

2 Methodology

The formulation and logic of the appropriate research design were based on the objectives of this research paper and the associated research questions presented in the introduction of this paper. The following chapter provides an overview of the research process and, therefore, starts with a general description of the procedure, followed by more detailed information regarding the empirical analysis in the subsequent subchapters.

2.1 Research Design

In general, methodological fit is a key criterion to ensure the quality of research and consequently, it is also highly relevant for this research paper. The literature review has shown that there are many studies covering the topic of volatility forecasting and the VIX Index in particular. Not only are there a high number of serious academic works on the topic, but also the fact that the constructs and concepts studied over time are well-developed allows the conclusion to be drawn that the current state of literature is perceived to be mature. A mature theory implies that research questions tend to focus on clarifying and elaborating existing concepts within a growing body of interrelated theories (Edmondson and McManus 2007). Since the status of literature is interpreted as being mature, already existing theories are examined deductively by applying theory to data. Traditionally, the deductive approach illustrated in Figure 1 goes hand in hand with a quantitative research method, but in this master thesis mixed methods are applied by integrating quantitative and qualitative data within one research project, an approach which is increasingly used and accepted (Bryman 2012). In doing so, a greater confidence in research findings will be achieved through triangulation, which was defined rather broadly by Denzin (1970) as an approach that uses multiple observers, sources of data, theoretical perspectives, methodologies, etc. Increasingly, however, the term triangulation is also used to refer to a process of cross-checking the research findings derived from quantitative and qualitative research (Deacon and Fenton 1998).

After reviewing the existing literature, the process of deduction continues with the formulation of the research hypothesis. The hypothesis and the process of data collection are described in chapter 2.3 and 2.4 of this research. Next, the research findings from both quantitative and qualitative analysis are presented in chapter 7 and the answers to the research questions and the confirmation or rejection of the related hypothesis are included in chapter 8. Finally, the theoretical reflection of the obtained findings concludes the research process illustrated in Figure 1 (see the discussion in chapter 8 for further information).

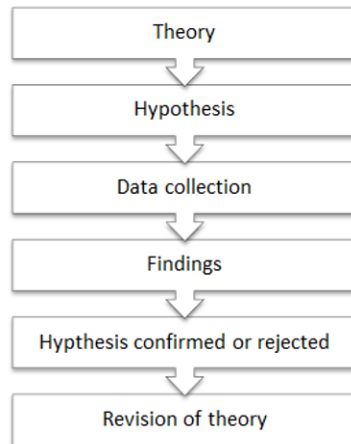


Figure 1: Process of deduction

2.2 Literature Review

The literature review is a key step in all research in order to determine all aspects which should be considered, namely what is already known about the topic and what kind of controversies exist. Furthermore, it also allows the researcher to link the research questions and hypothesis to the existing literature and consequently, is an important component for demonstrating the credibility and contribution of the research to existing studies (Bryman 2012). In doing so, the context of this research, namely risk management, volatility forecasting, the VIX Index and the influence of behavioral finance has always been a major consideration.

Source of Information	Examples
Electronic databases	SSRN, EBSCO, Wiley, acm, Emerald, etc.
Websites	CBOE website, yahoo.finance, etc.
Search engines	google scholar, google, google books, etc.
Specialised books	e.g. Social Research methods (Bryman)
Video channels	Youtube

Table 1: Sources of information (own table)

Table 1 gives some examples of the sources of information being used to search for relevant journal articles, index quotes, website content, specialised books, figures, tables, etc. It should be mentioned that the video channel Youtube was explicitly used in order to become familiar with data treatment and data analysis using SPSS. In addition, Figure 2 shows the main topics that were covered within the literature review.

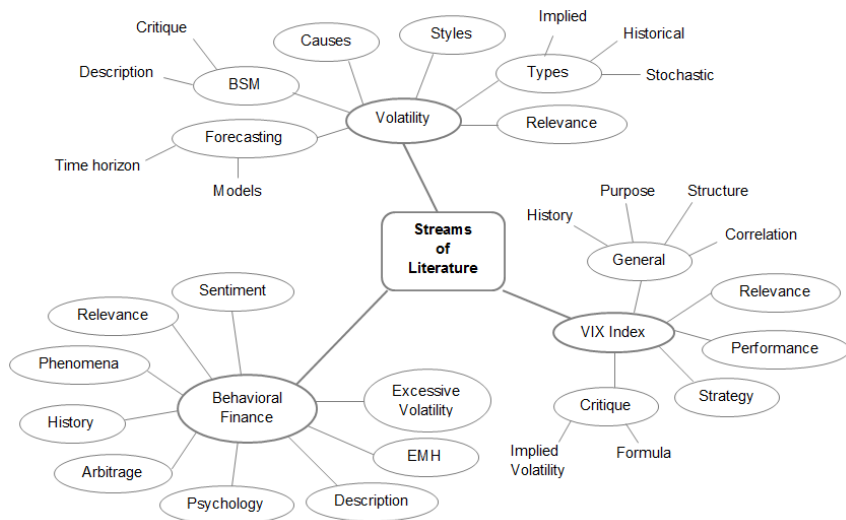


Figure 2: Streams of literature

2.3 Quantitative Research

In order to answer the question whether the SPX Granger causes the VIX and whether this is a reciprocal relationship, the relevant variables (daily changes of the SPX and VIX) were analysed statistically. The process of quantitative research is shown in Figure 3 and starts with the task of data preparation. The data sample used consists of the daily log-returns calculated from the daily close values of the S&P 500 Index and the VIX Index. Unfortunately, high-frequency data such as hourly or minute-by-minute quotes was not easily available and probably costly to collect leading to the focus in this research being explicitly on daily returns. Furthermore, the time horizon was divided into three sections in order to avoid bias through crisis-related index tendencies. The first section covers the period of economic upturn from 2003 to 2006, the second covers the recent financial crisis between 2007 and 2008 when the SPX dropped significantly and finally, the third section ranges from 2009 until 2013. This distinction makes it possible to show potential differ-

ences between the causal relationship of the SPX and the VIX during periods of economic growth and recession. After downloading the relevant data from the Yahoo Finance Website, the log-returns were calculated in Excel for the relevant time periods in order to prepare the data for further analysis. In total the sample size consists of 2,766 observations, whereby time period one covers 1,008 observations, period two covers 504 observations and finally, the most recent period consists of 1,254 observations. The sample size of 2,766 daily returns and an observation time frame of eleven years makes it possible to draw the conclusion that research results fulfil the stability criteria and that there is no fluctuation of research results (Bryman 2012). As a consequence, the assumed stability of research findings indicates that all elements of the quantitative research, including the descriptive analysis and the Granger causality test, are reliable.

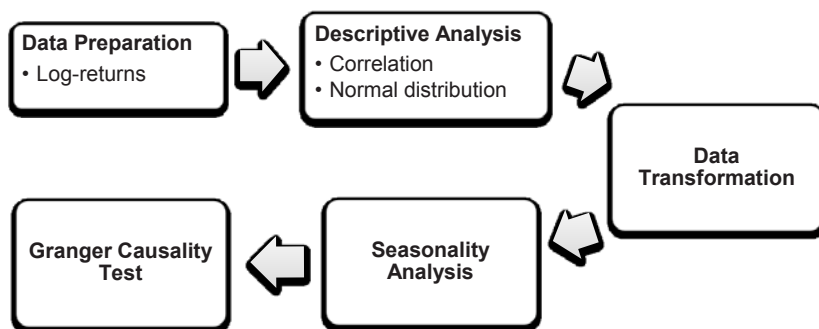


Figure 3: Quantitative research process (own figure)

The data preparation was followed by the next step of the quantitative research, namely the descriptive analysis of the time series. Firstly, although the correlation between the SPX and the VIX Index has already been proven by various pieces of research, the correlation analysis is supposed to be an introductory step of the quantitative study. SPSS was used for both, the analysis regarding normal distribution of the data set and for the correlation analysis. Next, it was assessed whether the data set is normally distributed and consequently, the necessity of data transformation procedures to adjust skewness and kurtosis was also appraised. In order to evaluate the fulfilment of the normal distribution assumption, the following criteria were formulated for the skewness and kurtosis levels of the log-returns.

Normal Distribution Criteria	
Normal Distribution	Non-normal Distribution
$[-1 \leq \text{Skewness} \leq +1]$	$[-\infty < \text{Skewness} < -1]; [+1 < \text{Skewness} < \infty]$
$2 \times \text{Std.Error} > \text{Skewness}$	$2 \times \text{Std.Error} < \text{Skewness}$
$2 \times \text{Std.Error} > \text{Kurtosis}$	$2 \times \text{Std.Error} < \text{Kurtosis}$

Table 2: Normal distribution criteria (own table)

Assessing the degree of normal distribution is also critical because one of the major inputs in the “Bivariate Granger Causality – Free Statistics Software”, which was used for the causal analysis, is the Box-Cox transformation parameter “Lambda” (Wessa 2013). This software computes the causal relationship between two variables in both directions. Figure 4 illustrates the input template of this software and all the necessary inputs. The following list serves as a description of these inputs and explains the applied procedure to find the appropriate variables.

2.3.1 Granger Causality Test Input:

- **Data X (SPX)**

- Log returns of daily close values (dcv) + constant value c

$$= \ln(\text{dcv}_{(t)} / \text{dcv}_{(t-1)}) + c$$

- **Data Y (VIX)**

- Log returns of daily close values (dcv) + constant value c

$$= \ln(\text{dcv}_{(t)} / \text{dcv}_{(t-1)}) + c$$

Data X (click to load default data)
0.4 0.3995 0.4222 0.3934 0.3858 0.4192
Data Y:
0.4 0.3716 0.4093 0.4088 0.4158 0.3486
Box-Cox transformation parameter (X series)
1.8
Degree (d) of non-seasonal differencing (X series)
0
Degree (D) of seasonal differencing (X series)
0
Seasonal Period
1
Box-Cox transformation parameter (Y series)
0.7
Degree (d) of non-seasonal differencing (Y series)
0
Degree (D) of seasonal differencing (Y series)
0
Number of non-seasonal time lags in test
2

Figure 4: Input layout of Granger causality test software (Wessa 2013)

▪ **Box-Cox transformation parameter (X and Y series)**

In order to find the appropriate Box-Cox transformation parameter for each variable in every period, the following procedure was applied. First, the data series were transformed using the formula presented in Equation 1. It should be noted that the first formula was used for all values smaller or greater than zero, whereas the second was used for Lambda equalling zero. Due to the fact that the “Bivariate Granger Causality – Free Statistics Software” only allows the transformation parameter to range between -2 and +2 with one decimal interval, the original data was Box-Cox transformed using each possible Lambda parameter, amounting to 41 transformations.

$$y^{(\lambda)} = \begin{cases} \frac{y^\lambda - 1}{\lambda} & (\lambda \neq 0), \\ \log y & (\lambda = 0), \end{cases}$$

Equation 1: Box-Cox transformation parameter formula

As a next step, all 41 time series were compared with regards to their level of skewness and kurtosis in order to find the time series that is most similar to a normal distribution. In doing so, the correction of skewness was chosen to be the top priority and kurtosis adjustment was the second priority. The Lambda value of this time series was later used as the Box-Cox parameter of the particular index and period for the Granger causality test. There is, however, another step in between, namely the determination of the constant value. This is necessary because the log-returns must be positive and hence, the constant value “c” was added to them. Therefore, the smallest value of all SPX and VIX log-returns was determined, which was -0.3650 (See Table 3). As a consequence, the constant value of 0.4 was added to the daily log-returns in order to ensure positive values across the whole data set (Box and Cox 1964).

Descriptive Statistics			
	N	Minimum	Maximum
SPX (2003-2013)	2766	-,0947	,1096
VIX (2003-2013)	2766	-,3506	,4960
Valid N (listwise)	2766		

Table 3: Minimum and maximum value of SPX & VIX

Figure 5 shows the most appropriate Lambdas that were determined by applying the criterion presented in Table 2. These Lambdas were then used as the Box-Cox transformation parameters for the Granger causality test (See the appendix for all SPSS outputs).

Optimal Lamdas						
	Time Period	Lamda	Skew		Kurtosis	
			Statistic	Std. Error	Statistic	Std. Error
SPX	2003-2006	1,8	-0,673	0,077	-0,764	0,154
	2007-2008	1,7	0,410	0,077	9,387	0,154
	2009-2013	1,7	0,089	0,069	1,915	0,138
VIX	2003-2006	0,7	0,134	0,077	3,750	0,154
	2007-2008	0,7	0,200	0,109	3,176	0,217
	2009-2013	0,6	0,078	0,069	4,605	0,138

Figure 5: Most appropriate lambda values (own table)

▪ Degree of non-seasonal (d) and seasonal differencing (D) for SPX

In order to detect any potential seasonal pattern of the S&P 500 Index that could affect the Granger causality test, its daily log-returns were analysed from January 2003. In Figure 6 you can see that especially between 2003 and 2007, the daily changes of the SPX stayed within a very narrow range of +/- 4%, followed by a more volatile period caused by the financial crisis. Since 2012 however, the situation is obviously the way it was before the economic recession without any major trends. In other words, the opportunity of spikes in the log-returns is definitely given and can be triggered by events such as global financial recessions. However, such developments are difficult to foresee and are not considered to be either seasonal nor stable over time.

As a consequence, the assumption can be made that there is no significant seasonal pattern in the log-returns of the S&P 500 Index. Hence, the degree of non-seasonal and seasonal differencing was kept stable with an input value of zero throughout all periods.

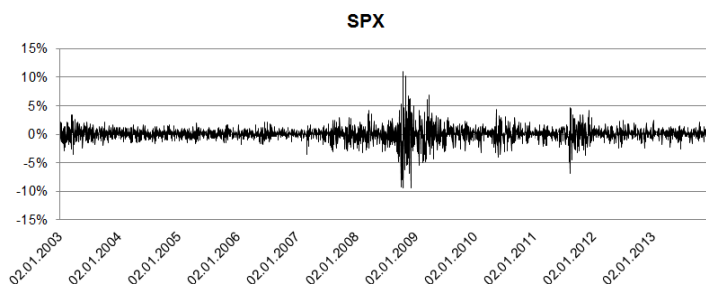


Figure 6: Daily returns SPX 2003 - 2013 (own Figure)

- **Degree of non-seasonal (d) and seasonal differencing (D) for VIX**

Similar to the procedure for the SPX that was mentioned above, the seasonality was also analysed for the VIX Index over the same time period. A first look at Figure 7 shows that in general, the range within the VIX Index fluctuates is definitely larger compared with the SPX. But there is no seasonal pattern observable in the VIX. Consequently, the assumption that no seasonal effect is incorporated can also be derived for the daily changes of the VIX Index. Therefore, the degree of non-seasonal and seasonal differencing was kept constant for the VIX as well with an input value of zero.

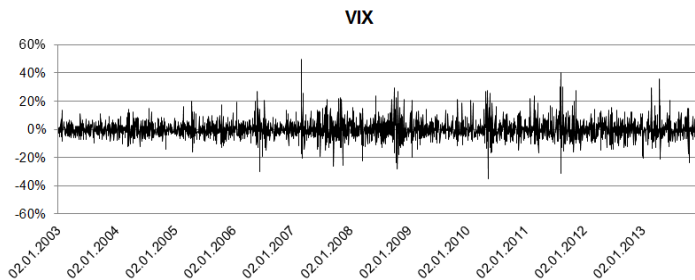


Figure 7: Daily returns VIX 2003 - 2013 (own Figure)

Due to the fact that the data set explicitly consists of daily close values, potential data structure phenomena like, for instance, intraday seasonality were not considered.

- **Seasonal Period**

Due to the fact that there is no significant seasonal pattern observable, the value for the seasonal period is always 1.

- **Number of non-seasonal time lags in test**

In order to test the decay of causality and forecastability, Granger causality was computed for each time lag that was possible to enter in the software, ranging from 1 to 11 lags.

The results obtained by using this software will provide answers to the research question of SPX and VIX Index causation and, therefore, help to confirm or reject the formulated hypothesis:

**RQ 1: *What is the causal relationship:
Does the VIX Granger cause the S&P 500 movement or vice-versa?***

In order to answer this research question, the following hypotheses have been formulated and derived from the literature review. In doing so, the level of statistical significance that is acceptable was $p < 5\%$, which implies that there are fewer than 5 chances in 100 observations that there could be a Granger causality relationship between the two variables (Bryman 2012):

H₀: The VIX Index does not Granger cause the S&P 500 index.

A null hypothesis stipulates that two variables are not related. In this respect, that would mean that the VIX Index cannot be used to forecast the SPX movement because there is no Granger causal relationship (Bryman 2012). For both situations, rejecting and confirming H₀, the alternative hypotheses H_A and H_B have been formulated:

H_A: The VIX Index Granger causes the S&P 500 Index.

As is mentioned in chapter 6.1, the VIX Index is also called “Investor Fear Gauge”, because in general, a high level of the VIX is related to a high level of fear among investors, whereas a low VIX level is associated with complacency (CBOE 2014c). Furthermore, Howard (2013) has shown that emotional crowds dominate market pricing and volatility and they drive prices based on the latest scenarios, whether optimistic or pessimistic. These facts lead to the argumentation that SPX investors observe the level of the VIX Index and thereby, the level of fear in the market when deciding to buy, hold or sell stocks. As a consequence, any significant change in the VIX Index results in certain behaviour of SPX investors. In the case of a sharp VIX increase, traders will rush to sell their assets, whereas in the case of a sharp VIX decline, traders will buy or at least hold their SPX stocks. This allows the formulation of the alternative hypothesis H_A as stated above.

H_B: The S&P 500 Index Granger causes the VIX Index.

The second alternative hypothesis H_B claims the exact opposite of H_A. In chapter 6.3 there is a presentation of the main sources of criticism regarding the VIX Index and its predictive performance. According to a study by Laszlo Birinyi and Kevin Pleines, which was presented in the Seattle Times, the VIX is just a coincidental indicator with limited predictive value and consequently all but useless for forecasting the direction of equity prices. Moreover, it is argued that the VIX measures the volatility of the market today, but not tomorrow or the day after and is supposed to have little connection to future equity prices. Instead, Birinyi and Pleines claim that the VIX Index moves in

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