**CHARLES UNIVERSITY**

FACULTY OF SOCIAL SCIENCES

Institute of Economic Studies

# Bachelor thesis

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# Impact of Terrorism on Stock Markets

*Bachelor thesis*

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## Abstract

Terrorism generally induces negative mood in the society. Financial markets performance exhibits the contingency on the mood of their trading participants. The thesis enhances the understanding of this interrelated entities by analysing the situation from 2000 to 2015 at the 20 world largest markets. Their composite indices are put under scrutiny employing a multifactor model, a difference equation and a logit model. The impact is confirmed and further discussed, while the logit model provides a simple framework for forecasting index returns just after an attack with more than 25 casualties.

## Keywords

global financial markets, terrorism, multifactor model, difference equation, logit model

## Abstrakt

Terorizmus vo všeobecnosti vytvára negatívnu náladu v spoločnosti. Výkon finančných trhov vykazuje závislosť na nálade účastníkov trhu. Táto práca prispieva k pochopeniu týchto navzájom súvisiacich entít tým, že analyzuje situáciu od roku 2000 do 2015 na 20 najväčších svetových trhoch. Ich kompozitné indexy sú skúmané pomocou multifaktorového modelu, diferenčnej rovnice a logit modelu. Vplyv je potvrdený a ďalej diskutovaný, zatiaľ čo logit model poskytuje jednoduchý rámec na predpovedanie výnosov jednotlivých trhových indexov v nádväznosti na útok s viac ako 25 obeťami.

## Kľúčové slová

globálne finančné trhy, terorizmus, multifaktorový model, diferenčná rovnica, logit model

## Declaration of Authorship

I hereby proclaim that I wrote my bachelor thesis on my own under the leadership of my supervisor and that the references include all resources and literature I have used.

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Prague, 28th July 2017

Signature

## Acknowledgment

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## The Bachelor's Thesis Proposal

**Author:** Marek Koščo

**Supervisor:** RNDr. Michal Červinka Ph.D.

**Topic:** The Impact of Terrorism on Stock Markets

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### Description

Globalization implies many significant relationships. The capital markets that we trade in nowadays have never been so interconnected. Acts of terrorism result in negative mood changes that usually demotivate investors. In this thesis we shall investigate the process of influencing financial markets by these events and also how this process evolves in the western financial markets. Many papers from the available literature in the field of global terrorism's impact focus on selected attacks only. When mentioning markets, the authors of previous works investigate just the length of the time interval for the particular indices to recover. Our goal in this thesis is to include multiple terrorist attacks, analyze investors' incentives and provide suitable guidelines for economic behavior in case of a terrorist attack.

In the practical part of our thesis, which shall contain the main contribution of the author, we shall identify relevant financial markets with global impact. Subsequently, using suitable mathematical tools, we shall identify the control variables which have influence on the movements of the main market indices. In addition, we shall examine the dynamics of the investigated process and estimate the parameters of the respective difference/differential equation model. In our numerical experiments, we shall use the data available in the Global Terrorism Database and in the market public statements.

### Outline

1. Introduction and literature review

2. Stock market determinants and role of terrorism

3. Regression and differential equation model of influence of terrorism on stock markets
4. Data description and numerical results
5. Conclusion

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## Contents

# 1 Introduction

Terrorism is undoubtedly a very actual topic that is present in the life of our society. Despite active prevention or retaliation by governments, it seems that under no circumstances is it feasible to completely eliminate its presence and influence. Terrorism has been recently lively debated, particularly in the developed democratic part of the world. These despicable acts evoke negative feelings in the populace. Negative feelings imply negative mood, and one of the areas where mood is an important determinant of performance is stock markets.

This thesis focuses on the period since 2000 as it was the first time in September 2001 when an investor indeed felt, experienced and realized the impact of terrorism on investments (Chen and Siems 2004). The aim is to deepen the understanding of the means of the terrorism risk. Moreover, we strive to predict the price evolution if an attack is of a reasonable size. If precise enough, such predictions might be, for example, practically used for a more specific choice of futures contract. Another study approach is used in order to capture only the price direction development in reaction to an incident which is the main interest of investors in general.

The rest of the thesis is organized as follows: Section 2 provides a comprehensive summary of the past research findings on this topic. This is followed by 'Stock Market Determinants and Role of Terrorism' – Section 3 which incorporates and applies the basic knowledge of the subject while outlining simple relationships between the financial markets and terrorism. Next, Section 4 is devoted to data description, its consolidation and basic features. Section 5 – 'Methodology' elaborates the models and possible methods, techniques or procedures used in this paper. Section 6 – 'Results' gradually presents the outcomes and results of the used models – the multifactor model, the difference equation and the logit model. Section 7 discusses the results and gives suggestions for future research and Section 8 – 'Conclusion' evaluates the contribution of the thesis and terminates it.

## 2 Literature Review

In the current interconnected and globalized world, a terrorist attack implies a broad spectrum of significant consequences. These not only apply to direct victims, but also indirectly to companies operating in the attacked environment. The latter feature exists owing to shares effectively entitling the holders to proportional ownership of a particular company. As a terrorist incident is generally perceived as negative information, these investors usually sell their stocks and the share price subsequently decreases. Such market decisions are easily and quickly processed because of high liquidity, reversibility and electronization of stock exchanges. This principle of price adjustment has been severally described by various researchers. (Abadie and Gardeazabal 2008; Chen and Siems 2004; Chesnay et al. 2011; Eldor and Melnick 2004; Karolyi and Martell 2006; Kumar and Liu 2013).

Many definitions of terrorism as a concept have been used in the related studies. These have been attempted either by scholars, governments, organizations or diplomats (Matusitz 2012). U.S. Department of State (1996) defines terrorism in the following way, which seems to concisely and sufficiently summarize other definitions:

> The term "terrorism" means premeditated, politically motivated violence perpetrated against noncombatant targets by subnational groups or clandestine agents, usually intended to influence an audience.

Vast research on this topic appeared rapidly in the aftermath of September 11, 2001, World Trade Center attacks in the United States, when the reaction of markets around the world was extraordinary (Chen and Siems 2004). The following part firstly reviews the research devoted to geopolitical reasons of terrorism and is followed by the link with the macroeconomic, large-scale and long-term implications. Then the focus is narrowed to the microeconomic effects on companies or individuals, such as capital allocation, strategy adaptation or redistribution of wealth.

Many scholars conducted their research to understand the roots of terrorism. Acemoglu and Robinson (2012) not only theoretically argue that less democracy leads to lower quality of life, which generally results in disorder and includes higher rate of terrorism, but also prove the statements using a number of historical examples. They argue that "societies are constantly subject to economic and political conflict...", which depends on many historical, individual or just random factors. A similar interdependence between terrorism and political regime/freedom was also empirically found by Li (2005) who studied whether "democracy promote[s] or reduce[s] transnational terrorist incidents" using a relatively large dataset. However, other studies were not able to fully back up the previous statement, but some other arguments were introduced. For example, the geographical position has explaining power according to Abadie (2006). He conducted cross-sectional analysis of multiple variables causing terrorism, yet apart from geography the author could not find any other significant relationship. Krueger and Malečková (2003) provide tentative evidence for connection between poverty, religion or education and terrorism rates. However, their analysis is done using a small sample. Furthermore, Blomberg et al. (2004) suggested and econometrically supported that recession in more democratic countries with strong established institutions leads to higher probability of terrorism than in countries with weak institutions. This research is based on the data from 127 countries over years 1968 – 1991. The main finding is that in the countries that have economies with strong established institutions, and that yet find themselves in a depression, the likelihood of terrorism increases. Another motion is that if weak institutions are combined with a weak national army, attempts of government suspension are often present. These incidents may be assessed as participation in terrorism, because they admittedly satisfy the definition of terrorism. Although Gassenber and Luechinger (2011) have not found any influence of countries' wealth on the number of terrorist attacks, the opposite claim was provided by Enders and Hoover (2012), who improved the model by distinction between domestic and transnational terrorism. Their main findings include non-linear but existent relationship between terrorism and poverty and identify income inequality as the main determinant of terrorism. *Ceteris paribus*, the higher the inequality between citizens, the higher the number of expected incidents.

Regarding the macroeconomic implications, the general view is that terrorism exacerbates the macroeconomic condition, which has been confirmed by research. Eckstein and Tsiddon (2004) developed and tested their theory on the case of Israel. The results are in line with the expectations – terror primarily decreases investment and consequently consumption, growth and income in the long run, as a result. Besides, it causes uncertainty and fear in the lives of citizens who tend to overestimate the risk of terrorism. According to the results of the paper, provided that terror had been absent in 2001 – 2003, the per-capita output would have been approximately 10% higher in Israel at the third quarter of 2003. Another research by Blomberg, Hess and Orphanides (2004) focused on the analysis of large unbalanced panel data comprised of 177 countries over the last 32 years of 20th century. The conclusion is that terrorism affects the reallocation of resources in the society from investments towards government spending. Derived results show a negative and slightly persistent effect on the society. Frey et al. (2007) take it a step further by analyzing the macroeconomic consequences of terrorism not only by using purely economic concepts, but also employing calculations based on utility losses of affected individuals. Their results suggest that involved people incur extensive losses as their life quality or satisfaction deteriorates. The main drawback of this paper is that it studies only Northern Ireland and the satisfaction levels are self-reported. Macro effects on Asia are closely analyzed in the paper by Gaibulloev and Sandler (2009), whose main focus is to understand the impact of terrorism on the growth in Asian countries. Constructing many econometrical models and including a reasonably large dataset (years 1970 – 2004), it indicates that "[a]n additional terrorist incident per million persons reduces gross domestic product per capita growth by about 1.5%." Moreover, smaller countries in terms of population are influenced more, and the same amplitude is present if the incident is domestic.

As indicated before, terrorist incidents are able to change the capital flow in the economy. This characteristic moves the focus closer towards individual industries and companies, which is the main focus of this thesis as well. Studies on the influence of terrorism on various financial markets have mostly been conducted in the beginning of the millennium as reactions to 9/11 attacks (Nikkinen and Vähämaa 2010). For instance, the article by Chen and Siems (2004) found significantly negative abnormal returns in each of the 33 studied markets around the world. They used the event-study method of capital markets' responses to the 14 most influential terrorist or military (the difference is that the latter is not organized by subnational groups) attacks since 1915. Furthermore, it suggests that markets are gradually more resilient primarily due to more stable financial and banking sectors.

Majority of research is based on small number of selected incidents and focuses on studying abnormal returns within the mathematical (statistical) framework provided by Brown and Warner (1985). Karolyi and Martell (2006) studied attacks in which publicly traded companies were included and found a drop in their stock price of -0.83% right after the attack. This percentage is equal to an average loss of 401 millions of dollars in market capitalization. The authors also discovered that losses of human capital reflect more significantly on the price than losses of physical assets. According to the researchers, in spite of the fact that attacks in wealthier, more democratic, better educated countries are associated with larger losses, there is no spillover effect to peers in the market. In contrast to these findings, Kumar and Liu (2013) claim that especially smaller trading partners bear losses when there is a terrorist attack on their bigger trading counterparty. They include data on stock market indices from 63 countries with the highest GDP worldwide within 1990 – 2010. Although they included business targets only, they claim that countries without a trading contact do not suffer from spillover effect. Apart from that, controlling for trade characteristics (trade dependence, import penetration, export penetration) has no effect. They also confirmed some macroeconomic results, specifically that larger countries are more resilient and that higher spillover happens in more democratic countries. Moreover, research by Czinkota et al. (2010) claimed that terrorist groups had a much smaller cost related with terrorism than did firms. The authors stated that as the governments increase security of public spots, business becomes a more appealing target. The paper offers future research agenda and implies big room for additional research on connection between business and terrorism.

There might emerge the question of why the proper understanding of terrorism risk is important. Scholars agree that the current extent of terrorism awareness among companies is not sufficient. It is primarily important for leaders of countries or corporations (Kaplan and Norton 2006). Same authors also assert that too much emphasis on terrorism risk may lead to erroneous strategy. Therefore the expectations of the leader shall be properly adjusted. Ghemawat (2013) finds that the anticipation of terrorism along with increasing globalization implies rising skepticism among practitioners. Sheffi et al. (2003) pinpoint the importance of increasing resilience.

Large amount of research concluded truly negative impact of terrorism, which undoubtedly represents significant and almost ubiquitous threat to our society. Right policies of the government and companies are necessary to be properly adapted. These effects vary from the largest worldwide ones to those that influence individuals. On the other hand, minimum research has been devoted to the process or development of the price movements after an attack, which is the main focus of this thesis.

# 3 Stock Market Determinants and Role of Terrorism

## 3.1 Financial Markets

"A stock market is crucial to the existence of capitalism and private property. For it means that there is a functioning market in the exchange of private titles to the means of production. There can be no genuine private ownership of capital without a stock market: there can be no true socialism if such a market is allowed to exist." – Ludwig von Mises (Rothbard 2006 p.426).

The term "financial market" refers to an entity where the exchange of securities between buyers and sellers takes place. Before the existence of stock markets, real assets (e.g. land, buildings, human capital,...) were traded directly and wealth was placed in them exclusively. Many advantages stem from the possibility of trading on the markets that facilitate the exchange. Firstly, they allow investors to hold claims to the real assets, hence distinguish and separate between the ownership and the control. This is generally perceived as a benefit, but sometimes agency problems arise due to the clash of incentives. Secondly, thorough portfolio diversification is possible owing to the existence of financial markets. Instead of placing restricted wealth in a few real assets, it is feasible to invest in many diverse assets. Not only is the direct investment possible, but various hedge tactics may be used to achieve even better risk robustness. Thirdly, the liquidity is increased in a significant way through using the financial markets. This feature helps to alleviate and overcome consumption timing issues linked to holding the real assets and encourages the investment by reducing the perceived transaction costs.

Markets can be divided into primary and secondary. Primary markets transactions include public offering and private placement. Both are intended to provide potential investors with the opportunity of ownership. The main difference lies in the disclosure requirements – the former one's are high, while the latter one is able to reduce the revelation of information. Yet, the private placement is subject to size limitations. Secondary markets include direct search (seller and buyer are supposed to connect on their own), brokered markets (brokers strive to connect potential market participants), dealer markets (dealers hold inventories of assets), auctions, etc.

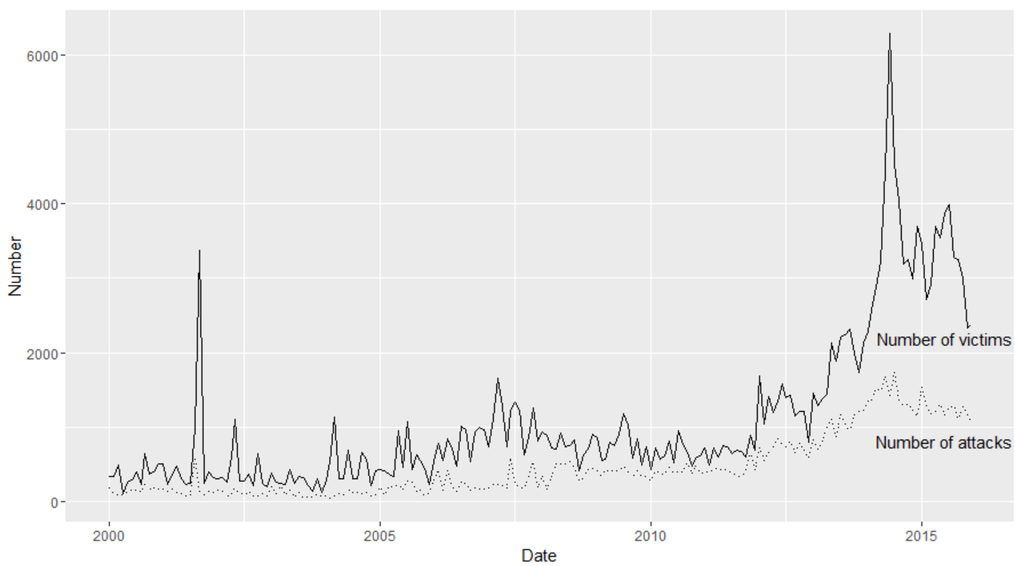
Another basic division of financial markets is connected with the content traded in a market. In terms of this characteristic, markets can be divided into money, capital, derivative, foreign exchange and others. Money markets assist in short-term borrowing and lending, whilst capital markets facilitate long-term exchange of funds. The purpose of a derivative market is to attenuate the risk by transferring it between market participants. Foreign exchange markets are mainly intended for exchange of international currencies and goods.

Market participants can earn either capital gains or direct income. In order to maximize their profits they may utilize various tactics. One of the possibilities is to buy and hold an asset that is believed to increase its price. In the event of an expected price fall, it is possible to employ a short position and sell borrowed securities. Some investors try to time the market by combining these two approaches. If an investor suffers from insufficient funds, it is often possible to buy on margin which increases the risk exposure and possible gains as well. With the rise of technology and electronization of the markets the algorithmic trading based on specific set of rules has mushroomed. Many analysts try to identify stocks that are either under or overpriced using various analytical models. Arbitrage opportunities (risk-free, simultaneous sale and purchase of disbalanced assets) are sought-after ways of profit seizing. There are also many anomalies (size anomaly, book-to-market anomaly, price-earning anomaly) reported by previous studies that can serve as an investment guideline. Another way is to utilize technical analysis and gain abnormal returns by exploiting the price patterns. Last but not least, fundamental analysis is one of the most important options to face the investment. Yet over all of these approaches one shall be conscious that a human being is not perfect, makes mistakes and is subject to many cognitive and behavioral limitations.

### 3.2 Basic Features of Terrorism related to Stock Markets

Regarding the features of the final dataset – after inspecting, cleaning and merging the data, 116 880 observations were obtained (more detail on data description can be found in Section 4). Generally, the largest amplitude of returns change can be noticed in the aftermath of 9/11 attacks. Figure 1 denotes the overall trend of the amount of terrorist attacks in total, including countries apart from our final dataset.

Figure 1: Comparison of number of attacks and victims based on monthly observations

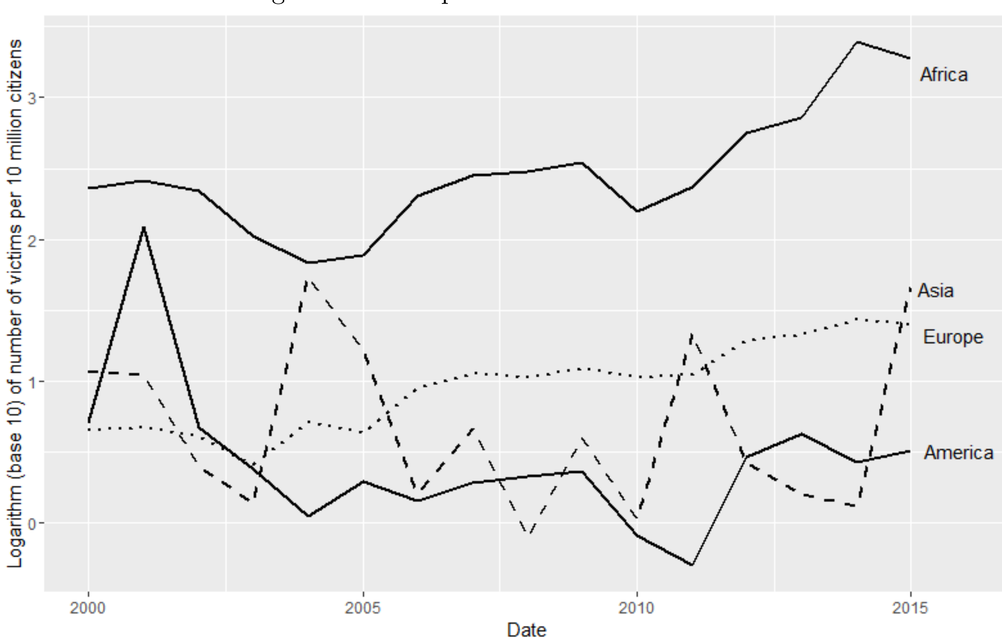



Not only is the total number of attacks gradually increasing, but also the number of killed citizens which, as argued in Section 5.1, is more appropriate to study for the effect on markets on average. Even though based on Figure 1 it might seem that these two variables are highly correlated, when the correlation is computed on a daily basis, on a country level, it results in circa 7.5%. The correlation gets more significant in case the variables are aggregated using larger domains and converges to over 88% when summed with respect to months worldwide (which can be observed in Figure 1). Nine out of ten attacks are successful, while half of the attacks are done by bombing. Perpetrators mostly targeted civilians and private property. Military, Police, Government and Business are among the other most common targets.

Countries with the highest count of terrorist attacks are Iraq, Pakistan, India, Afghanistan and Colombia. This characteristic is closely related with regions in which the frequency is the highest. Over one quarter of attacks in the study period took place in Middle East & North Africa, tightly followed by South Asia where almost one quarter took place. Average death rate per incident is approximately 2.4 while 3.1 persons were wounded.

It might be interesting to observe the number of casualties related to the population. Figure 2 summarizes this number along with classifying into the regions within our dataset. It is important to mention that an act of violence does not originate solely from terrorism, but it may possibly stem from organized national narrow groups.

Figure 2: Development of number of victims




Africa observation series (Figure 2) comprise only Johannesburg Stock Exchange. The situation is clearly driven by the country's environment which belongs to the most criminal ones in the world (Demombynes and Özler 2005). The region of America (consisting of Brazil, Canada and the USA) experienced very strong peak in 2001 (mainly consequence of 9/11 attacks), yet it steadily exhibits the lowest rates since then. These exchange stocks fall within the most performing ones, suggesting that a possible relationship exists between these two characteristics. Based on Figure 2, Western European populace is under constant threat of terrorism. These stock markets are prevailingly around average in terms of productivity in the observed sample. Finally, the number of killed people in terrorist incidents in the Asian region (containing East Asia, South Asia and Australasia & Oceania) fluctuates between the European and American levels. The position of its stock markets within our dataset is reminiscent of the uniform distribution.

### 3.3 Sensitivity of Studied Markets

Given by definition in the theory of single index model (Sharpe 1963), the practical calculation of sensitivities (beta parameters) of the studied markets (the largest 20 in terms of capitalization) with regard to the world market shall be slightly adjusted in this thesis. That holds owing to the fact that risk-free return rates are to be used based on the theory (see Section 4.5). Yet, only return rates computed based on prices are available. Even though risk-free returns cannot be used for above-stated reason, after considering the following sequence of equational operations

$$\begin{aligned}
\overbrace{r_{i,t} - r_f}^{excess\ return} &= \alpha_i + \overbrace{\beta_i}^{original} (r_{Mi,t} - r_f) + \epsilon_{i,t}, \\
r_{i,t} &= r_f + \alpha_i + \beta_i r_{Mi,t} - \beta_i r_f + \epsilon_{i,t}, \\
r_{i,t} &= \underbrace{\alpha_i + r_f(1 - \beta_i)}_{new\ intercept} + \underbrace{\beta_i}_{unchanged} r_{Mi,t} + \epsilon_{i,t},
\end{aligned}$$

it is obvious that beta coefficient is the same in the first equation and in the last one (iid $\epsilon_{i,t} \sim N(0, \sigma_i)$ represents the error term). The $i = 1, \ldots, n$ denotes the individual stock exchange, and $t = 1, \ldots, T$ represents one observation in time which is a trading day. The fact that the slope coefficient remains unchanged is due to the fact that $r_f$ does not vary over time. The only member of the equation that is changed is the intercept. Therefore, based on the last equation, it is possible to get beta coefficients using the normal returns instead the excess returns. After estimating the models, the sensitivities of exchange stocks to the world market were derived (Table 1).

Table 1: Stock market sensitivities

| Exchange | Sensitivity to World Index |
|---|---|
| NYSE | 1.16 |
| Nasdaq - US | 1.37 |
| Japan Exchange Group Inc. | 0.73 |
| Shanghai Stock Exchange | 0.62 |
| LSE Group | 0.94 |
| Euronext | 1.09 |
| Hong Kong Exchanges and Clearing | 0.88 |
| Shenzhen Stock Exchange | 0.69 |
| TMX Group | 0.91 |
| Deutsche Boerse AG | 1.20 |
| BSE India Limited | 0.73 |
| National Stock Exchange of India Limited | 0.81 |
| SIX Swiss Exchange | 0.84 |
| Korea Exchange | 0.71 |
| Australian Securities Exchange | 0.56 |
| Nasdaq Nordic Exchanges | 1.13 |
| Johannesburg Stock Exchange | 0.75 |
| Taiwan Stock Exchange | 0.54 |
| BM&FBOVESPA S.A. | 1.21 |
| BME Spanish Exchanges | 1.08 |

According to general knowledge (Bodie et. al 2012), beta coefficients tend to converge to 1 over large samples in terms of time. All beta coefficients are reasonably significant on 0.1% level. Very low sensitivities (below 0.6) can be observed in Taiwanese and Australian exchanges. On the other hand, NASDAQ is the most influenced stock exchange by the world market movements. Regarding the alpha measure which was introduced by Jensen (1968), from our sample only two of them are statistically different from zero. Yet, none of them exceeds the value 0.0005% which is not considered to be high. Thereupon, it is concluded that none of them is either over or under-priced.

### 3.4 Elemental Relationship between Terrorism and Market Returns

Moreover, in this section, a simple relationship between the number of victims and the market indices is suggested. Firstly, geometric (denoted by superscript $g$) average rates of returns are computed for each stock market within a region using the following formula:

$$\overline{r_i^g} = \sqrt[T]{\prod_t (1 + r_{i,t})} - 1$$

in which $t$ represent the whole observed period (01.01.2000 – 31.12.2015) and $r_{i,t}$ denotes the return at market $i$ at the end of day $t$. Employing the geometric mean is commonly perceived as the right way to evaluate and compare past returns in contrast to the arithmetic one (Bodie et al. 2012). Consequently, the arithmetic average of stock markets' geometric average returns is used to derive the average return within each region. This implies the complete formula for the average rate of return on a region during the studied period:

$$\overline{r} = \frac{\sum_i \left[ \sqrt[T]{\prod_t (1 + r_{i,t})} - 1 \right]}{n}.$$

The number of civilian casualties is simply defined as the sum within a region within the studied period. The results of this aggregation can be found in Table 2.

Table 2: Summary throughout the regions

| Region | Number of Victims | Average Return |
|---|---|---|
| North America | 3 282 | 0.0089% |
| South America | 2 882 | 0.0230% |
| East Asia | 814 | 0.0087% |
| South Asia | 58 888 | 0.0289% |
| Western Europe | 674 | 0.0011% |
| Sub-Saharan Africa | 42 546 | 0.0445% |
| Australasia & Oceania | 15 | 0.0117% |

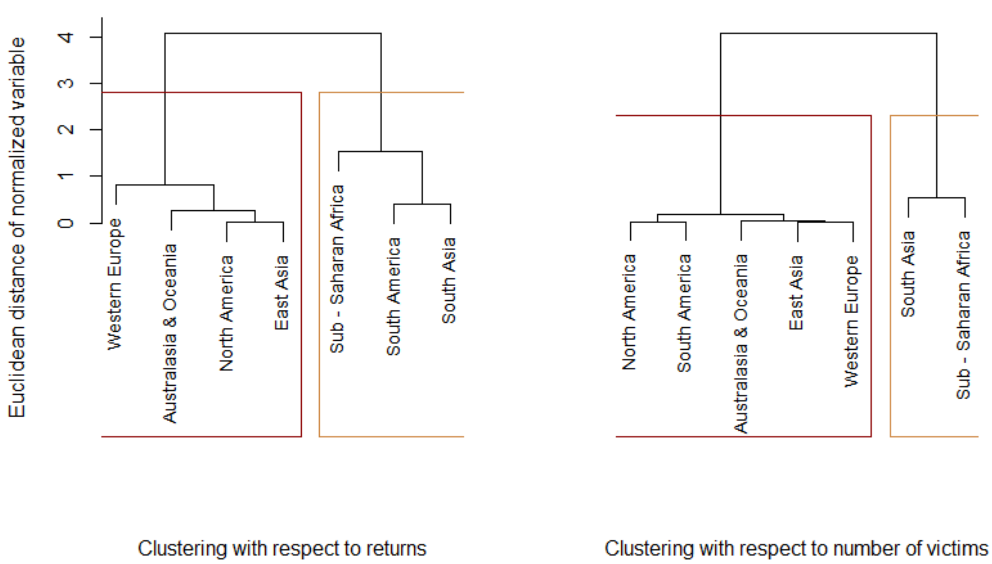
These values are subsequently standardized in order to achieve the normal $N(0, 1)$ distribution. When this step is done, euclidean distances

$$d(\mathbf{p},\mathbf{q}) = d(\mathbf{q},\mathbf{p}) = \sqrt{\sum_{i=1}^{n}(q_i - p_i)^2}$$

are applied for each observation within each column separately. These are used for visualizing Figure 3 which indicates the closest regions on a standardized basis for each variable. It reveals the proximity of some regions in terms of expected market returns and in terms of frequency of the terrorist incidents. If we divide each part of the figure into two clusters, we can observe that a number of regions exhibit similar levels. This scrutiny process suggests a simple link between the terrorism occurrence and returns at the markets.

However, referring to Table 2, it seems that higher casualty counts are connected with higher average returns which is not sensible in case of an individual incident (individual incidents lower returns). Regardless, higher rates of terrorism implies worse economic environment. Based on investments theory (Bodie et al. 2012), securities of lower quality (worse investment environment in our case) typically exhibit higher returns. In light of this argument, the link that is suggested in this section is reasonable.

Figure 3: Visual suggestion of the terrorism–returns link using clustering by regions



In spite of this approach being indeed simple, rough or ordinary, the illustration, which is easily understandable and tangible, might appeal to an involved reader. Provided they are interested, this is the first indication of the later-studied relationship between terrorism and market returns. Its subtlety is examined in a more rigorous manner in the following sections of the thesis.

## 4 Data Description

This section provides an overall picture of the large publicly available panel data used in the analysis. The dataset comprises of four primary datasets. The first one involves data on the main indices of the 20 largest exchange stocks worldwide. This was obtained from finance.yahoo.com and Bloomberg.com. The second database, which is called Global Terrorism Database, includes data on worldwide terrorist attacks since 1970. The unique collection is administrated by National Consortium for the Study of Terrorism and Responses to Terrorism (START). It includes a broad range of information on over 170 000 attacks. The third dataset is from the Polity IV project maintained by the independent Center for Systemic Peace. The data is, according to Princeton University Library (2017): "Well-known and highly respected polity data series..." (the word polity may be defined as a form or process of civil government or constitution). It was perceived among other sources as the most suitable for analytical purposes of this paper as it codes necessary information in a concise way. It observes and assesses the polity regime in every country with more than 500 000 inhabitants and covers the period 1800 – 2015. The fourth dataset – demographical data of included countries – is sourced from the World Development Indicators collection of The World Bank. All utilized databases together result in 116 880 individual observations, yet it is not possible to calculate return for 38 375 days either because the exchanges were closed or did not provide the information for unknown reasons.

### 4.1 Exchange Markets

The largest 20 exchange stocks in terms of capitalization as of January 2017 are chosen for the analysis. The covered period is from 01 January 2000 to 31 December 2015 which results in 16 years of observations [1]. The full list of exchange stocks and their respective capitalization and used tickers or their

[1] except Nasdaq Nordic Exchanges which is available from 28 December 2001 to 2 December 2015 and National Stock Exchange of India Limited which is available from 17 September 2007 onwards

major composite indices are provided in Table 3.

Table 3: World largest stock markets

| Exchange | Capitalization $M | Index Ticker |
|---|---|---|
| NYSE | 19 596 635.9 | ^NYA |
| Nasdaq - US | 8 125 737.2 | ^IXIC |
| Japan Exchange Group Inc. | 5 123 201.6 | ^N225 |
| Shanghai Stock Exchange | 4 274 537.8 | 000001.SS |
| LSE Group | 3 613 508.8 | ^FTSE |
| Euronext | 3 490 245.8 | ^N100 |
| Hong Kong Exchanges and Clearing | 3 367 578.0 | ^HSI |
| Shenzhen Stock Exchange | 3 242 724.1 | 399001.SZ |
| TMX Group | 2 069 066.3 | ^GSPTSE |
| Deutsche Boerse AG | 1 769 166.5 | ^GDAXI |
| BSE India Limited | 1 663 722.5 | ^BSESN |
| National Stock Exchange of India Limited | 1 632 829.3 | ^NSEI |
| SIX Swiss Exchange | 1 455 722.9 | ^SSMI |
| Korea Exchange | 1 325 522.1 | ^KS11 |
| Australian Securities Exchange | 1 324 459.6 | ^AXJO |
| Nasdaq Nordic Exchanges | 1 295 137.4 | ^OMXN40 |
| Johannesburg Stock Exchange | 995 119.5 | JN0U.FGI |
| Taiwan Stock Exchange | 891 057.7 | ^TWII |
| BM&FBOVESPA S.A. | 837 774.3 | ^BVSP |
| BME Spanish Exchanges | 716 009.5 | ^IBEX |

The returns are calculated on a daily basis using closing prices of indices employing the formula

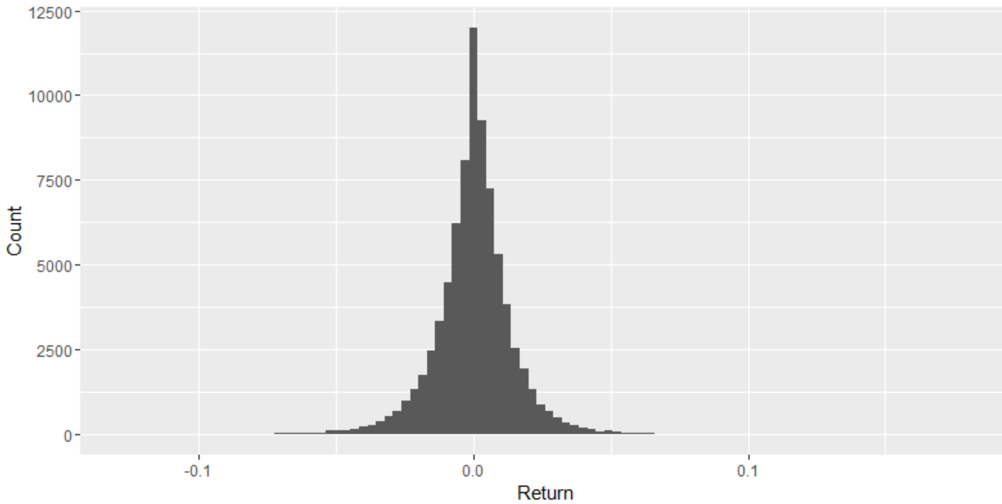
$$r_{i,t} = \frac{p_{i,t} - p_{i,t-1}}{p_{i,t-1}}$$

where $r$ denotes return and $p$ indicates daily closing price of an index.

Plotting basic histogram of returns of these market indices within the observed period (Figure 4), it might be observed that they follow the expected Gaussian distribution (Brown and Warner 1985; Fama 1976; Officer 1972) with the mean close to zero (0.0002) and the standard deviation equal to 0.0145.

Although based on calculations, small positive skewness is present (0.0026), just seeing Figure 4 does not reveal any obvious skewness. It is important to mention that returns sample is always inevitably truncated from the left as a company cannot lose more than 100% of its value. This feature is widely

Figure 4: Distribution of returns




known as the survivorship bias (Brown et al. 1992), causing average returns to be above the true value as nobody can observe non-listed companies that have failed. Even though past research generally concludes that persistence of returns in a short term exists (e.g. Andersen and Bollerslev 1997), regressing present values on their first lags yields the coefficient of 0.0053, which is not statistically different from zero. This test allows an econometrical analysis without the need for treating the potential bias as the process is integrated of order zero.

### 4.2 Terrorism

Global Terrorism Database is a rich resource of data with tens of coded variables. For the purpose of this thesis the number of attacks for each trading day and the number of victims are used. If there is an attack on a day when a market is closed, this attack is attributed to the first day when the market operates. The reason is that only then can the investors reflect their mood or information. Data on the number of killed victims are computed and assigned in a similar way. Another variable that stems from this database is the region. This categorical variable identifies the region in which the incident occurred. The regions are divided into the following

12 categories: 1 = North America, 2 = Central America & Caribbean, 3 = South America, 4 = East Asia, 5 = Southeast Asia, 6 = South Asia, 7 = Central Asia, 8 = Western Europe, 9 = Eastern Europe, 10 = Middle East & North Africa, 11 = Sub – Saharan Africa, 12 = Australasia & Oceania.

### 4.3 Polity

Regarding the Polity IV dataset, only two variables are used in the analysis. The first one is polity, which is an ordinal variable coding the level of the countries' openness. It "is computed by subtracting the autocracy score from the democracy score. The resulting unified POLITY scale ranges from +10 (strongly democratic) to -10 (strongly autocratic)" (V – Dem Institute, 2016, p.355). Its main purpose in this analysis is to control for the countries' political situation which might be related with the way the people invest. Among all the stock exchanges, only those in China operate in the predominantly autocratic environment (with the score equal to -7). Other countries have been assessed as democratic with polity scores equal to 8 at minimum throughout the whole observed period. Similarly, the cardinal variable durable includes the information on the persistence of a regime since the last change. Again, the expectation is that a more stable regime (even though autocratic) attracts more investment and results in positive returns. This is just a control variable, therefore we are not interested in how it influences the returns at the markets. Its main purpose is to attenuate the impact of unobservable effects, hence to make the impact of terrorism on the markets more precise.

### 4.4 Demography and Economy

The dataset sourced from The World Bank consists of various control variables including demographic ones such as the length of compulsory education in the country, its population, density, growth and urbanization. Also economic variables – specifically the growth of gross domestic product, inflation (based on GDP deflator) and interest rate are involved. These were chosen in order to capture numerous macroeconomic factors. Again, the purpose of their inclusion in the model is not to study the particular relationships between them and returns, yet to make the prediction of impact of terrorism on stock markets more precise. Some of them (GDP growth, interest rate) arise from researchers' experience (Bodie et al. 2012), others like population, density, growth, urbanization and others are just general macroeconomic determinants. There were missing observations of the interest rate in United Kingdom in 2015, Netherlands in 2013 – 2015 and Sweden in 2006 – 2015. These were simulated using past available data points, assuming their normal distribution and preserving their means and standard deviations. After the simulation which implies including new generated observations, the standard deviation of all the observation of a country's interest rate together necessarily changes. The highest difference of approximately 3% was achieved. Based on GDP growth, the economies of the observed countries were generally developing, apart from the period when the global financial crisis took place.

### 4.5 World Market

All of above–mentioned databases were aggregated into one final dataset that represents large panel data. Other variables (e.g. lags of returns) were constructed using downloaded data. Especially, there is one variable called 'world market' (denoted by $w$) worth mentioning. Firstly the theory upon which it builds is explained, then the exact construction is noted.

The concept of this variable stems from the single index model (mentioned in Section 3.3) introduced by Sharpe (1963):

$$r_{i,t} - r_f = \alpha_i + \beta_i(r_{Mi,t} - r_f) + \epsilon_{i,t},$$
$$\epsilon_{i,t} \sim N(0, \sigma_i),\ iid,$$

which regresses risk premium returns of individual companies on market excess returns. Risk premium is equivalent to excess returns which means normal returns with subtracted risk-free returns. Risk-free returns may for example be returns on government bonds in practice which have low volatility. As they generally do not fluctuate much, they are used as a substitution for estimation risk-free rates. In practice, market returns are immeasurable, hence composite market indices are used as proxies instead. Market indices, such as the ones that are used in this thesis, provide a generally sufficient approximation for the models similar to the single index model despite vast critique (e.g. Roll 1977). They argue that we can never know the true market portfolio, thereby we can never estimate the model properly.

Since this thesis aims to explain the movements of the world indices caused by terrorism, $w$ is calculated using the following formula:

$$w_{i,t} = \frac{\sum_{j \neq i} r_{j,t} \cdot c_{j,t}}{\sum_{j \neq i} c_{j,t}},$$

which is the weighted mean of returns (denoted by $r$) on a specific day, using market capitalization (denoted by $c$) as respective weights. The "$j \neq i$" notation means that it takes into account every observation but the one of the market $i$. This is to avoid the inclusion of the effect of a market's movement in the world index. It means that if a terrorist attack is observed in a country, its effect is not included in the world market variable for the specific market on the specific day (this relationship holds in case of negligible spillover effect which is discussed and asserted in Section 5.1). Utilization of the market capitalization as a weighted element is reasonable as the larger the market is, the assumption might be that the more it influences the world market as a whole. Market indices are usually composed of tens of the most influential companies. In this case, our world market index is built from 20 market indices that are used in the analysis. In spite of a quite small number, it might be sensibly argued that it is sufficient as they represent over 91% of the world market in terms of capitalization. It is important to include this variable in the analysis as it incorporates the movement of the world's expectations. In particular, in a situation similar to the global financial crisis, it smoothes off its effect and maintains focus on the variables in which we are interested. The principle of using such variable is similar to using the time variable to detrend the data or using the seasonal dummy variables to deseason the data.

# 5 Methodology

## 5.1 Multifactor Model

#### Characterization

Firstly, the linear regression model is introduced in order to understand the overall picture. There emerges the question of which variable linked with terrorism to use so as to assess its effect in the model. Two primary possibilities are to be considered – either number of attacks or number of victims. We assert that number of casualties is more useful in this case. Imagine a high number of attacks with almost irrelevant number of victims in contrast to an attack of the size of 9/11 attacks where 2 996 people were killed. It is expected that the latter shall have a much more significant influence on exchange returns. Furthermore, even property damages are often connected with human casualties. This is due to the fact that people perceive, consider and evaluate humankind losses to be worse than destruction of physical assets (Karolyi and Martell 2006). As a result of that, terrorists are incentivized to attack venues with potential presence of people (hence, it is more valid to used number of victims as the predictor variable). To sum up the argumentation – the number of killed people was chosen to be the representative variable of terrorist attacks on exchange markets.

The second task is to choose the right area with respect to which attacks are to be aggregated (possible levels – country, region or world). Because of including the world market variable to smooth out the trend effect of markets, it would not be reasonable to aggregate and study the effect of number of attacks around the world. That is because the world market proxy variable already incorporates the effect of world factors. The choice between the region and country levels is driven by the following argument. Firstly, researchers refused any spillover effect in case of a terrorist incident (Karolyi and Martell 2006); consequently, it does not make sense to consider the possibility of including the region level. On the other hand Liu (2013) allowed for transferring of losses between partners, yet only in the direction from large to small entities. As we study the largest 20 stock markets worldwide, based on these two arguments, it is rational to assume no spillover effect within a region. Thereupon, for the sake of conservation of the proximity of an attack, the country level is used in the analysis.

In order to derive whether or not any lags of the above-decided variable *nkill_country* would be relevant, the partial autocorrelation function was used. The outcome is that no lag is necessary. However, it was decided that its square form will be included in order to allow for non-linear increasing effect beyond a specific threshold. This is sensible as investors may reflect their beliefs in a more negative manner in case of a large-scale attack.

Various demographic, economic and polity variables are used (described in Sections 4.3 and 4.4) in order to smooth away their effect on returns on the exchange markets. To our best knowledge, no similar approach has ever been employed in relevant literature.

All aforementioned variables are used in the following OLS regression model

$$r_{i,t} = \beta_0 + \beta_1 x_{i,t} + \beta_2 x_{i,t}^2 + \beta_3 w_{i,t} + \gamma f_{i,t} + u_{i,t},$$

where $r$, return, is the response variable and $x$, the number of victims is the main explanatory variable. So as to control for systematic changes (Wooldridge 2012), the intercept $\beta_0$, the vector of other factor variables $f$ and the created world market – variable $w$ are included in the model. Notation $u$ stands for disturbances.

#### Assumptions and Related Tests

Firstly, it is recommended to test for stationarity before constructing an econometric model (Wooldridge 2012). In order to be correct, it is sufficient for our data to follow the covariance-stationary process. Provided the regressor did not fulfill the condition, the analysis would be biased. Primarily, the most usual test – Augmented Dickey-Fuller will be employed (Dickey and Fuller 1979). The test's null hypothesis questions if there is a unit root process present in a time series sample. It is expected that this is not the case in our sample as our response variable is constructed as a fraction where in the numerator there is the difference between the subsequent two observations of index prices. The denominator is just the older one of those two price observations which has no influence on the potential unit root process. That kind of manipulation generally eliminates the unit root characteristics, so it is expected to distinctly reject the null hypothesis. The other possible test is KPSS (Kwiatkowski, Philiphs, Schmidt and Shin 1992). The main difference is the inverted null hypothesis. In this case "the process does exhibit the feature of being (trend) stationary" which is tested against the alternative. The formulation of the null hypothesis is effectively opposite to the one of Augmented Dickey Fuller test; consequently, high $p$-value is anticipated. Provided the stationarity was not verified by the preceding tests, a different transformation of the variable would have to be used.

The common feature of time series is the presence of serial correlation of the residuals. If present, even though beta coefficient was precise, the related statistics as $t$-test or $F$-test would be biased. It is important to test for the autocorrelation and eventually calculate robust values. So as to detect the presence, Durbin-Watson test is used (Durbin and Watson 1971). Under the null hypothesis, there is no serial correlation. If it is rejected, the serial correlation is confirmed.

Similarly, the heteroskedasticity of residuals shall be tested. One of the Gauss-Markov assumptions needs the variance of residuals (conditional on all explanatory variables) to be constant for all observations in time. If this condition is not satisfied, the coefficients are calculated correctly, yet it is necessary to adjust $t$ and $F$-statistics. The suitable test was developed by Breusch and Pagan (1979). This test checks on homoskedasticity (constant error variances across all observation points) against the alternative hypothesis – heteroskedasticity (inconstant variances). If all assumptions' requirements are satisfied, the OLS estimator is the best linear unbiased one.

### 5.2 Difference Equation

This recurrence analysis strives to estimate the development of expected returns after an attack that involves more than 25 casualties. This threshold was arbitrarily chosen in order to include the 100 most influential terrorist attacks in terms of number of victims. The objective is to be able to predict the development of price with on the 80% correlation level with respect to the real past-observed data. The model encompasses only forms of variables $r$ and eventually $t$ (time) in order to achieve a proper difference equation. No other non-related variables are included. The model focuses on a short period of time (3 days) right after an incident takes place.

We approach the model by choosing the right amount of lags. As it is crucial for the investors to react quickly to exploit the arisen situation, and in combination with the fact that the more lags are chosen the more observation are lost, just one lag is used in this part. This choice is done despite the fact that tests like Akaike or Schwartz information criteria could provide us with a guideline for the right number of lags, but we assert that losing more information (and time) would not be beneficial and desired for an investor. The square modification of the first lag of $r$ is included as well to allow for inverted effect of the variable above/below a specific value. The variable coding the time (in terms of number of days) since an attack is included as well to assess the eventual mood development. These choices are reflected in the actual model

$$r_{i,t} = \beta_1 r_{i,t-1} + \beta_2 r_{i,t-1}^2 + \beta_3 t + c + u_{i,t}. \tag{1}$$

After evaluating the model, we proceed to assessing its precision by calculating the correlation between the predicted values and the observed ones. There exist two ways to predict the values in this case. It is possible to use the observed value of $r$ on the day of an attack and then compute the following values based on it. The other way is to compute each prediction using the preceding value. The former method might be useful for people trading futures, the latter one is primarily dedicated to investors directly trading the shares.

This section puts emphasis on forecasting the future value of return when an attack happens. As mentioned in the paragraph above, this might be used in order to buy or sell the right futures contracts.

### 5.3 Logit Model

In contrast to the previous section, this section focuses on forecasting the future movement of an index price. That is the main concern of an investor who holds the shares, is willing to buy some or earn capital gains by selling borrowed shares. This holds as knowing the direction is sufficient for timing a market. These actions can be done by holding or selling, long buying or short selling respectively, depending on the position of an investor. The benchmark for assessing the quality of the model is the coin toss process.

We consider the following dependent binary variable for the logit model

$$r\_bin_{i,t} = \begin{cases} 1, & \text{if } return_{i,t} > 0, \\ 0, & \text{otherwise.} \end{cases}$$

The function codes 1 when price increases and 0 when it stays constant or drops.

The model is similar to (1), but the output variable is binary

$$r\_bin_{i,t} = G(\beta_1 r_{i,t-1} + \beta_2 r_{i,t-1}^2 + \beta_3 t + c),$$

where $G(x) = \frac{exp(x)}{1+exp(x)}$ denotes the logistic transformation which guarantees the strictly positive output lower than 1 (equivalent to $0 < G(x) < 1$). No error term is present as the logit model essentially asks $P(y = 1|\boldsymbol{x})$ which is equal to $E(y|\boldsymbol{x})$ which yields no error term ($y$ and $\boldsymbol{x}$ denote a dependent variable and a full set of independent variables respectively).

The quality of the model is evaluated mainly based on the sensitivity and specificity. Sensitivity (equivalent of true positive rate) measures the ratio of correctly identified points when the price increased and specificity (true negative rate) expresses the proportion of observations when the price decreased and it was identified this way by the model. However, the logit model provides prediction within the interval of $(0, 1)$. Hence, before assessing the quality, a threshold must be chosen so it is possible to classify a prediction as either 1 or 0. The most reasonable is 0.5 as the middle of the interval. Owing to its rationality it will be employed in the analysis in spite of the fact that a better fit might be generally achieved by manipulating this threshold. The eventual better fit is not desired unless rationally tenable.

Moreover, closely related 'area under curve' measure can be used for assessing the model. It is derived as the surface under the 'receiver operating characteristic' curve which is created by moving the threshold and plotting the true positive rate. In this case the coin toss benchmark is the straight 'receiver operating characteristic' line resulting in the area equal to 0.5 units squared.

The last measure for the juxtaposition of the developed model and the coin toss process is the comparison of potential return if the model had been used for forecasting the investment before all the terrorist attacks happened. For the purpose of this measure, the geometric mean is used as it is suitable for comparing past returns – analogously to Section 3.4. The returns for computing this value are adjusted in the following way

$$r\_bin_{i,t} = \begin{cases} +|r\_bin_{i,t}|, & \text{if the predicted direction is the same as the actual one,} \\ -|r\_bin_{i,t}|, & \text{if the predicted direction is opposite to the actual one.} \end{cases}$$

# 6 Results

Based on the approach which was designed in Section 5, the findings are presented in this section. Firstly the multifactor model verifies the influence of terrorism on stock markets, followed by the utilization of the difference equation in order to forecast the price development after an attack. Finally, the logit model is introduced in order to study specifically the direction of price development in case of a terrorist incident.

The complete analysis including aggregating variables, modeling, optimizing, visualizing and other actions was computed using RStudio version 1.0.136 on Intel®Core™i7-4710HQ CPU @ 2.50GHz and 16GB RAM running Windows 8.1. The whole process took approximately 6 hours and 12 min.

## 6.1 Multifactor Model

The first inevitable step is to verify the necessary assumption – stationarity – to gain an unbiased model. Based on the intrinsic definition of market returns which includes first differencing of closing prices, the result of augmented Dickey-Fuller test is as expected. Its null hypothesis of a present unit root was rejected on lower than 1% level. As having non-stationary data might have dire consequences on the quality of the analysis, KPSS test with the opposite tested hypothesis was used as well. The $p$-value in this case is greater then 10%; consequently, we cannot disprove the stationarity of our regressand which is desired.

These results allow us to proceed to the tests of serial correlation and homoskedasticity of residuals. Durbin-Watson test produces $p$-value close to 1 which means that it is very unlikely to reject no serial correlation among the residuals. On the other hand, Breusch-Pagan test yields $p$-value close to 0 which represents a logjam for usage of the original $t$ and possibly $F$-statistics. To achieve the robust statistics, the following FGLS approach is used. It builds on the assumption that $Var(u|X) = \sigma^2 h(X)$; thus the model is redefined with every member of the equation being weighted by the factor (denoted by $s_{i,t}$) equal to (2) which allows to gain the expected value of updated errors to be constant (3)

$$s_{i,t} = \frac{1}{\sqrt{h_{i,t}}} \tag{2}$$

$$\Rightarrow$$

$$\mathbb{E}\left[\left(\frac{u_{i,t}}{\sqrt{h_{i,t}}}\right)^2\right] = \frac{\mathbb{E}\left(u_{i,t}^2\right)}{h_{i,t}} = \frac{\sigma^2 h_{i,t}}{h_{i,t}} = \sigma^2. \tag{3}$$

The weight are estimated using the exponential form of $h(X)$ function. This approach yields consistent and asymptotically more efficient estimates than simple OLS.

Table 4 provides the summary of the findings of the multifactor model (complete Table 7 with other factor variables can be found in Appendix A).

Table 4: Multifactor model 1 – return as the response variable

| | Coefficient | Std/ Error | $t$-value | $p$-value |
|---|---|---|---|---|
| (Intercept) | -1.981e-03 | 4.277e-03 | -0.463 | 0.6433 |
| nkill_country | 9.543e-05 | 3.377e-05 | 2.826 | 0.0047 ** |
| nkill_countryˆ2 | -1.417e-07 | 2.495e-07 | -0.568 | 0.5700 |
| world_market | 7.570e-01 | 5.140e-03 | 147.259 | <2e-16 *** |
| N | 73 575 | note: ***$p$<0.001; **$p$<0.01; *$p$<0.05 | | |
| Mult/ R-squared | 0.3895 | Adj/ R-squared | | 0.3893 |
| $F$-statistics (20; 74 387) | 2 392 | $p$-value ($F$) | | <2.2e-16 *** |

At the first glance, the model illogically suggests a positive coefficient for the variable that denotes the number of victims (because an attack is a negative information which is typically reflected by a drop in price). Yet, this may be balanced by the its square-form variable which is, however, not statistically significant. It is worth testing for mutual significance using robust $F$-statistics for the composite hypothesis $\beta_1 = \beta_2 = 0$. With the $p$-value of this test over 0.5, there is no point in keeping the square form in the model. This leads to reevaluating the model, the results of which are summarized in Table 5 (its full form can be found in Appendix A again).

Table 5: Multifactor model 2 – return as the response variable

| | Coefficient | Std/ Error | $t$-value | $p$-value |
|---|---|---|---|---|
| (Intercept) | -1.979e-03 | 4.277e-03 | -0.463 | 0.6435 |
| nkill_country | 7.911e-05 | 1.775e-05 | 4.457 | 8.32e-06 *** |
| world_market | 7.570e-01 | 5.140e-03 | 147.259 | <2e-16 *** |
| N | 73 575 | note: ***$p$<0.001; **$p$<0.01; *$p$<0.05 | | |
| Mult/ R-squared | 0.3891 | Adj/ R-squared | | 0.3887 |
| $F$-statistics (19; 74 387) | 2 421 | $p$-value ($F$) | | <2.2e-16 *** |

## 6.2 Difference Equation

This section builds upon the methodology derived in Section 5.2. The 100 attacks with the highest amount of casualties are used for this analysis. The results of the simple OLS regression are summed up in Table 6. The $\beta_1$ coefficient exhibits low statistical significance, yet after testing the joint hypothesis: $\beta_1 = \beta_2 = 0$ and getting a $p$-value close to zero, it was decided to keep it for the predicting purposes.

Table 6: Difference equation model

| | Coefficient | Std/ Error | $t$-value | $p$-value |
|---|---|---|---|---|
| (Intercept) | 0.012075 | 0.005003 | 2.414 | 0.016726 * |
| $\text{return}_{\text{t-1}}$ | 0.069411 | 0.061623 | 1.126 | 0.261400 |
| $\text{return}^2{}_{\text{t-1}}$ | 4.827400 | 1.404646 | 3.437 | 0.000721 *** |
| time | -0.004951 | 0.001919 | -2.581 | 0.010600 * |
| N | 200 | note: ***$p$<0.001; **$p$<0.01; *$p$<0.05 | | |
| Mult/ R-squared | 0.1307 | Adj/ R-squared | | 0.1171 |
| $F$-statistics (3; 193) | 9.669 | $p$-value ($F$) | | 5.632e-16 *** |

These results can be rewritten in the form of recurrence:

$$\hat{r_t} = 0.0694 r_{t-1} + 4.8274 r_{t-1}^2 - 0.0050t + 0.0121$$

which leads to the following predictions:

$$t = 1 \Rightarrow \text{observed } r_1$$

$$t = 2 \Rightarrow \hat{r_2} = 0.069r_1 + 4.827r_1^2 + 0.0022$$

$$t = 3 \Rightarrow \hat{r_3} = 0.006r_1 + 0.460r_1^2 + 3.235r_1^3 + 112.497r_1^4 - 0.003$$

It was calculated that the point in which the effect of $r_{t-1}$ becomes positive is equal to -1.44%.

Computing the correlations in both ways described in the methodology – either based on the value from $t = 1$ (this one is the objective of this part) or based on $t-1$ for each observation, yields insufficient levels of 0.3442 and 0.3615 respectively. These values are far from the desired threshold of 80%.

### 6.3 Logit Model

Given the methodology in Section 5.3, after producing the independent binary variable (1 if return is positive, 0 otherwise), we started by evaluating the model. Its derived form is displayed in the equation

$$r\_bin_t = G(-0.8516r_t + 220.2755r_{t-1} - 0.3895t + 0.8401).$$

As all the predictions fall within $(0, 1)$ interval, the threshold for categorizing them as 1 or 0 is 0.5 (every prediction equal or greater than 0.5 is noted as 1 and vice versa). Both sensitivity (true positive rate) and specificity (true negative rate) of the model reach 60%. Furthermore, the 'area under curve' exceeds 0.6 squared units. Based on this statistic, it may be concluded that the model outperforms the eventual coin toss process predictions which would yield an 'area under curve' equal to 0.5.

The most important measure in which an investor might actually be interested is the comparison of eventual returns if the model had been employed before the observed period. While the average geometric return of the observed returns is circa 0.14%, the adjusted returns based on the model (if an investor is aware of this relationship) yield an average of 0.36%. This is 2.57 times more than in the original instance.

## 7 Discussion

There might emerge a discussion about a possible inclusion of the number of wounded people in the analysis. However, looking at the data, sometimes there are attacks with large number of casualties and no wounded, sometimes vice-versa. The correlation between these two variables is slightly above 57%. It would be possible to produce an index variable consisting of both, yet the proper choice of weight would be impossible (and controversial). Substituting the number of casualties with the sum of both variables yields lower R-squared by 1 percentage point and the beta estimate has a much lower significance. It is concluded that the informative value is higher in our actual analysis.

Looking at Table 5, it seems that *ceteris paribus* assumption a terrorist attack of size of 100 casualties increases the expected return on a market by approximately 0.79%. This result contradicts the empirical observations of the individual events. It goes against the sensible consideration as well. Nevertheless, we argue that the outstanding significance of the *world_market* variable implies a very strong spillover effect (the variable includes the average of all returns on a day apart from the observed market). As was discussed earlier in Section 2, previous research discovered no spillover effect, but it is important to mention that it was primarily focused on the spillover between trading partners, not the whole international markets. Our analysis suggests a very strong spillover effect, hence it can be argued that it holds even in case of an attack. Therefore we assert that each attack is embedded in the world market variable in a tacit way. As the *world_market* variable comprise returns from other 19 stock markets, it overestimates the effect of an incident. That is why $\beta_1$ coefficient of 'number of killed' variable is positive and significant, correcting the overestimation. This result is sufficient for confirming the impact of terrorism on stock markets, but it might be beneficial to study this more closely in future research.

Another possible explanation is that the unit of time in our analysis is one day, but the development right after an attack might be turbulent (possibly even strongly negative) within the subsequent hours and result in a positive effect (eventually due to a positive information about elimination of perpetrators or similar) at the end of the day. We suggest this being studied closer in future research as it is beyond the scope of this thesis.

# 8 Conclusion

This thesis strives to discuss and contribute to the problematics of terrorism with relation to stock markets. Its main distinctive attribute lies in the size and quantity of observations of the used dataset. It comprises the development of the largest 20 markets worldwide and thousands of terrorist incidents within the recent 16 years. The primary contribution stems from the employment of the OLS regression model which verifies the impact of terrorism on stock markets while controlling for various demographic, economic and political variables. It also identifies a gap for subsequent related research. Next, a difference equation and a logit model, which look for ways to forecast the price development in the following days after an attack, are elaborated.

The important part of the multifactor model is the world market variable. It is included mainly in order to smooth out the effect of the unobserved effects on the world level. The idea of using it is based on the widely accepted, used and known single index model (Sharpe 1963) which essentially studies the quality of stocks by regressing their returns on a corresponding market index and possibly other factors. Yet, the usage of the world market variable is adjusted for studying the worldwide effect in contrast to the national ones. The variable is derived as a capitalization-weighted index of the returns of the observed market indices. To the best of our knowledge, this approach has not been used before and the idea of the world index might facilitate future research.

While the long-term terrorism-markets link suggested in Part 3.4 indicates that a worse investment environment is connected with higher returns, judging from the multifactor model, related argumentation, past research and experience we assert that terrorism impacts the world financial markets in a negative way in the short run. The thesis also developes and estimates a difference equation which might be used for forecasts of the investors interested in futures contracts, yet its predictive power is objectively weak.

After transforming the recurrence into a logit model with the sensitivity and specificity reaching 60% it seems that by proper market timing an aware investor could have reached an average return over twice as large as an unaware one.

The scope and complexity of the topic is large and exceeds the possibilities of the thesis. We conducted and provided a basic introduction to the problematics, various models and possible ways of forecasting. We suggest to study the effect with a lower granularity of time and possibly by employing a more complex or detailed approaches.

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# Appendix A

Table 7: Complete multifactor model 1 – return as the response variable

| | Coefficient | Std/ Error | t-value | p-value |
|---|---|---|---|---|
| (Intercept) | -1.981e-03 | 4.277e-03 | -0.463 | 0.6433 |
| nkill_country | 9.543e-05 | 3.377e-05 | 2.826 | 0.0047 ** |
| nkill_country^2 | -1.417e-07 | 2.495e-07 | -0.568 | 0.5700 |
| world_market | 7.570e-01 | 5.140e-03 | 147.259 | <2e-16 *** |
| polity | 2.355e-05 | 1.538e-04 | 0.153 | 0.8783 |
| durable | 8.779e-07 | 1.873e-06 | 0.469 | 0.6392 |
| surface_area | 1.400e-10 | 2.809e-10 | 0.498 | 0.6182 |
| educ | 1.330e-06 | 6.938e-05 | 0.019 | 0.9847 |
| pop | -5.070e-13 | 1.073e-12 | -0.473 | 0.6365 |
| pop_dens | 5.163e-07 | 8.175e-07 | 0.632 | 0.5276 |
| pop_grow | -8.900e-05 | 1.639e-04 | -0.543 | 0.5871 |
| pop_urban | 4.318e-06 | 1.325e-05 | 0.326 | 0.7446 |
| gdp_growth | 4.952e-05 | 2.542e-05 | 1.948 | 0.0514 |
| inflation | -2.890e-05 | 3.300e-05 | -0.876 | 0.3811 |
| int_rate | 3.683e-05 | 2.377e-05 | 1.549 | 0.1213 |
| region_3 | -6.174e-04 | 1.059e-03 | -0.583 | 0.5598 |
| region_4 | 9.271e-04 | 2.715e-03 | 0.341 | 0.7327 |
| region_6 | 1.443e-03 | 2.670e-03 | 0.540 | 0.5889 |
| region_8 | 1.061e-03 | 2.597e-03 | 0.408 | 0.6830 |
| region_11 | 1.748e-03 | 2.547e-03 | 0.686 | 0.4926 |
| region_12 | 1.291e-04 | 6.315e-04 | 0.204 | 0.8380 |
| N | 73 575 | note: ***p<0.001; **p<0.01; *p<0.05 | | |
| Mult/ R-squared | 0.3895 | Adj/ R-squared | | 0.3893 |
| F-statistics (20; 74 387) | 2 392 | p-value (F) | | <2.2e-16 *** |

Table 8: Complete multifactor model 2 – return as the response variable

| | Coefficient | Std/ Error | t-value | p-value |
|---|---|---|---|---|
| (Intercept) | -1.979e-03 | 4.277e-03 | -0.463 | 0.6435 |
| nkill_country | 7.911e-05 | 1.775e-05 | 4.457 | 8.32e-06 *** |
| world_market | 7.570e-01 | 5.140e-03 | 147.259 | <2e-16 *** |
| polity | 2.278e-05 | 1.538e-04 | 0.148 | 0.8822 |
| durable | 8.804e-07 | 1.873e-06 | 0.470 | 0.6383 |
| surface_area | 1.394e-10 | 2.809e-10 | 0.496 | 0.6196 |
| educ | 1.526e-06 | 6.938e-05 | 0.022 | 0.9825 |
| pop | -5.082e-13 | 1.073e-12 | -0.474 | 0.6358 |
| pop_dens | 5.141e-07 | 8.175e-07 | 0.629 | 0.5294 |
| pop_grow | -8.922e-05 | 1.639e-04 | -0.544 | 0.5862 |
| pop_urban | 4.440e-06 | 1.325e-05 | 0.335 | 0.7376 |
| gdp_growth | 4.949e-05 | 2.542e-05 | 1.947 | 0.0515 |
| inflation | -2.895e-05 | 3.300e-05 | -0.877 | 0.3804 |
| int_rate | 3.691e-05 | 2.377e-05 | 1.553 | 0.1205 |
| region_3 | -6.221e-04 | 1.059e-03 | -0.588 | 0.5568 |
| region_4 | 9.217e-04 | 2.715e-03 | 0.340 | 0.7342 |
| region_6 | 1.476e-03 | 2.669e-03 | 0.553 | 0.5803 |
| region_8 | 1.056e-03 | 2.597e-03 | 0.406 | 0.6844 |
| region_11 | 1.746e-03 | 2.547e-03 | 0.685 | 0.4932 |
| region_12 | 1.270e-04 | 6.315e-04 | 0.201 | 0.8406 |
| N | 73 575 | note: ***p<0.001; **p<0.01; *p<0.05 | | |
| Mult/ R-squared | 0.3891 | Adj/ R-squared | | 0.3887 |
| F-statistics (19; 74 387) | 2 421 | p-value (F) | | <2.2e-16 *** |