Force-majeure events and financial market's behavior

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2013

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FORCE-MAJEURE EVENTS AND FINANCIAL MARKET'S BEHAVIOR

Efficient market hypothesis fails from time to time. There are many reasons why it happens. We will try to concentrate on one of them – force-majeure events – situations when something important happens unexpectedly. In this case market simply can't absorb information in one moment. So for some period of time it becomes inefficient and stays inefficient until new information will not be included by the market. Such situations give us possibility to predict the market's behavior. This is our intuitive assumption. To confirm or refuse it we will analyze the reaction of financial markets to the biggest force-majeure events during last 20 years. Also we will try to develop a trading strategy based on financial market's reaction to force- majeure events.

Key words: financial market, force-majeure event, financial market's efficiency, events study.

Účinné finanční hypotézy čas od času selhávají. Je hodně důvodů proč k tomu dochází. Pokusíme se zaměřit na jeden z nich– případ vyšší moci – mimořádnou událost nebo okolnost mimo naši kontrolu. V případě takovýchto událostí trhy nedokáží vstřebat informaci okamžitě. To znamená, že po určité časové období se trhy stávají neefektivní až do chvíle, kdy je trhem přijata v potaz nová informace. Takováto situace nám dává možnost předpovídat tržní chování. Toto je náš intuitivní předpoklad. Je to důvod proč musíme analyzovat reakci finančního trhu na největší události vyšší moci za účelem potvrzení či vyvrácení našeho předpokladu. Taktéž se snažíme rozvíjet obchodní strategii založenou na reakci finančního trhu k vyšší moci.

Klíčová slova: finanční trh, případ vyšší moci, efektivita finančního trhu, případové studie.

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1. FORCE-MAJEURE EVENTS AND EFFICIENT MARKET HYPOTHESIS

Today, the dominant hypothesis explaining the behavior of financial markets is "Efficient market hypothesis". According to this hypothesis, all the essential information immediately and fully reflected in the value of assets [6, 10, 11,12, 13, 15] that actually eliminates the possibility of earnings from the use of any information by market participants.

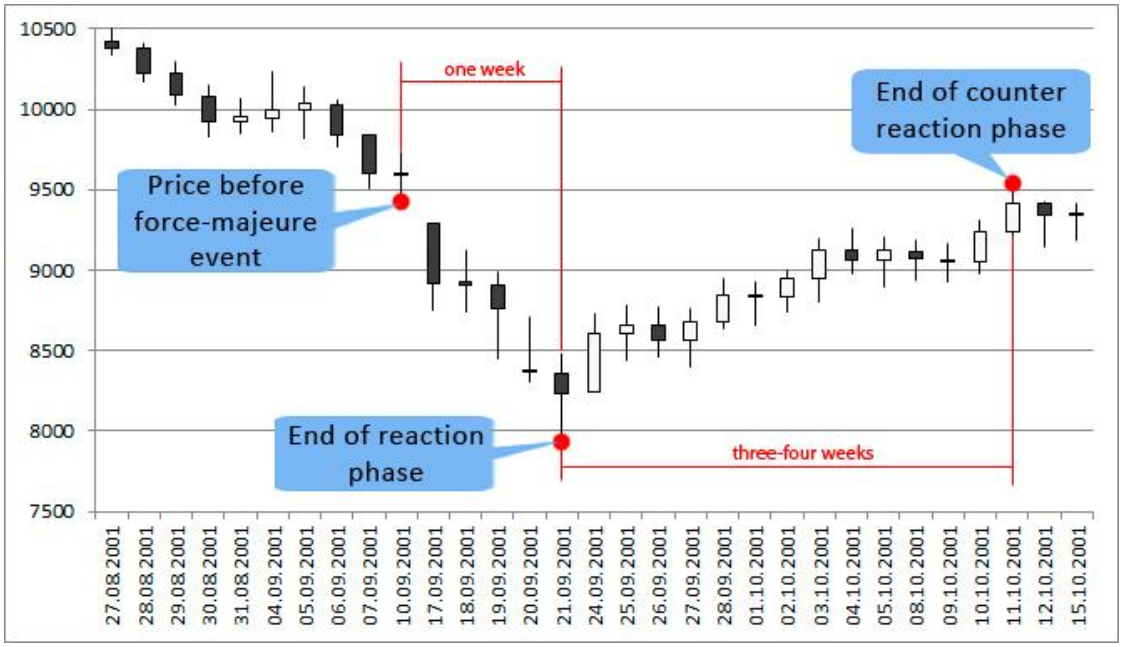
Thus, the market is always in the state of dynamic equilibrium. However, there are information flows, which can't be taken into account in the market prices and are able to disrupt this balance, at least for a while. We are talking about force major events.

Force majeure in general is compelling, extraordinary circumstances that do not depend on the will and actions of participants of economic events [17]. They are floods, earthquakes, disasters, terrorist attacks etc. Moreover, using this term in the context of financial markets and analyzing their behavior, we consider the necessity to expand the proposed list with extraordinary economic events, such as unexpectedly positive / negative economic news. Obviously, information, generated by force major events can not be included by market in

advance. Thus, we can assume without prejudice to the efficient market hypothesis, that new information gives us a possibility to earn on market prices deviations.

Here are some classic force-major events and analysis of financial markets' reaction to them. The first example of force majeure event is the terrorist attack on the United States (September 11, 2001). In Fig. 1 we can see the reaction of U.S. stock market to this event (as a tool of analysis we selected the Dow Jones Index).

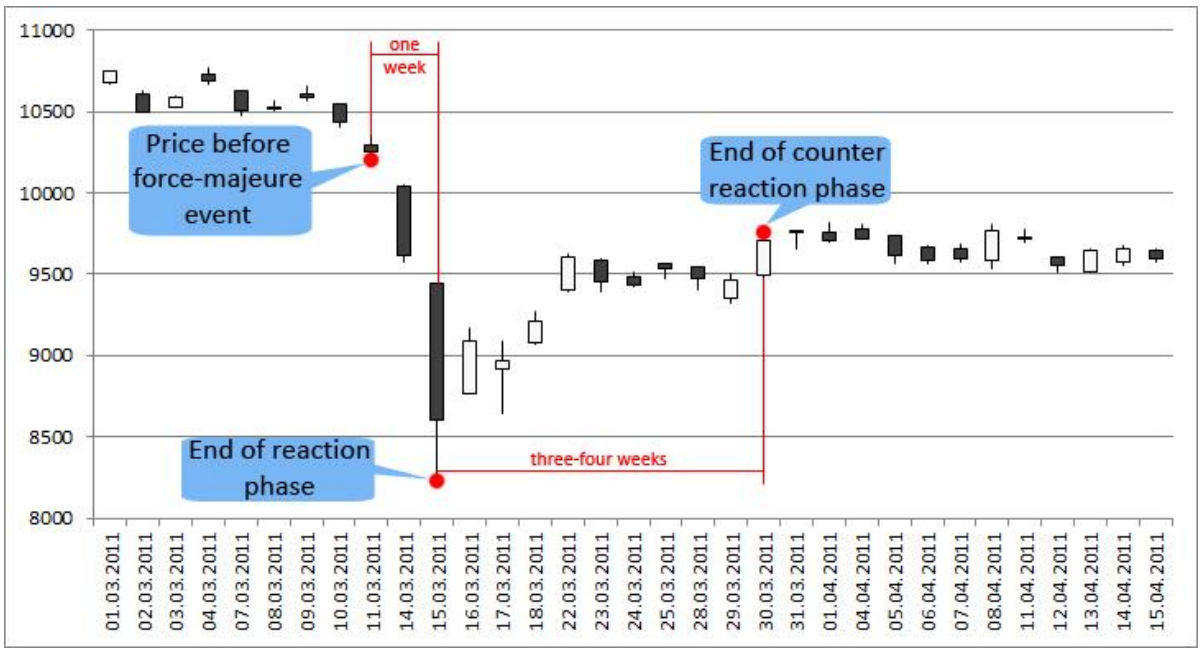
Figure 1. Reaction of the U.S. stock market to the terrorist attack (September 11, 2001) [14]



It appears that the active phase of the reaction lasted for about a week, while the index lost approximately 17% of its value. This is not surprising, the reaction is quite predictable. What is more interesting is that next month the Dow Jones Index showed an opposite trend in the first decade of October and returned to its initial value. It demonstrates how market takes into account (absorb) information and returns to its equilibrium state.

Let's consider another force majeure event – a strong earthquake in Japan (March 11, 2011). There were huge losses: economic, human, environmental etc. The reaction of Japanese stock market (index Nikkei) is shown in Fig. 2.

Figure 2. Reaction of Japanese stock market to the earthquake (March 11, 2011) [14]

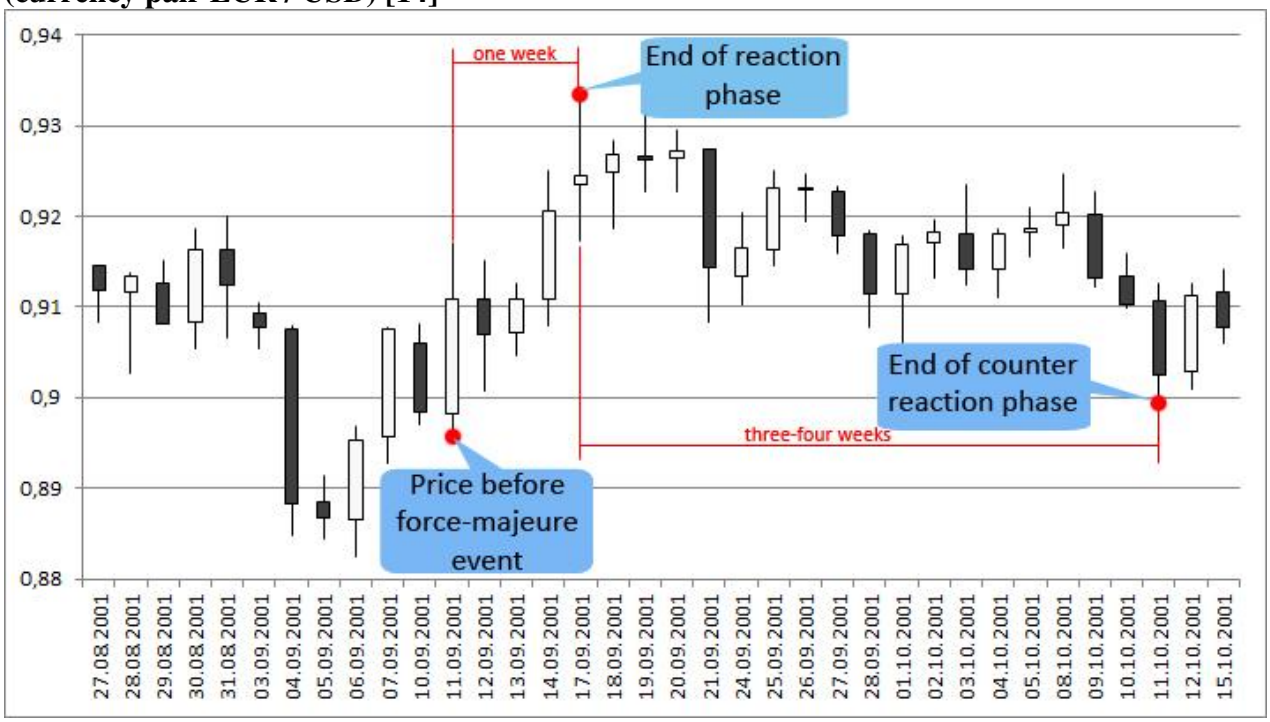


The picture is quite similar to the behavior of U.S. stock market in September 11, 2001. During the first week market absorbed information and Nikkei index lost 18%. Then there was a counter reaction and market returned to its previous state during next 3 weeks.

It is noteworthy that this behavior is typical not only for the stock markets, but also for other markets (foreign exchange and commodities).

For example reaction of foreign exchange market (currency pair EUR / USD) to terrorist attacks in September 11, 2001 on the U.S. is shown in Fig. 3.

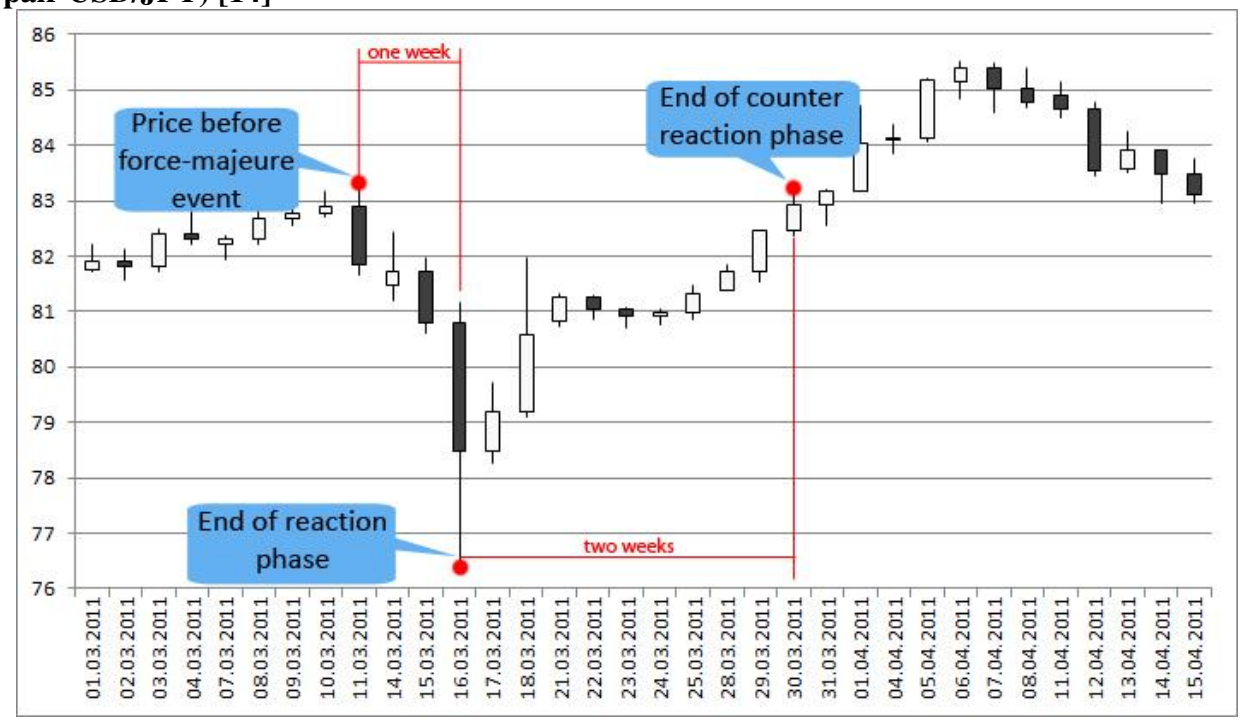
Figure 3. Reaction of foreign exchange market to the terrorist attack in September 11, 2001 (currency pair EUR / USD) [14]



Exchange rate of USD to EUR was fallen during the first week and then returned to the initial position over next 3 weeks.

However, market's reaction to force major events is not always typical. For example, in case of the earthquake in Japan (March 11, 2011) behavior of USD/JPY is atypical (Fig. 4). Japanese yen strengthened during first week (almost by 10%). Then it fell and returned to the initial position (during next two weeks). Such behavior can be explained by the repatriation of Japanese capital for economic recovery.

Figure 4. Reaction of foreign exchange market to earthquake in March 11, 2011 (currency pair USD/JPY) [14]



Thus, above examples provide the basis for reasonable doubt in the market's efficiency during force major events because market loses its equilibrium for a while and stabilizes later. At the same time, even short market failure opens up opportunities for speculative earnings and extra profits.

In this case we have some specific practical issues. How market behaves after force major events? How long is market's reaction to force-major? How strong it is? And so on. Another potentially very important observation that needs to be verified is the presence of two phases in force majeure events: phase of reaction and phase of counter reaction. It is vital to find out the relationship of these phases and their parameters (are they equal in size, are they differ in duration, etc.).

Examples show that markets require some specific periods of time to absorb force majeure information and some periods of time for a return to the equilibrium point. It is possible that the scale of market reaction is typical, which allows to predict not only the time (duration) of market reaction, but the magnitude of this response. This knowledge gets a possibility to extra profits from the speculative operations with financial assets during force major events.

Naturally, we can't make conclusions from two events because analyzed force majeure situations are unprecedented in scale and impact, so it is possible that in other cases similar reaction will occur. So before we look for certain patterns in the behavior of markets during the occurrence of force major, we will try to prove statistically the existence of anomalies during force major events. If market prices behavior after force majeure events differs from the behavior before force major event, it can be argued that the market really is in some non-typical state. In this case it is ineffective and temporary loses its equilibrium.

To verify the identity of one data set to another in statistics, there are several specific methods (criteria):

1) Student's t-test;
2) Pearson's chi-squared test;
3) Kolmogorov–Smirnov test;
4) Bartlett's test and others.

The specific features of analyzed data are limited selection and its normal distribution.

The sample size is limited because of a small number of significant force majeure events that accrued during the last 20 years.

On the issue of compliance of the analyzed data to the normal distribution law we talk a little bit more, because it affects the analysis tools.

Normal distribution, so-called Gaussian distribution, is the probability distribution, under which the resulting value is affected by a large number of random factors.

Central Limit Theorem: If a random variable is exposed to an infinite number of infinitely small random factors, it is normally distributed.

Random variable is a variable which value results from the measurement of a quantity that is subject to variations due to chance (i.e. randomness, in a mathematical sense).

There are many factors that affect the movement of market prices and their influence is very different. So the price movement assumes the character of random fluctuations (usually for a limited period of time). Talking about force-major events, we consider them as a time limited. Thus, financial assets prices can be regarded as random variables.

However, in order to confirm above-mentioned logical assumptions, we analyze the "normality" of data using specially designed criterion.

In order to check data, we used the Pearson criterion. We randomly selected 100 consecutive ranges of prices for the period 2006-2008 (Table 1) and calculated values of test statistics. If test statistics does not exceed the critical value of chi-square distribution, the value is normally distributed.

Table 1. "Normality" of EUR/USD data

	2006	2007	2008
Number of values	100		
Average	80.14	73.62	145.19
Standard deviation	28.37	24.5	51.67
Confidence probability	0.95		
Test statistics	6.1	9.37	9.12
Chi-square distribution (hi(p=0.95, f=7))	14.1		
Conclusion	Data is normally distributed		

Thus, financial assets prices are normally distributed. So the data is relevant to use Student's t-test because it meets the terms of the limited sample size and belongs to normal distribution.

2. METHODOLOGY ANALYSIS

The main goal pursued by this research is to identify the affiliation of force majeure events with the sample data for the previous period. It means we test hypothesis (H0) that the average values of certain variables (before force-major and after force-major) are the same. An alternative hypothesis (H1) is an inequality of sample means before and after force major event. As a population, we have chosen the period, which included 30 values of a particular asset.

As for force major events duration, we chose four fixed periods, which include 5, 7, 10 and 15 values of a particular asset. This approach takes into account lags in market's reaction to the certain type of force major events.

Test of hypotheses is performed with probability p = 0.95.

After forming the sample data, we count mean and standard deviation before and after the force major event. Calculated values of Student's t-test are compared with the critical ones.

If the obtained value of t-test does not exceed critical, we made conclusions about the equality of sample means, and thus hypothesis (H0) is confirmed. Otherwise we adopt alternative hypothesis (H1); sample means are not equal and we can talk about the abnormal market reaction to the force majeure event.

In order to take into account various changes in market equilibrium (loss of its efficiency) we test different varieties of samples for statistical significance

1) dynamics of market fluctuations in relative terms (formula 1) - so we try to demonstrate that force majeure event causes an abnormal changes of market prices

$$P_i = |close_i - close_{i-1}| ./ close_{i-1} \quad (1)$$

where P_i - calculated sample data;

$close_i$ - the daily close price of a current period;

and $close_{i-1}$ - the daily close price of a prior period.

2) dynamics of price changes over the period (formula 2) - so we tried to demonstrate that after force majeure events one-way movement of prices appears and it differs in terms of normal fluctuations of market prices for the period (one side directed movement);

$$P_i = open_i - close_i + GAP_{i-1} \quad (2)$$

where P_i - calculated sample data;

$open_i$ - open price for the current period;

$close_i$ - close price for the previous period

GAP - the difference between closing price and opening price.

3) volatility of market prices during the period (formula 3) - so we tried to prove that sharp increase in stock price fluctuations indicates panic in the market. Panic indicates loss of market's stability and, as a consequence, temporary loss of its efficiency.

$$P_i = high_i - low_i \quad (3)$$

where P_i - calculated sample data;

$high_i$ - maximum price of asset for the current period;

low_i - minimum price of asset for the current period.

Sample data is formed for various assets and time periods that meet force major events.

3. MAIN FORCE-MAJEURE EVENTS DURING LAST 20 YEARS

Force-majeure events are classified into the following categories:
- terrorist attacks;
- natural disasters;
- technological disasters;
- economic events.

For each category we formed a particular list of force majeure events for the last 20 years (Table 2-5).

Table 2. The list of major terrorist attacks occurred over the 1995-2005 period [7]

Force-	Description and consequences	Date	Injured

majeure event			country
Sarin gas attacks in the Tokyo Metro	Five members of Aum Shinrikyo launched a chemical attack on the Tokyo Metro, killing 13 people, severely injuring 50 and causing temporary vision problems for nearly a thousand others.	20 March 1995	Japan
The United States embassy bombings	A series of attacks, in which hundreds of people were killed in simultaneous truck bomb explosions at the United States embassies in the East African capitals of Dar es Salaam, Tanzania (at least 11 people were killed and 85 wounded), and Nairobi, Kenya (approximately 212 people were killed, and 4,000 wounded).	7 August 1998	USA
The USS Cole bombing	A suicide attack against the United States Navy guided-missile destroyer USS Cole (DDG-67) while it was harbored and being refueled in the Yemen port of Aden. 17 American sailors were killed and 39 injured	12 October 2000	USA
Suicide attacks in New York City and the Washington, D.C. areas	The hijackers intentionally flew planes into the North and South towers of the World Trade Center complex in New York City, the Pentagon and the United States Capitol Building (unsuccessfully). Nearly 3,000 people died in the attacks, including all 227 civilians and 19 hijackers aboard the four planes	11 September 2001	USA
The Madrid train bombings	Simultaneous, coordinated bombings against train system of the city of Madrid. 191 people were killed and 1,800 wounded.	11 March 2004	Spain
London bombings	A series of coordinated suicide attacks in London Underground which targeted civilians using the public transport system during the morning rush hour. 52 civilians and 4 bombers were killed in the attacks, and over 700 more were injured.	7 July 2005	Great Britain

Table 3. The list of the largest technological disasters occurred over the 2000-2010 period [5,8,9]

Force- majeure event	Description and consequences	Date	Injured country
Baia Mare cyanide spill	A leak of cyanide near Baia Mare, Romania, into the Someş River by the gold mining company Aurul. The polluted waters eventually reached the Tisza and then the Danube, killing large numbers of fish in Hungary and Yugoslavia.	31 January 2000	Romania
Air France Concorde Flight 4590 crash	All one hundred passengers and nine crew members on board the flight died. On the ground, four people were killed and one left with serious injuries. Revenue service was resumed in 2001, until the remaining aircraft were retired in 2003.	25 July 2000	France
The Prestige oil spill	An oil spill off the coast of Galicia caused by the sinking of an oil tanker. The spill polluted thousands of kilometers of coastline and more than one thousand beaches on the Spanish, French and Portuguese coast, as well as causing great harm to the local fishing industry. An estimated cost of the clean-up is €2.5 billion.	13 November 2002	EU
The Space Shuttle	The Space Shuttle Columbia disintegrated over Texas and Louisiana during re-entry into the Earth's	1 February	USA

Columbia disaster	atmosphere, resulting in the death of all 7 crew members. The total cost of the disaster (according to the NASA) was $13 billion.	2003	
The Andersen Air Force Base B-2 accident	A B-2 Spirit stealth heavy bomber, crashed on the runway shortly after takeoff from Andersen Air Force Base in Guam. The aircraft was destroyed, a total loss estimated at US$1.4 billion	23 February 2008	USA
The Deepwater Horizon oil spill	It is the largest accidental marine oil spill in the history of the petroleum industry. The spill stemmed from a sea-floor oil gusher that resulted from the 20 April 2010 explosion of Deepwater Horizon. The explosion killed 11 men working on the platform and injured 17 others. An estimated 53,000 barrels per day escaped from the well just before it was capped. The spill caused extensive damage to marine and wildlife habitats and to the Gulf's fishing and tourism industries	20 April 2010	USA

Table 4. The list of the largest natural disasters occurred over the 1995-2011 period [5,8,9]

Force- majeure event	Description and consequences	Date	Injured country
The Great Hanshin earthquake	The earthquake with magnitudes up to 7.3 on the Richter scale. Approximately 6,434 people lost their lives. The earthquake caused approximately ten trillion yen ($100 billion) in damage, 2.5% of Japan's GDP at the time.	17 January 1995	Japan
The South Asian tsunami	The earthquake was caused by subduction and triggered a series of devastating tsunamis along the coasts of most landmasses bordering the Indian Ocean, killing over 230,000 people in fourteen countries, and inundating coastal communities with waves up to 30 meters high.	26 December 2004	South-Eastern Asia
Hurricane Katrina	Hurricane Katrina was the deadliest and most destructive Atlantic hurricane of the 2005 Atlantic hurricane season. The most significant number of deaths occurred in New Orleans, Louisiana, which flooded as the levee system catastrophically failed. At least 1,833 people died in the hurricane and subsequent floods; total property damage was estimated at $81 billion.	27 January 2005	USA
The 2010 Haiti earthquake	An estimated three million people were affected by the quake; the Haitian government reported that an estimated 316,000 people had died, 300,000 had been injured and 1,000,000 made homeless. The government of Haiti also estimated that 250,000 residences and 30,000 commercial buildings had collapsed or were severely damaged.	12 January 2010	Haiti
The 2010 eruptions of Eyjafjallajökull	Volcanic events at Eyjafjallajökull in Iceland which, although relatively small for volcanic eruptions, caused enormous disruption to air travel across western and northern Europe over an initial period of six days in April 2010. Additional localized disruption continued into May 2010.	14 April 2010	Iceland
The Great East Japan	Undersea mega thrust earthquake off the coast of Japan. It was the most powerful known earthquake ever to have	11 march 2011	Japan

Earthquake	hit Japan. The earthquake triggered powerful tsunami waves that reached heights of up to 40.5 meters. A Japanese National Police Agency report confirmed 15,870 deaths, 6,114 injured, and 2,814 people missing across twenty prefectures, as well as 129,225 buildings totally collapsed, with a further 254,204 buildings 'half collapsed', and another 691,766 buildings partially damaged. The World Bank's estimated economic cost was US$235 billion, making it the most expensive natural disaster in world history.		

Table 5. The list of the largest force-majeure economic events occurred over the 1989-2010 period [16]

Force- majeure event	Description and consequences	Date	Injured country
The Friday the 13th mini-crash	The crash was caused by a reaction to a news story of the break-down of a $6.75 billion leveraged buyout deal for UAL Corporation, the parent company of United Airlines.	13 October 1989	USA
Black Wednesday	The British Conservative government was forced to withdraw the pound sterling from the European Exchange Rate Mechanism (ERM) after they were unable to keep it above its agreed lower limit. In 1997 the UK Treasury estimated the cost of Black Wednesday at £3.4 billion	16 September 1992	UK
Black Tuesday	Daily Shanghai Composite index lost nearly 9%, which was the most serious decline over the last 10 years. The fall was caused by rumors and fears that Chinese stock market is overheated and fueled with speculative, often borrowed funds.	27 February 2007	China
Bankruptcy of Lehman Brothers	Financial services firm Lehman Brothers filed for Chapter 11 bankruptcy protection. The filing remains the largest bankruptcy filing in U.S. history, with Lehman holding over $600 billion in assets.	15 September 2008	USA
FOMC Announcement	The Committee decided to increase the Fed balance sheet by making additional purchases of MBS amounting to $750 billion, which would increase the total purchases of these securities this year to $ 1.25 trillion., and also to buy agency debt securities up to $100 billion, bringing total purchases to $ 200 billion; the Committee decided to buy long-term government bonds amounting to $ 300 billion	18 march 2009	USA
Speech by U.S. Federal Reserve Chairman Ben Bernanke	Ben Bernanke said that the federal funds rate will remain low for a long time.	15 October 2010	USA

4. FINANCIAL MARKETS REACTION TO FORCE MAJEURE EVENTS

To analyze the reaction of different types of markets to force majeure events we chose the following objects of analysis: foreign exchange market (currency pair, which includes currency

of injured country and currency pair USD / CHF to study the behavior of shelter-currency, which is Swiss franc), stock market (represented by the leading stock index of injured country), commodities market (gold and oil prices).

Example of data set formation and t-test calculations is presented in Appendix 1 (case of stock market reaction to terrorist attack on 11/09/01, volatility of market prices during the period method). Such data sets and calculations were formed and done for other 71 cases. Overall results of t-test for 4 different groups of force majeure events are presented in Appendixes 2-5. Value "0" in a particular cell means that t-test is not passed, so force majeure event movements are not differ from normal movements of the markets. Value "1" in a particular cell means that price movements after force majeure event are not typical for the market. In this case we can make a conclusion that market becomes inefficient for some time.

Final results of t-test statistics for each of the proposed methods of data set formation are presented in the Table 6.

Table 6. Final results of t-test statistics for each of the proposed methods of data set formation

Sample formation approach	Results (percentage of anomalies)
Volatility of market prices method	32.5%
Dynamics of market fluctuations in relative terms method	17.5%
Dynamics of price changes method	8.3%

As we can see from the table 6, best results (the biggest percentage of anomalies) are shown by the volatility of market prices method. So this method we take as a basis for detailed analysis.

Our calculations of t-test results in case of volatility method are shown in the Table 7.

Table 7. T-test for market reaction to force majeure events (percentage of events when financial market lost equilibrium)

Type of market	Foreign exchange		Stock	Commodity	
Type of force major	Injured country currency	Shelter currency (USD/CHF)	Leading stock index	Oil	Gold
Natural disasters	33%	0%	67%	17%	33%
Technological disasters	50%	33%	33%	0%	50%
Acts of terrorism	0%	17%	50%	33%	17%
Economic events	67%	50%	50%	0%	50%
Average	**38%**	**25%**	**50%**	**13%**	**38%**

Results of the study show the benefit of the efficient market hypothesis. Despite the relatively large scale and suddenness of force majeure events (we selected events with the biggest losses) it is very difficult to disturb market equilibrium. Financial markets quickly absorb new information and continue to function in usual rhythm. Fluctuations (in prices of assets) that occur in the post-force majeure period match fluctuations during the pre-force majeure period.

A characteristic feature of exchange markets' behavior is that the more developed the country the greater reaction to force majeure event is shown by markets.

The most inert assets are oil and shelter currency USD / CHF (13% и 25% confirmed reactions accordingly). Almost the same reaction shows currency of the injured country and gold price (38% confirmed reactions each). Stock market demonstrates the biggest response (50% confirmed reactions).

Despite the fact that financial markets do not lose their equilibrium due to force majeure events stock markets provide a good opportunity for speculations because of a relatively large number of market disbalances. It should be noted that the average percentage of disequilibrium (50%) may actually be higher, taking into account the existence of time lags in certain types of force majeure events (i.e. the time required to assess the scale of the technological / natural disasters and determine the approximate loss of economy from them), and potential shortcomings of the analysis.

Very often a reaction to the force majeure events is quite short - 1-2 days or even less, and the same is true for a counter reaction. It is almost impossible to statistically determine these anomalies. Thus, short-term market reactions to the force majeure events are not taken into account in the final results. So the real rate of market reactions to force majeure events is higher, but short-term force majeure events are not suitable for development of effective trading strategies.

One more thing we should mention: t-test is rather tough thing in case of critical value for t-distribution. Sometimes even strong reaction to force-majeure events gives no appropriate results of t-test to exceed the critical value. In our case there are results which can't be counted in favor of market inefficiency because they are not big enough to exceed critical value, but they are very close to this. So the real percentage of confirmed reactions must be higher.

Anyway, stock markets showed abnormal reactions in 50% cases and that gives us basis for test of some patterns in markets behavior during the force majeure event. Thus, our next step is to find regularities in the behavior of stock markets after force majeure events and to identify potential results of stock market reaction. Analysis of other markets is pointless because they show too low probability of ineffectiveness. In addition, we have significantly narrowed the list of force major events for analysis (we choose those ones which show the best reaction).

List of some statistically significant force major events and results of their analysis are presented in Table 8.

The analysis confirmed the presence of two phases of market reaction to force major events:

- phase of reaction, which is a natural reaction to negative market news (in our case – fall of the stock index of the affected countries), and
- phase of counter reaction, which is not just a correction to the previous price movement, but is an attempt (usually successful) to return to the basic equilibrium.

Typical parameters of the stock markets reaction to the force majeure events are presented in the table. 9.

Table 9. Parameters of typical stock market reaction to the force majeure events

Phase of Reaction		Phase of Counter Reaction	
Duration (days)	Size of reaction (%)	Duration (days)	Size of reaction (%)
5,4	10,5%	5	7,6%

The main conclusions of this part of research are:

• typical market reaction to the force majeure events is a two-phase model: phase of reaction and phase of counter reaction;

• in most cases the size of phase of reaction and counter reaction approximately equal or fit into the limits of permissible errors;

• on average, phase of reaction lasts 5,4 days;

• the average size of phase of reaction is approximately 10.5%;

• the average duration of phase of counter reaction is very close to the phase of reaction and is up to 5 days;

• the size of phase of counter reaction is close to the size of phase of reaction and is 7.6% on average;

• market reaction to force majeure events (with rare exceptions) is typical - negative event for a particular country leads to decline of its stock market index.

Table 8. Analysis of the stock market reaction to the biggest force major events

Force-major	Date	Injured country	Instrument	Reaction phase					Counter Reaction phase				
				End of reaction phase	Duration (days)	Max price	Min price	% change	End of counter reaction phase	Duration (days)	Max price	Min price	% change
The Friday the 13th mini-crash	13.10.1989	USA	Dow Jones	18.10.1989	3	2773	2638	-4.87%	19.10.1989	1	2707	2638	2.62%
Black Wednesday	16.09.1992	Great Britain	FTSE	21.09.1992	5	2611	2291	13.97%	22.09.1992	1	2611	2545	-2.53%
The Great Hanshin earthquake	17.01.1995	Japan	NIKKEI	24.01.1995	7	19362	17699	-8.60%	01.02.1995	7	18869	17699	6.60%
Baia Mare cyanide spill	31.01.2000	EU	FTSE	07.02.2000	5	6376	6101	-4.31%	09.02.2000	2	6451	6101	5.74%
The USS Cole bombing	12.10.2000	USA	Dow Jones	12.10.2000	1	10462	9874	-5.62%	16.10.2000	4	10429	9874	5.62%
Suicide attacks in New York City and the Washington, D.C. areas	11.09.2001	USA	Dow Jones	21.09.2001	7	9740	7927	-18.61%	28.09.2001	5	8945	7927	12.84%
The Madrid train bombings	11.03.2004	EU	FTSE	24.03.2004	11	4545	4291	-5,6%	13.04.2004	14	4525	4291	5,5%
Bankruptcy of Lehman Brothers	15.09.2008	USA	Dow Jones	18.09.2008	3	11416	10460	-8.37%	19.09.2008	1	11483	10460	9,78%
The 2010 eruptions of Eyjafjallajökull	14.04.2010	EU	FTSE	22.04.2010	7	5810	5652	-2,72%	26.04.2010	3	5800	5652	2,6%
The Great East Japan Earthquake	11.03.2011	Japan	NIKKEI	16.03.2011	5	10440	8320	-20.31%	01.04.2011	12	9850	8320	18.39%

5. TRADING ON FORCE-MAJOR EVENTS

Based on assessments and conclusions made above, we can formulate the following rules of trading on the stock markets in case of force majeure events:

• make sure that the reaction is typical (a trader needs to analyze the reaction of the market during the first day of event), open positions in the direction of force majeure events (short positions);

• hold positions during an average duration of phase of reaction and close shot positions before the beginning of phase of counter reaction;

• as soon as the phase of counter reaction begins close all shot positions and open long positions;

• hold long positions until the market return to its initial state. Some positions should be closed when asset price reaches 50% of its value in phase of reaction. Close all long positions at the pre-force- majeure event price.

We demonstrate these rules on a particular force majeure event – The Great Hanshin earthquake (January 17, 1995). Dynamics of Nikkei225 index is shown in Table 10.

Table 10. Nikkei 225 index for the period from 11.01.1995 to 03.02.1995

Date	Open	High	Low	Close
11.01.1995	19518	19603	19480	19548
12.01.1995	19536	19547	19344	19410
13.01.1995	19408	19408	19265	19331
17.01.1995	**19322**	**19362**	**19088**	**19241**
18.01.1995	**19232**	19321	19201	19223
19.01.1995	19218	19298	18978	19076
20.01.1995	19034	19034	18754	18840
23.01.1995	18807	18818	17779	17785
24.01.1995	17807	18139	17699	18061
25.01.1995	**18096**	18413	18096	18159
26.01.1995	**18168**	18407	18017	18071
27.01.1995	18091	18257	17938	18104
30.01.1995	18137	18819	18137	18753
31.01.1995	18790	18855	18583	18650
01.02.1995	**18647**	18869	18610	18739
02.02.1995	18720	18720	18521	18604
03.02.1995	18607	18646	18437	18539

Let's analyze trader's actions according to proposed rules.

After the force majeure event trader confirms type of market reaction (typical or atypical). Downward trend is a typical reaction of the Nikkei index in this case (see close value of this index). That's why the trader should open short position at a price of 19232 on January 18th. Average reaction lasts 5 days and the average size reaction is 7.5% (see Table. 9). Trader holds his position while the price continues to fall.

On January 24 the Nikkei index lost 8% of its value, so the position had to be closed at a price of 17807 (open price on January 24). Profitability of these actions is 8%.

Next day the index began to grow. As a result, trader should open long position at a price of 18186 (according to proposed algorithm). Expected reverse movement of the index is less than the movement of the phase of reaction.

In January 31st close price was lower than the open price, thus the trader should close long position next day (February 1st) at a price of 18647. Long positions earnings totaled up to 2.5%, which is certainly less than expected 7-8%, but also is a good result.

Ultimately, the overall financial performance after this force majeure event amounted up to 10% in 10 days, which is a good result.

Despite the fact that this analysis is made post factum, nevertheless it is important to illustrate the algorithm of trader's actions according to proposed trade rules.

6. CONCLUSIONS

As the result of this research we came to the conclusion that force majeure events in most cases are unable to disrupt the balance of financial markets (at least more then for 1-2 days). The majority of financial markets (commodity, foreign exchange) are extremely inert and in 80% of cases do not lose their equilibrium state.

The most sensitive type of financial markets to force majeure events is stock market. The more economically developed country is the larger will be reaction to force majeure event. But even such sensitivity does not guarantee loss of equilibrium by stock market in a half of the cases.

The analysis showed that, market's reaction on force majeure events (if it happens of course) is presented by a typical model, which consists of two parts - phase of reaction and phase of counter reaction. This gives opportunities for speculations during force majeure events. Evaluation of basic parameters of the phase of reactions and phase of counter reaction (duration and size of changes in asset prices) for stock markets lets to determine typical ranges of market reaction to certain type of force majeure events. Based on these results, we developed trade rules to follow in case of force majeure events.

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Appendix 1

Example of data set and calculations

Dow Jones Index (analysis of the reaction to 11/09/01)

Pre-force-majeure event dataset

Date	High	Low	High-Low
27.07.2001	10316.3	10516.4	
30.07.2001	10301.1	10513.3	212.2
31.07.2001	10364.8	10639.4	274.6
01.08.2001	10423.3	10659.3	236
02.08.2001	10454.5	10663.1	208.6
03.08.2001	10381.1	10593	211.9
06.08.2001	10337.2	10549.6	212.4
07.08.2001	10324.5	10520.1	195.6
08.08.2001	10245.7	10509.8	264.1
09.08.2001	10160.5	10361.5	201
10.08.2001	10164.7	10473.3	308.6
13.08.2001	10315	10504.8	189.8
14.08.2001	10333.3	10513.7	180.4
15.08.2001	10289	10530.4	241.4
16.08.2001	10198.2	10460.8	262.6
17.08.2001	10143.5	10418.7	275.2
20.08.2001	10146.1	10388.2	242.1
21.08.2001	10132.9	10436.4	303.5
22.08.2001	10099.1	10340.8	241.7
23.08.2001	10142.7	10357.1	214.4
24.08.2001	10190.3	10487.5	297.2
27.08.2001	10334.9	10498	163.1
28.08.2001	10175.6	10405.9	230.3
29.08.2001	10030.4	10292.6	262.2
30.08.2001	9829.4	10149.1	319.7
31.08.2001	9846.7	10072.2	225.5
04.09.2001	9858.3	10238.5	380.2
05.09.2001	9821	10140.8	319.8
06.09.2001	9762	10053.7	291.7
07.09.2001	9507	9842.1	335.1
10.09.2001	**9431.1**	**9740.4**	**309.3**

Post-force-majeure event dataset

Date	High	Low	High-Low
17.09.2001	**8755.5**	**9294.6**	**539.1**
18.09.2001	8743.9	9126.9	383
19.09.2001	8453	8990.4	537.4
20.09.2001	8304.5	8711.4	406.9
21.09.2001	7926.9	8484.2	557.3
24.09.2001	8242.3	8733.4	491.1
25.09.2001	8435.6	8778.2	342.6
26.09.2001	8457.4	8766.8	309.4
27.09.2001	8398.1	8757.5	359.4
28.09.2001	8633.8	8945.7	311.9
01.10.2001	8659.9	8931.7	271.8
02.10.2001	8737.6	9001	263.4
03.10.2001	8801	9193.3	392.3
04.10.2001	8982.3	9259.6	277.3
05.10.2001	8894.5	9208.4	313.9

T-statistics for the force-majeure event

Force-majeure duration period	15	10	7	5
Pre-force-majeure event average	253.67	253.67	253.67	253.67
Post-force-majeure event average	383.78	423.81	465.34	484.74
Post-force-majeure event standard deviation	102.19	98.23	86.61	82.76
T-test	4.93	5.47	6.46	6.24
Critical t	2.14	2.26	2.44	2.77

Appendix 2

Results of t-test for terrorist attacks

Table 2.1 – Dynamics of market fluctuations in relative terms method

	Foreign exchange		Stock	Commodity		
Force- majeure event	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	**Overall**
Sarin gas attacks in the Tokyo Metro	0	0	0	0	0	0
The United States embassy bombings	0	0	0	0	0	0
The USS Cole bombing	0	0	1	0	0	1
Suicide attacks in New York City and the Washington, D.C. areas	0	0	1	1	0	2
The Madrid train bombings	0	0	1	0	0	1
London bombings	0	0	0	0	0	0
Overall	0	0	3	1	0	4

Table 2.2 – Dynamics of price changes over the period method

	Foreign exchange		Stock	Commodity		
Force- majeure event	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	**Overall**
Sarin gas attacks in the Tokyo Metro	0	0	0	1	0	1
The United States embassy bombings	0	0	0	0	0	0
The USS Cole bombing	0	0	0	0	0	0
Suicide attacks in New York City and the Washington, D.C. areas	0	0	0	0	0	0
The Madrid train bombings	0	0	0	0	1	1
London bombings	0	0	0	0	0	0
Overall	0	0	0	1	1	2

Table 2.3 – Volatility of market prices during the period method

Force- majeure event	Foreign exchange		Stock	Commodity		**Overall**
	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	
Sarin gas attacks in the Tokyo Metro	0	0	0	1	0	1
The United States embassy bombings	0	0	0	0	0	0
The USS Cole bombing	0	0	1	0	0	1
Suicide attacks in New York City and the Washington, D.C. areas	0	1	1	1	1	4
The Madrid train bombings	0	0	1	0	0	1
London bombings	0	0	0	0	0	0
Overall	0	1	3	2	1	7

Appendix 3

Results of t-test for natural disasters

Table 3.1 – Dynamics of market fluctuations in relative terms method

Force- majeure event	Foreign exchange		Stock	Commodity		**Overall**
	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	
The Great Hanshin earthquake	0	0	0	0	0	0
The South Asian tsunami	0	0	0	0	0	0
Hurricane Katrina	0	0	0	0	0	0
The 2010 Haiti earthquake	0	0	1	0	0	1
The 2010 eruptions of Eyjafjallajökull	0	0	1	0	0	1
The Great East Japan Earthquake	1	0	1	0	0	2
Overall	1	0	3	0	0	4

Table 3.2 – Dynamics of price changes over the period method

Force- majeure event	Foreign exchange		Stock	Commodity		**Overall**
	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	
The Great Hanshin earthquake	0	0	0	0	0	0
The South Asian tsunami	0	0	0	0	0	0
Hurricane Katrina	0	0	0	0	0	0
The 2010 Haiti earthquake	0	0	0	1	0	1
The 2010 eruptions of Eyjafjallajökull	1	1	1	0	0	3
The Great East Japan Earthquake	0	0	0	0	0	0
Overall	1	1	1	1	0	4

Table 3.3 – Volatility of market prices during the period method

Force- majeure event	Foreign exchange		Stock	Commodity		**Overall**
	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	
The Great Hanshin earthquake	0	0	1	0	0	**1**
The South Asian tsunami	1	0	0	0	0	**1**
Hurricane Katrina	0	0	0	1	1	**2**
The 2010 Haiti earthquake	0	0	1	0	0	**1**
The 2010 eruptions of Eyjafjallajökull	0	0	1	0	0	**1**
The Great East Japan Earthquake	1	0	1	0	1	**3**
Overall	**2**	**0**	**4**	**1**	**2**	**9**

Appendix 4

Results of t-test for technological disasters

Table 4.1 – Dynamics of market fluctuations in relative terms method

Force- majeure event	Foreign exchange		Stock	Commodity		**Overall**
	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	
Baia Mare cyanide spill	0	0	0	0	1	1
Air France Concorde Flight 4590 crash	0	0	0	0	0	0
The Prestige oil spill	0	0	0	0	0	0
The Space Shuttle Columbia disaster	1	0	0	0	1	2
The Andersen Air Force Base B-2 accident	0	1	0	0	0	1
The Deepwater Horizon oil spill	0	0	1	0	0	1
Overall	1	1	1	0	2	5

Table 4.2 – Dynamics of price changes over the period method

Force- majeure event	Foreign exchange		Stock	Commodity		**Overall**
	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	
Baia Mare cyanide spill	0	0	0	0	0	0
Air France Concorde Flight 4590 crash	0	0	0	0	0	
The Prestige oil spill	0	1	0	1	0	2
The Space Shuttle Columbia disaster	0	0	0	0	0	0
The Andersen Air Force Base B-2 accident	1	1	0	0	0	2
The Deepwater Horizon oil spill	0	0	0	0	0	0
Overall	1	2	0	1	0	4

Table 4.3 – Volatility of market prices during the period method

Force- majeure event	Foreign exchange		Stock	Commodity		**Overall**
	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	
Baia Mare cyanide spill	1	0	1	0	1	3
Air France Concorde Flight 4590 crash	0	0	0	0	0	
The Prestige oil spill	0	0	0	0	1	1
The Space Shuttle Columbia disaster	1	0	0	0	1	2
The Andersen Air Force Base B-2 accident	0	1	0	0	0	1
The Deepwater Horizon oil spill	1	1	1	0	0	3
Overall	3	2	2	0	3	10

Appendix 5

Results of t-test for economic events

Table 5.1 – Dynamics of market fluctuations in relative terms method

Force- majeure event	Foreign exchange		Stock	Commodity		**Overall**
	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	
The Friday the 13th mini-crash	0	0	0	0	0	0
Black Wednesday	1	0	0	0	0	1
Black Tuesday	1	1	1	0	0	3
Bankruptcy of Lehman Brothers	0	0	1	1	1	3
FOMC Announcement	0	0	0	0	0	0
Speech by U.S. Federal Reserve Chairman Ben Bernanke	0	1	0	0	0	1
Overall	2	2	2	1	1	8

Table 5.2 – Dynamics of price changes over the period method

Force- majeure event	Foreign exchange		Stock	Commodity		**Overall**
	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	
The Friday the 13th mini-crash	0	0	0	0	0	0
Black Wednesday	0	0	0	0	0	0
Black Tuesday	0	0	0	0	0	0
Bankruptcy of Lehman Brothers	0	0	0	0	0	0
FOMC Announcement	0	0	0	0	0	0
Speech by U.S. Federal Reserve Chairman Ben Bernanke	0	0	0	0	0	0
Overall	0	0	0	0	0	**0**

Table 5.3 – Volatility of market prices during the period method

Force- majeure event	Foreign exchange		Stock	Commodity		**Overall**
	Injured country currency	Shelter currency	Leading stock index	Oil	Gold	
The Friday the 13th mini-crash	0	0	1	0	0	1
Black Wednesday	1	0	1	0	0	2
Black Tuesday	1	1	0	0	1	3
Bankruptcy of Lehman Brothers	1	1	1	0	1	4
FOMC Announcement	0	0	0	0	0	0
Speech by U.S. Federal Reserve Chairman Ben Bernanke	1	1	0	0	1	3
Overall	4	3	3	0	3	13