetIBOVdoesnotGrangerCauseRetSPX$	3,854	0.23001	0.6315
$RetNDXdoesnotGrangerCauseRetIBOV$	3,854	25.342	0.0000004
$RetIBOVdoesnotGrangerCauseRetNDX$	3,854	0.061332	0.8044

Figure 1: Level data of returns, normalized to a 100

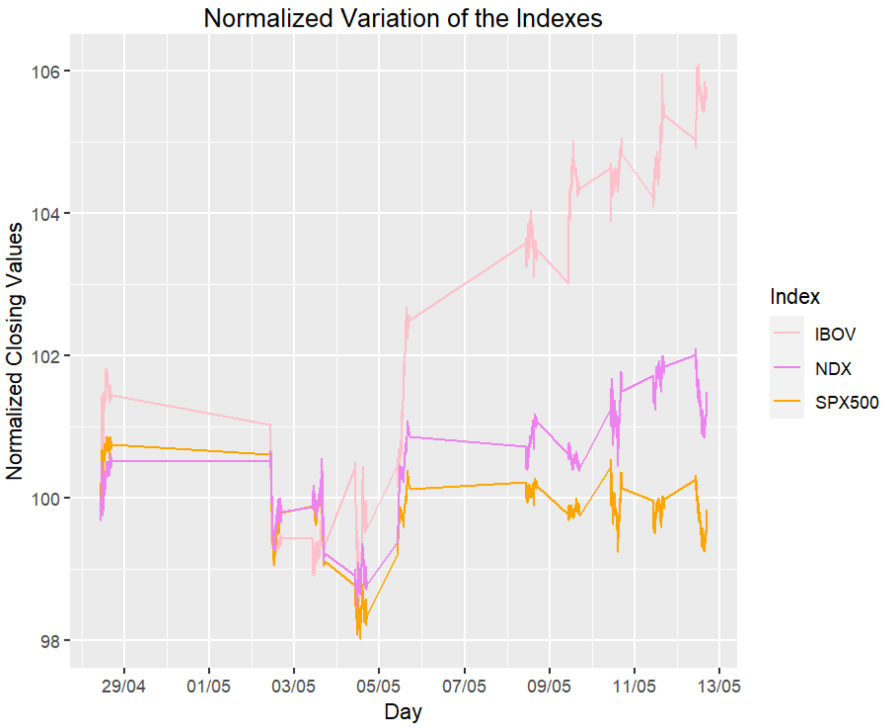

Figure 2: Histogram for Returns of IBOV

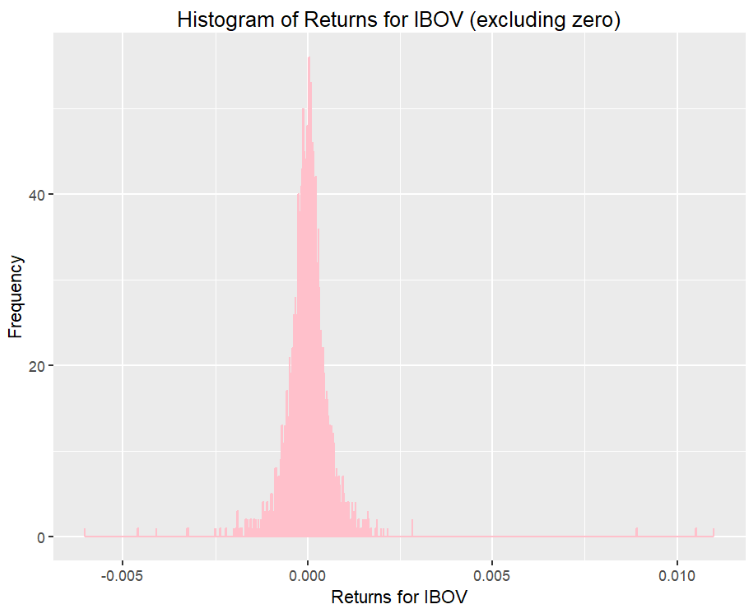

Figure 3: Histogram for Returns of SPX

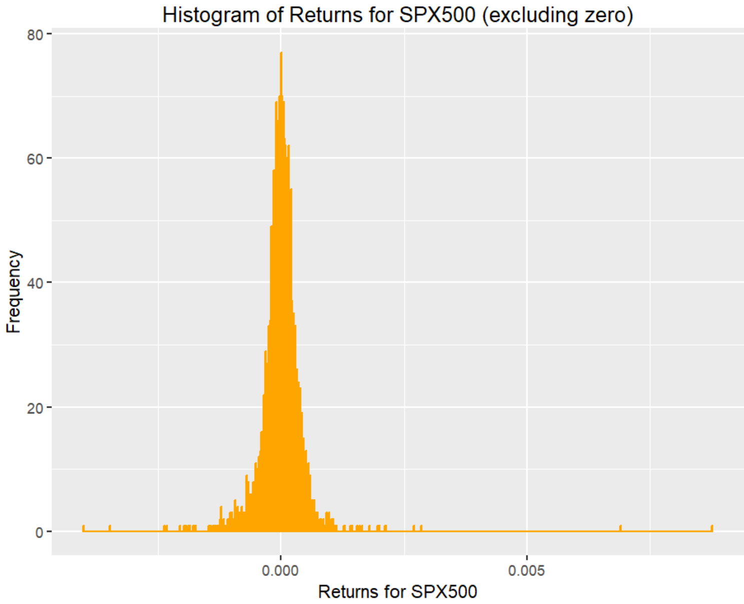

Figure 4: Histogram for Returns of NDX

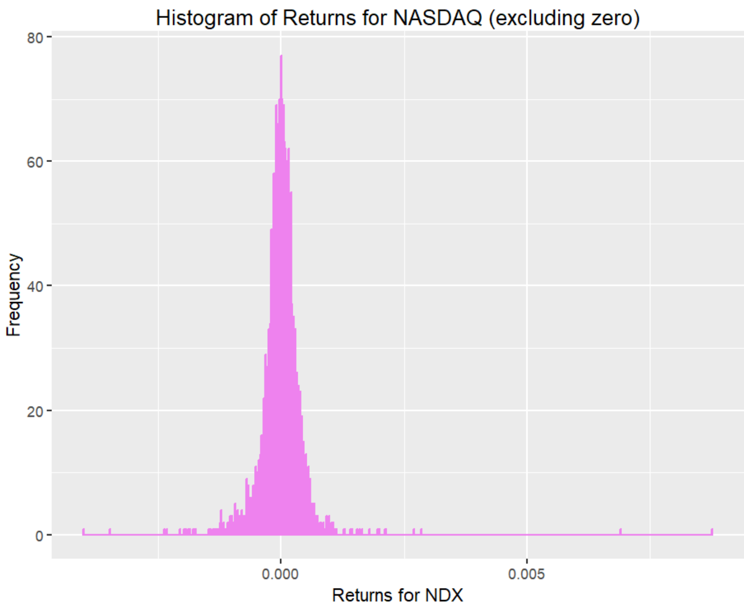

Figure 5: IRF of impulse in SPX on IBOV

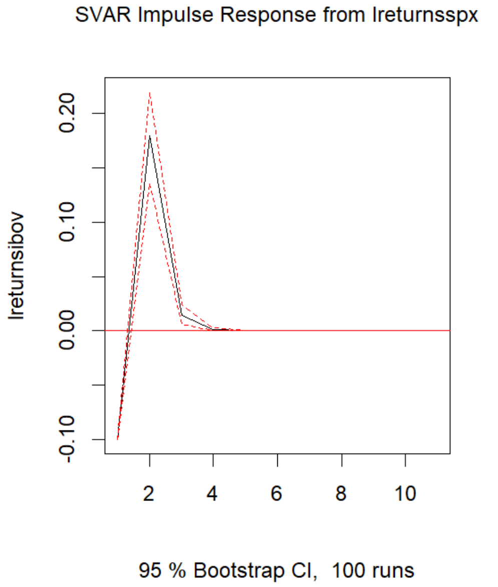

Figure 6: IRF of impulse in NDX on IBOV