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How do stocks react to extreme market events? Evidence from Brazil

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ABSTRACT

This paper studies the short-term (21 trading days) behavior of Brazilian stocks in the event of extreme movements in the Brazilian market index. Using cumulative abnormal returns, we find that stocks tend to overreact after both positive and negative events, as well as global and domestic shocks. Interestingly, this behavior is particularly intense when the events are not clustered. This counterintuitive finding can be explained by the Contrast Hypothesis, since shocks during calm circumstances can be viewed by investors as more surprising. In fact, when we split events according to market volatility, we document a stronger overreaction when volatility is low.

1. Introduction

Do extreme daily market movements represent a fitting response to major value relevant information and events in less developed markets? This paper provides empirical evidence in this regard for a major emerging market known for its high day-to-day volatility, namely, the Brazilian market. The empirical exercise in this paper joins two major strands of literature, the overreaction (cum irrational exuberance-excess volatility) hypothesis (De Bondt and Thaler, 1985; Shiller, 1981), and the extreme or tail risk phenomenon in financial markets. The bulk of the evidence in the overreaction and momentum literatures is based on portfolio formation and performance evaluation using typical returns over many sequential long intervals of a month to more than a year. The extreme risk phenomenon, on the other hand, refers to market moves that are high in severity, low in frequency and short-term in duration. Such an episode is most dramatically illustrated by the US market crash of 1987 and the 2008–09 financial crisis, but may also occur on days of major macroeconomic or leading company information and geopolitical events, or simply due to technical trading (overbought/oversold). Thus, the informational aptitude of extreme market movements is an empirical issue that we strive to answer first for the Brazilian market.

Second, although the extreme negative events (market returns) draw most attention, extreme positive events do also occur and should not be ignored. Hence, we wish to find out if the Brazilian market's informational aptitude differs in dealing with extreme negative versus positive developments. Profitable trading strategies may thus vary conditional upon extreme negative versus positive market movements.

Third, the profitability of a contrarian strategy (long the past losers, short the past winners) in support of the overreaction hypothesis relies upon return reversal while that of a momentum style strategy (short the past losers, long the past winners) rests on return continuation. Whether returns reverse or continue may, however, depend on the term structure of returns and the investment horizon (De Bondt and Thaler, 1985; Jegadeesh and Titman, 2001; Novy-Marx, 2012; Goyal and Wahal, 2013). Short term return

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reversal is reported by Brown et al. (1988), Lehmann (1990) and Atkins and Dyl (1990). To date, however, there is little published research about continuation versus reversals of extreme market movements, that is, whether an extreme fall in the market on one day is followed by an extreme fall or rise in the market in the following days and vice versa.[1] As our events are defined using the broader market movements, microstructure effects (bid-ask bounce, volume, etc.) and group or stock specific issues (e.g., size, earnings, book to market ratios, analyst coverage, etc.) should have minimal influence on our results. Further, all individual stocks in this paper share the same event dates.

Our main results are as follows. First, considering all events, the Brazilian market appears to overreact to extreme negative and positive events, but in a more pronounced way in the case of the former. This reaction is also observed in the wake of domestic as well as global shocks. This reaction remains, even when these events are considered in isolation, with no other events during the analysis window (non-overlapping shocks). This broadens support for the market overreaction hypothesis and the short-term return reversal literature in the case of extreme market events and a very short-term horizon of 21 trading days. Second, considering different patterns of overlaps or clustered shocks, the Brazilian market underreacts to momentum type overlaps (two adjacent extreme shocks in the same direction) and overreacts to reversals (two adjacent extreme shocks in opposite directions) and mixed overlaps (several extreme shocks in the post-event window).

Third, we identify that the overreaction during the first days following a non-overlapping event is more intense than after reversals and mixed type events, when the shocks are clustered. We advocate that this puzzling finding can be explained by the psychology literature regarding surprise. According to the Contrast Hypothesis, the magnitude of how surprising an event is can be partially explained by how strongly it contrasts with common expectations. Applying this principle to our study, a market shock that occurs during turbulent periods (when extreme events are clustered) is seen as less surprising than one that occurs when the market is calm. Consequently, even though market participants will overreact to both, this behavior is more intense in the latter, as it contrasts expectations more sharply. Indeed, when we split the events according to current market volatility, we find that the overreaction of stocks is stronger when volatility is low vis-à-vis the high volatility set. Finally, we also identify that the reversal after extreme events is sensitive to size and value factors, indicating that small and value stocks have a stronger overreaction.

Overall, our results support the short-term overreaction hypothesis to unexpected events in the Brazilian stock market, as well as investors' psychological bias (in this case, the surprise effect) as a possible explanation for the phenomena in question, in accordance with the behavioral finance literature (Bahloul and Bouri, 2016; Frugier, 2016). The remainder of this paper is organized as follows. After a brief review of studies dealing with large stock price movements in Section 2, the data and methodology are described in Section 3. The empirical results are presented in Section 4 and the summary and concluding remarks follow in Section 5.

2. Literature review

The focus in this paper is on the short-term reaction of individual stocks to extreme movements in the broader market. To place the empirical evidence of this paper in perspective, it is nonetheless worthwhile to briefly review the prior findings where events are defined in terms of large movements in individual stock prices.

Brown et al. (1988) found positive abnormal returns in the 60 days following an individual stock price change greater than 2.5% in magnitude, for both positive and negative shocks. They advocate that this supports the Efficient Market Hypothesis (EMH) since the positive abnormal returns simply reflect the increase in risk following the event. The authors name this framework as the Uncertain Information Hypothesis (UIH). Corrado and Jordan (1997) argue that the 2.5% event threshold of Brown et al. (1988) is too low, thus generating too many events. For example, assuming a Normal distribution, this threshold means that one event is expected to occur every ten days. Accordingly, Corrado and Jordan (1997) employed a much larger event filter of 10% price change and found that, consistent with the Overreaction Hypothesis (OH) of De Bondt and Thaler (1985), the negative (positive) events are followed by positive (negative) abnormal returns (AR). Similarly, Bremer and Sweeney (1991) reported a significant price reversal (above average returns), for the individual stocks of Fortune 500, in the days after a stock experiences a large price decline such as more than 10%. Also, they did not find this phenomenon to be related to market movements.

Further studies in different markets and for distinct shock magnitudes led to divergent results, as stated by Amini et al. (2013). Lasfer et al. (2003), studying international markets, found positive (negative) shocks leading to positive (negative) abnormal returns on a 10 day window, and attributed this result to momentum. They also found that the intensity of the abnormal returns is proportional to the magnitude of the event, and that this effect is more pronounced in emerging markets than in developed countries. Employing a ± 20% threshold, Himmelmann et al. (2012) reported positive abnormal returns on European stocks after both negative and positive events, thus supporting Brown et al. (1988). In contrast, although adopting the same threshold, Ising et al. (2006) found overreaction (underreaction) to positive (negative) events in the German market. Recently, Savor (2012) used analyst reports as a proxy for information and found that the informed events are followed by drifts (momentum) and the uninformed events are followed by reversals (overreaction).

Regarding emerging markets, the short-term behavior to shocks remain inconclusive. Using a qualitative approach to define favorable and unfavorable events, Mehdian et al. (2008) reported positive abnormal return for both cases in the Turkish market, lending support to the UIH. Examining the Indian Market, Maher and Parikh (2011) found contradictory short-term behavior depending on the signal of the event and the pre and post 2008 crisis periods: underreaction (overreaction) to negative events in pre

[1] Chaudhury (2014) reports that the US stocks had many days of extreme upswings in the midst of the general downturn during the recent financial crisis, leading to unprecedented volatility but reduced skewness.

(post) crisis periods, and normal reaction to positive events in all periods. Boubaker et al., 2015 investigate the response of stocks to specific events in Egyptian Stock Exchange and find a short-term overreaction behavior after unexpected events. Finally, Foster and Kharazi (2008) investigate the short run behavior of stocks in Iran's market and do not found anomalies (under/overreaction) in such analysis.

Aside from the fact that the above studies do not consider events in terms of extreme market movements, there is also an important methodological issue. With the exception of Corrado and Jordan (1997), most of the studies do not control their samples for overlapping events, that is, one or more days in the post-event period for calculating abnormal returns where the price change is of the magnitude used to define the event. It is thus not clear whether the reported abnormal returns support a given hypothesis (overreaction, momentum or the UIH), or simply reflect the influence of another extreme event in the "post-event" period. The extant evidence becomes even more confounded as many studies measure the expected (or normal) return from the "pre-event" window that itself contains an event in the case of an overlap.

This paper improves the event study methodology in question in three ways. First, we control for overlaps between events. We are not aware of any study that explicitly compares the results between overlapping and non-overlapping price shocks. Second, we divide the overlapping events into groups according to the signals (positive, negative) of the events: (a) momentum when they maintain the same signal, (b) contrarian when they reverse, and (c) mixed when several signals in the same window indicate a conflicting pattern. This procedure enable us to verify in which circumstances the abnormal reactions are more pronounced, enhancing the comprehension of the under and overreaction phenomena. Third, our events are defined in terms of extreme market movement, but we employ the daily excess return of the stock (the return above or below the market) in the post-event period of abnormal return calculation. Thus, a given stock may have a movement of the market magnitude or more on the event day as well as in the pre-event or post-event window and still it is retained when eliminating overlapping market events. This allows all stocks under study to be retained in any experiment.

The market that we study is also worth mentioning, since there are very few studies focusing solely on emerging markets (Maher and Parikh, 2011). Although the status of Brazil's economy in the world has been on the rise for a while now, studies about the Brazilian stock market published in the global research arena are rather lacking. A better understanding of this important market at times of wide swings should be useful to not just Brazilian market participants and policy makers, but also to researchers and practitioners around the globe, especially those involved in investments and risk management.

3. Data and methodology

The primary data of this paper comprises of 2000–2013 daily logarithmic returns, adjusted for dividends and inflation, on the *Economática* database of the largest 200 companies listed on the São Paulo Stock Exchange. For a given event, only stocks with complete data on the event day and the post-event window are retained.

A common critique in extreme event literature has to do with the arbitrariness involved in choosing the threshold to define an event. To avoid this issue, we adopt the concept of Value at Risk to select the events, since Basel II recommends this methodology as the capital required by financial institution to face turbulent circumstances. Specifically, we define an event as a daily return of the BOVESPA Index,[2] either positive or negative, that exceeds its 99.50% Value at Risk for a short or long position in the index, over the thirteen-year sample period.[3] Under a normal distribution with zero mean, this definition corresponds to an event that is expected to occur 2.52 times a year. Before further screening, our sample contains 63 events (35 negative, 28 positive) over the thirteen-year period or an average of 4.85 events per year. Not so unexpectedly, the realized index distribution has fatter tails than the Normal and is negatively skewed.

With slight modifications, we follow the methodology of Cox and Peterson (1994), but focusing on market-level events, rather than on stock-level events, avoiding liquidity issues to drive our results. Furthermore, since the recent literature attests that overreaction is more pronounced in uninformed events (Savor, 2012), this approach biases the result against overreaction, since it is not plausible that a market-event would not be accompanied by information. The abnormal return (AR) of the stocks is defined as the excess return of the stock over the return of the market index. These returns are cumulated during the post-event window, generating the Cumulative Abnormal Returns (CAR). The overreaction to market events is then tested using the following equation:

$$CAR_{1,t2} = \gamma_0 + \gamma_1 AR_0 + \varepsilon_t \quad (1)$$

Where $CAR_{1,t2}$ is the Cumulative Abnormal Returns of the security in a window that ranges from the day after the event (D1) to distinct values of t_2 (1–21), and AR_0 is the abnormal return of the security on the market-event day. The one-day portfolio formation window (Brooks et al., 2003; Coleman, 2012; Boubaker et al., 2015) assumes that the market's reaction to unanticipated events occurs on the day of the event (D0). For a given interval, the regression is estimated using pooled data of stocks over all events. Our focus is on γ_1. A statistically significant negative coefficient would indicate a reversal.

The non-annualized average daily return of the market index over the entire 2000–2013 sample period is de minimus (3.14×10^{-6}) with a standard deviation of 1.87%. Avoiding double counting of days that overlap between events leads to 709

[2] The BOVESPA (Bolsa de São Paulo) Index is the main index of the Sao Paulo Stock Exchange. It is a weighted portfolio of the most representative stocks of the Brazilian stock market based on liquidity and market capitalization. This portfolio (stocks and weights) is revised every three months.

[3] We also replicate the analysis employing the Extreme Shortfall (ES) concept over a 99%VaR approach as recommended by Basel III. We not only find that the results hold for this threshold, but also that the overreaction is even economically stronger in comparison with the VaR thresholds. Since ES is a more rigorous filter, this evidence supports our findings. The results are available upon request. We are grateful to an anonymous referee for raising this point.

Table 1
Summary information on extreme Brazilian market events.

Event	Market Returns (%)	Stocks returns				Event News	Source
		Minimum	Maximum	Mean	SD		
		(%)	(%)	(%)	(%)		
Panel B: Positive Events							
6/2/2000	4.88	−9.53	10.83	1.73	4.48	Expectatins about fall in US interest rates. Dow Jones rises 1.88%	Global
12/5/2000	4.85	−7.55	11.04	2.81	4.16	Expectatins about fall in US interest rates. Dow Jones rises 2.77%	Global
1/3/2001	7.34	−8.96	14.31	6.53	5.02	US cuts interest rates. Dow Jones rises 2.81%	Global
9/17/2001	4.96	−18.70	14.58	2.57	7.14	Cut in interest rates.	Local
10/17/2002	6.15	−4.11	11.49	4.20	3.65	Dow Jones rises 2.89%. Country risk drops 9.5%	Global
10/23/2002	5.31	−2.37	22.21	3.88	4.39	Drift of last event	Global
5/11/2004	5.16	−1.82	12.36	3.59	3.57	Rebounds after 05.10	Global
5/25/2006	4.85	−3.84	14.33	3.72	3.54	Brazil's public surplus surprises the market	Local
3/6/2007	4.83	−2.32	9.16	3.45	2.53	Dow Jones rises 1.30%. Xangai, 1.89%	Global
1/24/2008	5.78	−5.91	11.65	3.88	3.65	US government agrees to tax cuts	Global
4/30/2008	5.59	−2.76	14.03	4.18	4.08	Brazil is up-graded to Investment Grade	Local
9/18/2008	5.33	−9.27	20.29	1.56	4.77	Bush administration discusses intervention	Global
9/19/2008	9.14	−5.81	25.13	7.23	5.59	Henry Paulson anounces measures to buy problematic assets	Global
9/30/2008	7.10	−13.04	68.26	4.39	8.16	Rebounds after 09.29	Global
10/13/2008	13.68	−10.30	32.57	9.20	7.57	US government anounces a U$ 2.5 trillion package	Global
10/20/2008	8.03	−4.88	28.77	5.05	5.18	Brazilian Government announces a recovery package	Local
10/28/2008	12.60	−14.67	28.93	6.22	8.23	Price correction. Dow Jones rises 10.88%	Global
10/30/2008	7.20	−35.67	32.92	3.14	8.25	Brazilian Central Bank decides to not raise interest rates	Local
11/4/2008	5.11	−17.87	26.31	4.24	5.28	Global markets recovery. Dow Jones rises 3.28%	Global
11/24/2008	8.99	−11.12	45.20	3.85	6.74	US Treasury rise participation in Citibank	Global
12/8/2008	7.98	−13.35	20.31	3.51	5.34	Barack Obama announces plans to recover economy. Dow Jones rises 3.46%	Global
3/4/2009	5.17	−5.85	13.96	1.95	3.27	Expectation about a new program from China. Dow Jones rises 2.23%	Global
3/10/2009	5.44	−4.47	13.35	2.69	3.40	Citi anounces profits. Dow Jones rises 5.80%	Global
3/23/2009	5.73	−13.35	14.98	2.62	3.76	US Treasury announcs a plan to buy toxic assets. Dow Jones rises 6.8%	Global
5/18/2009	4.89	−10.54	17.66	3.31	3.90	Price recovery in global markets. Dow Jones rises 2.85%	Global
7/15/2009	4.84	−2.93	9.53	2.44	2.52	Global companies announce surprising results. Dow Jones rises 3.07%	Global
10/29/2009	5.75	−2.57	15.06	3.83	3.03	US GDP preview suprises. Dow Jones rises 2.05%	Global
8/9/2011	4.97	−9.18	14.70	3.28	3.56	Price correction. Dow rises 3.98%	Global

All daily returns are in percentage and are calculated using the logarithmic approach: $R_{i,t} = \ln_{i,t}/\ln_{i,t-1}$. An extreme market event is defined as the magnitude of daily return on the BOVESPA Index greater than 4.84%. Panel A is for the negative events (negative index return) and Panel B is for the positive (positive index return) events.

calendar days for analysis, representing 21% of the trading days in the 2000–2013 period.

Table 1 presents the summary information regarding the extreme market events. The 2008–09 financial crisis accounts for the largest number of market events and the most intense negative (−12.10% on October 15, 2008) and positive (+13.68% on October 13, 2008, announcement of capital injection by the US Federal Reserve and the European Central Bank) events. While the negative market events are more numerous than the positive ones, their intensities are interestingly similar. The average market return is −6.61% for the negative events and +6.49% for the positive events. The cross-sectional standard deviations of individual stock returns on the event days are also close with a mean standard deviation of 4.59% for the negative events and 4.81% for the positive events.

Table 1 also provides a brief description of the news associated with the event and identifies whether its origin has a Local or Global occurrence. It is clear that the extreme swings shown in the Brazilian market are dominated by Global events (50 out of 63), such as the sub-prime and Eurozone crises. However, our screening also contains some domestic events, such as Brazil's Sovereign Debt downgrade (2002) and upgrades (2008), the "Lula Effect" (2002), driven by market apprehension over the forthcoming election of a left-wing government in Brazil that was indeed the case in October of the same year. Another domestic event was the announcement that Brazilian Government would nationalize problematic public companies during the subprime-crises.

4. Empirical results

Empirical results for all events (and all positive and negative events separately, as well as local and domestic events) in the sample are first presented and by a sub-period test of the findings for all events. This is followed by results for the subsamples of 23 non-overlapping (no other event in the post-event window) events, 7 cases of momentum (an event of same sign in the post-event window), 10 cases of reversals (one event of opposite sign in the post-event window), and 23 cases of mixed events (more than one event of either sign in the post-event window). The determinants of the CARs are reported next followed by an examination of the relation between overreaction and market volatility.

Table 2
Overreaction to extreme events.

	All Events (N = 4437)		Positive (N = 2037)		Negative (N = 2437)		Local (N = 572)		Global (N = 3902)	
	AR_0	R^2	AR_0	R^2	AR_0	R^2	AR_0	R^2	AR_0	R^2
CAR_1	−0.075	0.7	0.047	0.3	−0.127	1.6	−0.010	0.0	−0.127	1.6
	(−5.86)***		(2.61)***		(−6.20)***		(−0.309)		(−6.20)***	
$CAR_{1,3}$	−0.170	1.2	−0.013	0.1	−0.186	1.1	−0.194	1.3	−0.186	1.1
	(−7.49)***		(−0.40)		(−5.15)***		(−2,69)***		(−5.15)***	
$CAR_{1,6}$	−0.283	1.9	−0.101	0.3	−0.330	1.8	−0.299	2.5	−0.330	1.8
	(−9.20)***		(−2.34)***		(−6.68)***		(−3,86)***		(−6.68)***	
$CAR_{1,12}$	−0.422	2.5	−0.250	0.8	−0.486	2.7	−0.306	1.6	−0.486	2.7
	(−10.81)***		(−4.19)***		(−8.25)***		(−2996)***		(−8.25)***	
$CAR_{1,21}$	−0.494	4.7	−0.248	0.6	−0.454	1.6	−0.316	1.1	−0.454	1.6
	(−10.42)***		(−3.54)***		(−6.24)***		(−2500)***		(−6.24)***	

The table reports the coefficient γ_1 for the regression: $CAR_{1,t2} = \gamma_0 + \gamma_1 AR_0 + \varepsilon_t$.
$CAR_{t1,t2}$ is the cumulative return of the stock over the holding periods ranging between 1 and 21 days and AR_0 is the abnormal return on Day 0, the event day. The t-statistics are in parentheses. Local (Global) events are those originated by news in Brazil (out-of-Brazil).
*Significant at the 10% level; **at the 5% level; ***at the 1% level.

4.1. All events

Table 2, Column 1 presents the results for the Overreaction Hypothesis (OH) for all events. For brevity, we provide the results only for days 1, 3, 6, 12 and 21. The remaining results are available on request. The overreaction appears to occur quickly, with an average reversion of 7.5% in the opposite direction of the last day's event. This behavior continues to grow for approximately half of the window, when the initial movement on Day-0 has recovered by 42%. Afterwards, the rebounds lose power, ending the window with a total retrieval of almost 50%. This is in keeping with other studies (e.g., Corrado and Jordan, 1997; Choi and Hui, 2014; Boubaker et al., 2015) that report overreaction after extreme events.

The stocks show overreaction for both positive and negative events, although in a more pronounced way in the latter, with a strong 12.7% reversion in the day-after that rises to 45% by the end of the window. This finding can be reconciled with one of the Prospect Theory corollaries, which attest that individuals tend to overvalue outcomes involving losses more sharply than those involving gains.

Regarding the origin of the event (local or global), Brazilian stocks seem to present a less pronounced overreaction to domestic than to global shocks, as they take longer to begin recovery, and even so, in a less pronounced way. This finding is somewhat puzzling since global events are presumably more noticed than domestic ones, counteracting the Information Hypothesis (Savor, 2012; Choi and Hui, 2014). Furthermore, since the Brazilian market opens after other important markets (usually at −13:00 GMT), such as Asian and European ones, there would be more time left for market participants to absorb new information in comparison with local live events. In any case, it is worth mentioning that stocks exhibit significant overreaction to both types of events.

To gauge whether the documented overreaction could be driven by a particular period, we divide our sample period in three sub-periods, each one containing approximately the same number of events. The results are shown in Table 3. The difference between the durations of each sub-period is due to the clustering of events during the subprime crises. This division also enables us to have a sub-

Table 3
Sub-periods of extreme events.

	Sub-period 1 (2000–2006)		Sub-period 2 (2007–2008)		Sub-period 3 (2009–2013)	
	N = 420		N = 2531		N = 1517	
	AR_0	R^2	AR_0	R^2	AR_0	R^2
CAR_1	−0.242	6.3	−0.031	0.1	−0.208	6.9
	(−5,31)***		(−1,78)**		(−10,61)***	
$CAR_{1,3}$	−0.168	1.5	−0.156	0.9	−0.234	3.5
	(−2,49)***		(−4,92)***		(−7,40)***	
$CAR_{1,6}$	−0.205	0.9	−0.326	2.3	−0.169	1.1
	(−1,99)**		(−7,66)***		(−4,02)***	
$CAR_{1,12}$	−0.059	0.0	−0.490	3.2	−0.312	1.9
	(−0.48)		(−9174)***		(−5,46)***	
$CAR_{1,21}$	−0.250	0.5	−0.531	2.7	−0.494	2.9
	(−1,57)*		(−8,32)***		(−6,76)***	

The table reports the coefficient γ_1 for the regression: $CAR_{1,t2} = \gamma_0 + \gamma_1 AR_0 + \varepsilon_t$.
$CAR_{t1,t2}$ is the cumulative return of the stock over the holding periods ranging between 1 and 21 days and AR_0 is the abnormal return on Day 0, the event day. The t-statistics are in parentheses.

period focused on the reaction of Brazilian stocks to subprime events (Sub-period 2). It is clear that, despite being present in all sub-periods, the overreaction is less pronounced during the first, and concentrated in the week following the event. It is important to mention that most domestic events (9 out of 15) belong to this sub-period, which is consistent with the observation that Brazilian stocks appear to overreact more to global than to local shocks.

Another interesting pattern is that the market seems to reverse more strongly during the very first days after the shock (Day 1 and Day 1–3) for events that occurred out of the subprime crises (Sub-periods 1 and 3). This is quite counterintuitive, since such a crisis concentrates the events with the higher magnitude. In this sense, we provide an explanation derived from the psychology literature (Teigen and Keren, 2003). According to this field of knowledge, surprise at a phenomenon depends not only on the strength of an event but also on how it contrasts with the expectations of those involved, the Contrast Hypothesis. Applying this concept to stock market, during more turbulent periods, extreme swings in stocks are to be expected, not contrasting so dramatically with the expectations of market participants. However, when the event takes places during calmer periods, the shock contradicts expectations in a more pronounced way, leading to a stronger overreaction that is rapidly corrected. The next section sheds more light on the discussion of overreaction and event clustering.

4.2. Subsamples of events

Table 1 shows clustering of events implying possible overlapping of an event and the post-event window of a prior event. Such overlaps can potentially bias/confound the results since the post-event price changes may simply reflect market reaction to a new unanticipated event (in the post-event window of a close by prior event). To illustrate this argument, let's take the example of the event on May 10, 2004 (Panel A, Table 1), when the market fell 5.61%, and then rose 5.16% on the day after, May 11, 2004 (Panel B, Table 1). In this case, the fact that the loser portfolio outperforms the winner after the negative event on May 10, 2004, could perhaps be explained by the difference in beta risk between the stocks. If individual stocks are priced in a rational (CAPM sense) and apt (speedily incorporating the valuation impact of the market shock) manner, the stocks with higher (lower) betas are expected to be more (less) adversely affected by the negative market event on May 10, 2004. As the market rebounds strongly on May 11, 2004, (thus constituting a positive event that overlaps with the post-event Day 1 of the May 10, 2004 negative event), the higher (lower) beta May 10, 20004 losers (winners) will recover more (less). But these stock price reactions could also be erroneously interpreted as an episode of market overreaction to the initial event on May 10, 2004. To address this issue and to obtain a clearer picture, we divide the sample if events into different subsamples in the following way:

a) Non-overlapping: Events with no other event in their post-event window. This is the cleanest subsample.
b) Reversal: Events that are followed by another event in the opposite direction (positive/negative or negative/positive) in the post-even window. In these situations, we expect to find overreaction even when market reaction is truly rational and apt.
c) Momentum: Events that are followed by another event in the same direction (both-positive or negative) in the post-event window. Since the second event reinforces the first one, underreaction or delayed overreaction is possible.
d) Mixed: Events with more than one event of either sign in the post-event window. During highly turbulent occasions like the 2008–09 financial crisis, the market gyrates wildly leading to a cluster of multiple events on close-by dates.

Table 4 reports the results for subsamples. The Momentum set exhibits a significant positive coefficient of AR_0, meaning that the overlapping same-signal event strengthens the previous one, leading to a continuity of abnormal returns on stocks. Since this group is, by definition, biased towards the Momentum hypothesis, these results are in line with previous expectations. Likewise, the Reversal

Table 4
Overreaction to extreme events for subsamples formed regarding the signal of the overlapping sample.

	Momentum (N = 271)		Reversal (N = 706)		Mixed (N = 2097)		Non-overlapping (N = 1400)	
	AR_0	R^2	AR_0	R^2	AR_0	R^2	AR_0	R^2
CAR_1	−0.018	0.1	−0.170	4.4	−0.029	0.1	−0.172	4.4
	(−0.38)		(−5.67)***		(−1.49)*		(−8.02)***	
$CAR_{1,3}$	−0.050	0.1	−0.256	3.1	−0.134	0.1	−0.260	4.2
	(−0.65)		(−4.77)***		(−3.78)***		(−7.82)***	
$CAR_{1,6}$	0.297	2.3	−0.277	2.3	−0.321	2.1	−0.201	1.4
	(2.53)***		(−4.10)***		(−6.69)***		(−4.49)***	
$CAR_{1,12}$	0.450	2.8	−0.630	6.4	−0.440	2.6	−0.330	2.1
	(2.79)***		(−6.95)***		(−7.41)***		(−5.41)***	
$CAR_{1,21}$	0.689	3.0	−0.976	11.8	−0.465	2.0	−0.490	2.8
	(2.90)***		(−9.70)***		(−6.57)***		(−6.35)***	

The table reports the coefficient γ_1 for the regression: $CAR_{1,t2} = \gamma_0 + \gamma_1 AR_0 + \varepsilon_t$.
$CAR_{t1,t2}$ is the cumulative return of the stock over the holding periods ranging between 1 and 21 days and AR_0 is the abnormal return on Day 0, the event day. The t-statistics are in parentheses. The groups were formed in accordance to the signal of the overlapping events. Non-overlapping are those events with no other event during their window analysis. Momentums are those events with equal signal events in the same window. Reversals are those with contrarian signal events in the same window. Mixed are those with multiple equal/contrarian signal in the same window.

subsample shows a pronounced overreaction (the strongest among the groups) throughout the post-event window. The coefficient is also economically significant since it indicates that, by the end of the period (Day 21), the movement exhibited on the respective event day has virtually recovered ($\gamma_1 = 0.98$). As this group is biased in favor of the Overreaction Hypothesis (OH), the results per se are inconclusive to attest this hypothesis, as the behavior in this group could be explained by risk factors, such as market beta, as shown above. We address this issue later.

The Mixed subsample also exhibits a strong overreaction, which is more pronounced a day or two after the event. This result is particularly puzzling since this subsample contains a variety of overlapping events, some of which are of the momentum type, with two consecutive same-direction events (e.g., September 18, 2008 and September 19, 2008, or October 28, 2008 and October 30, 2008). Furthermore, the overreaction documented here could be associated with market mispricing, which is believed to be more common in turbulent circumstances.

The most striking results are found in the Non-Overlapping set. Since there are no events driving the results in the post-event window, the fact that this group reports a strong prevailing overreaction is a robust evidence for this hypothesis. This is particularly true in the very first days (Day 1 and Day 1,3) after the event, when the overreaction of stocks is economically and statistically more pronounced than in any of the remaining subsamples. Once again, this counterintuitive finding can be reconciled with the Contrast Hypothesis. As there is no cluster of events in this subsample, the turbulence of the market is less pronounced in comparison with the overlapping groups. Consequently, a dramatic move on such an occasion is seen as more unexpected, contradicting common beliefs and resulting in a stronger surprise and, eventually, a more pronounced overreaction.

The distinct reactions observed in the subsamples (no-overlap: no significant overreaction, momentum: underreaction/delayed overreaction, reversal: overreaction, mixed: strong overreaction) help explain the divergent results in the literature about the reaction to market shocks (Lasfer et al., 2003; Himmelmann et al., 2012; Ising et al., 2006; Mehdian et al., 2008; Maher and Parikh, 2011).

To identify the determinants of the abnormal returns,[4] we add a set of risk factors (X_t) from the CAPM and the Fama-French 3 factors model, since the previous literature reports that stock overreaction is sensitive to one or more of these factors (Cox and Peterson, 1994; Lasfer et al., 2003; Savor, 2012):

$$CAR_{1,t2} = \gamma_0 + \gamma_1 AR_0 + \delta X_t + \varepsilon_t \quad (2)$$

The market returns are on the São Paulo stock exchange index (*BOVESPA*) and the risk-free rate is the Brazilian interest rate obtained from the database of the Ipea (Institute of Applied Economic Research). Since the factors for size (SMB) and book-to-market (HML) are not available for the Brazilian stock market in French's website, we calculated them employing the Fama and French, 1993 methodology. The pooled data used in regression for a subsample are for the post-event days of all the events in the subsample.

Since no overreaction was observed for the momentum group, we did not include this subsample in our analysis. Table 5 shows the results. The factors appear to capture a considerable part of the effect in the non-overlapping event (Panel A), mainly at the beginning and the end of the window. However, during most of the period, the overreaction remains significant at the 5% level. The signals and the t-statistics of the factors indicate that the Size (market capitalization) and the Value (Book/Market ratio) of the stocks are determinants of its behavior after major events. In the Reversal set (Panel B), although the factors have explanatory power, a good part of the CAR is still attributed to AR_0 coefficient, meaning that Overreaction Hypothesis still holds after controlling for risk. In this regard, by comparing the R^2 of this set in Tables 4 and 5, one sees that AR_0 has higher explanatory power than the factors, what is consistent with OH. Finally, Panel C shows that the overreaction for the Mixed group is restricted to the beginning and the second-half of the window. This late reaction is probably connected to events that occur in this period of the window and, therefore, drive the results.

The following section enhances the discussion of the link between market volatility and short-term overreaction, and the role of the Contrast Hypothesis in this relationship.

4.3. Overreaction to extreme events and volatility

To investigate the link between overreaction and market volatility, we split the whole sample into two subsamples, based on the standard deviation of the daily market returns using Days 0–21 of each event. Events with standard deviation below the median estimate were classified as "Low Volatility" and the others as "High Volatility", resulting in 31 events per subsample. We use expression (2) to investigate the determinants of CAR in each subsample.

The results are shown in Table 6. Although both groups exhibit a significant overreaction, this behavior is particularly pronounced in the low volatility set. Since, this subsample is compounded by events in a less stressful environment than that of the High Volatility group, this result is further evidence in favor of Contrast Hypothesis (Teigen and Keren, 2003), resulting in a more surprising outcome and leading investors to overreact to it (Griffin and Tversky, 1992).

In line with this finding, we see that the R^2 of the low volatility subsample remains higher than for the high volatility one during the first days following the event, suggesting that the abnormal return on Day-0 helps to explain the subsequent rebounds of the market. Indeed, in a test not reported in the paper, AR_0 alone explains 7% and 4.5% of the variations of CAR_1 and $CAR_{1,3}$, respectively. In both sets, the overreaction disappears by the end of the window. Overall these results are consistent with a bulk of recent researches reporting the influence of investors sentiment on the direction of stocks price (Ghazani and Araghi, 2014; Bahloul and Bouri, 2016; Frugier, 2016).

[4] We would like to thank an anonymous referee for raising this point.

Table 5
Determinants of Cumulative Abnormal Returns.

	Intercept	D0	MRP	SMB	HML	R^2
Panel A: Non-overlapping subsample						
CAR_1	−0.013	0.000	−0.178	−0.004	0.040	4.7
	(−0.63)	(0.53)	(−8.22)***	(−0.34)	(2.10)**	
$CAR_{1,3}$	0.044	−0.003	−0.188	0.022	0.067	3.5
	(1.59)*	(−2.58)***	(−6.47)***	(1.31)*	(2.62)***	
$CAR_{1,6}$	−0.041	−0.004	−0.205	0.036	0.088	2.0
	(−0.95)	(−2.31)**	(−4.52)***	(1.41)*	(2.21)**	
$CAR_{1,12}$	0.082	−0.007	−0.311	0.060	−0.060	2.4
	(1.39)*	(−2.68)***	(−5.04)***	(1.70)*	(−1.09)	
$CAR_{1,21}$	−0.041	0.000	−0.450	0.122	−0.079	3.8
	(−0.55)	(−0.08)	(−5.78)***	(2.75)***	(−1.14)	
Panel B: Reversal subsample						
CAR_1	0.080	−0.008	−0.163	0.121	0.041	8.7
	(2.05)**	(−6.15)***	(−5.55)***	(4.94)***	(1.39)*	
$CAR_{1,3}$	0.165	−0.008	−0.248	0.167	0.075	6.6
	(2.35)***	(−3.39)***	(−4.69)***	(3.78)***	(1.41)*	
$CAR_{1,6}$	0.020	−0.023	−0.279	0.000	0.117	3.2
	(0.23)	(−7.42)***	(−4.13)***	(0.03)	(1.72)**	
$CAR_{1,12}$	−0.166	−0.026	−0.628	0.045	0.339	8.6
	(−1.39)*	(−6.13)***	(−6.99)***	(0.59)	(3.77)***	
$CAR_{1,21}$	−0.271	0.002	−0.962	0.199	0.380	15.1
	(−2.06)**	(0.45)	(−9.71)***	(2.41)***	(3.83)***	
Panel C: Mixed subsample						
CAR_1	0.152	−0.010	−0.028	−0.052	−0.112	1.0
	(2.44)***	(−3.79)***	(−1.46)*	(−3.38)***	(−2.03)**	
$CAR_{1,3}$	0.072	−0.001	−0.141	0.030	−0.106	1.0
	(0.63)	(−0.29)	(−3.95)***	(1.07)	(−1.04)	
$CAR_{1,6}$	0.266	−0.003	−0.338	0.028	−0.177	2.6
	(1.72)**	(−0.49)	(−7.01)***	(0.73)	(−1.283)*	
$CAR_{1,12}$	−0.125	−0.026	−0.439	−0.008	0.379	2.9
	(−0.65)	(−3.13)***	(−7.34)***	(−0.16)	(2.22)**	
$CAR_{1,21}$	−0.308	−0.027	−0.476	0.141	0.507	2.5
	(−1.35)*	(−2.80)***	(−6.69)***	(2.51)***	(2.50)***	

The table reports the coefficients for the regression: $CAR_{1,t2} = \gamma_0 + \gamma_1 AR_0 + \delta X_t + \varepsilon_t$.

$CAR_{t1,t2}$ is the cumulative return of the stock over the holding periods ranging between 1 and 21 days and AR_0 is the abnormal return on Day 0, the event day. Xt is a set of factors from the CAPM and the Fama-French 3 factors models. The t-statistics are in parentheses.

5. Summary and conclusions

The focus of this paper has been on the short-term reactions of individual stocks on the day of an extreme movement in the Brazilian stock market index and during the 21 trading days following such an event. An extreme movement here refers to market index return on a given day exceeding the threshold magnitude of 99.5% VaR of the market index (2.60 times the standard deviation of daily market index return over the sample period of 2000–2013). We have examined 63 such events in this paper.

We find that the Brazilian market overreacts to both positive and negative extreme events, but in a stronger way in the latter. This behavior is observed after local as well as global shocks, and for different subperiods. We also report that Size and Value factors influence stock overreaction, meaning that small and value stocks tend to overreact more.

When we control for overlapping events, we continue to see a strong overreaction that is also economically significant, since we document that stocks reverse almost 50% of the initial shock within 21 days. The short-term reaction of the market during non-overlapping events is particularly interesting when compared to the behavior exhibited when several events overlap, since the overreaction is stronger for the former group.

At first, these findings are counterintuitive because, due the cluster of events, one would expect to see a more pronounced overreaction in such circumstances when volatility increases dramatically. Using the psychology literature, we explain this phenomenon based on the Contrast Hypothesis, which claims that the surprise with regard to an unexpected event is also explained by the way it contrasts with common beliefs. Therefore, when a market shock occurs in a calm environment, it is seen as more surprising than a shock during a stressful period, leading to a more intense overreaction. Indeed, when we split our events into two samples according to market volatility, we observe that, although overreaction is present in both, it is more pronounced when volatility is low. Overall, our evidence indicates that the Brazilian stock market exaggerates when pricing domestic as well as global shocks.

A limiting factor in our study though is the relatively small sample of 63 events. It nonetheless provides motivation for research on other emerging as well as developed markets to understand better the reaction to and the trading and market aptitude implications of extreme events.

Table 6
Overreaction to extreme events for Low Volatility and High Volatility subsamples.

	Intercept	D0	MRP	SMB	HML	R^2
Panel A: Low Volatility (N = 1539)						
CAR_1	−0.018	−0.002	−0.228	0.020	0.092	9.0
	(−0.97)	(−2.19)**	(−10.82)***	(1.51)*	(5.01)***	
$CAR_{1,3}$	0.052	−0.005	−0.269	0.060	0.083	6.3
	(1.81)**	(−4.10)***	(−8.36)***	(3.02)***	(2.96)**	
$CAR_{1,6}$	0.004	−0.007	−0.206	0.086	0.144	3.5
	(0.11)	(−3.97)***	(−4.65)***	(3.16)***	(3.72)***	
$CAR_{1,12}$	0.107	−0.017	−0.301	0.146	−0.004	3.0
	(1.93)**	(−6.71)***	(−4.92)***	(3.89)***	(−0.07)	
$CAR_{1,21}$	−0.010	−0.005	−0.368	0.164	0.027	2.8
	(−0.14)	(−1.59)*	(−4.59)***	(3.33)***	(0.38)	
Panel B: High Volatility (N = 2227)						
CAR_1	0.191	−0.012	−0.032	−0.057	−0.232	0.1
	(3.32)***	(−4.81)***	(−1.75)**	(−3.71)***	(−3.11)***	
$CAR_{1,3}$	0.073	−0.001	−0.144	0.030	−0.113	1.1
	(0.69)	(−0.30)	(−4.22)***	(1.08)	(−0.81)	
$CAR_{1,6}$	0.389	−0.024	−0.319	−0.045	−0.559	2.5
	(2.72)***	(−3.65)***	(−6.91)***	(−1.16)	(−2.99)***	
$CAR_{1,12}$	−0.078	−0.031	−0.460	−0.020	0.214	3.0
	(−0.44)	(−3.82)***	(−8.01)***	(−0.43)	(0.92)	
$CAR_{1,21}$	−0.425	−0.003	−0.508	0.235	0.840	3.5
	(−2.02)**	(−0.32)	(−7.45)***	(4.16)***	(3.05)***	

The table reports the coefficients for the regression $CAR_{1,t2} = \gamma_0 + \gamma_1 AR_0 + \delta X_t + \varepsilon_t$.
$CAR_{t1,t2}$ is the cumulative return of the stock over the holding periods ranging between 1 and 21 days and AR_0 is the abnormal return on Day 0, the event day. Xt is a set of factors from the CAPM and the Fama-French 3 factors models. The subsamples are formed based on the standard deviation of the daily market index returns on 22 days, namely, Days 0 (event day) to 21 (last day of post-event window). Events with below (above) median market standard deviation are classified as Low (High) Volatility.

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