## Executive Summary

The development of the Black-Scholes (1973) option pricing model, sometimes also referred to as the Black-Scholes-Merton model due to the underlying mathematical model that Merton developed, not only enriched the toolbox of market participants but also aroused the interest of academic researchers. The formula was a breakthrough and laid the ground for the vast growth of options markets around the world. Besides all its extensions and the ability of the Black-Scholes model to value European options in a continuous time setting, its characteristics, especially the fact that it is invertible, were of great interest to its applicants.

Breeden and Litzenberger (1978) and Banz and Miller (1978) used the invertibility of the model to show how the otherwise unobservable risk-neutral density function, which is used to price contingent claims, can be obtained from option prices. The risk-neutral density functions, together with the subjective density functions that are estimated by historical returns, reveal an enormous amount of information about the aggregated expectations of market participants and their aggregated risk preferences to the observer that is otherwise not directly measurable (Figlewski (2008, p. 2)). By monitoring changes in these density functions over time, especially before and after a major event has taken place, the dynamics can point out how the new information gathered by market participants may affect their personal – and therefore the aggregate – attitude towards risk, and with it the whole market (Figlewski (2008, p. 2)). Furthermore, equipped with the subjective and risk-neutral probabilities, it is possible to establish an important link between economics and finance – the pricing kernel. In standard models of financial economics with a representative agent, the pricing kernel is the scaled marginal utility of that agent and hence the aggregated marginal utility in the economy (Brown and Jackwerth (2001, p. 4)). The empirically derived pricing kernel connects the information contained in asset prices with fundamental economic principles, such as the scarcity of endowment and the decreasing marginal utility of wealth (Hens and Reichlin (2012, p. 2)).

As the purpose of this thesis is to examine the impact of major stock market crashes on the pricing kernel, whereby the dynamics of implied volatility smiles, risk-neutral and subjective density functions and pricing kernels observable around these meltdowns are analyzed, the fitted implied volatilities, density functions and pricing kernels for six different events are estimated from two cross-sections of index option data on the US S&P 500 index and from two historical return samples of the US S&P 500 index. For this, the thesis first introduces the

reader to the broad topic by providing an overview of the related literature on how to estimate the risk-neutral density function from a cross-section of option prices. Subsequently, the techniques used in the empirical part of the thesis – the “Fast and Stable Method” of Jackwerth (2004, pp. 25-29) to estimate the risk-neutral density function from a cross-section of option prices and a kernel density estimation procedure to find the subjective density function from gross monthly log returns – are outlined in great detail and the link between the empirical results and standard economic theory – the pricing kernel – is revealed. In addition, the six events covered in the empirical part – 9/11, Bear Stearns, Lehman Brothers, TARP Rejection, Flash Crash, and Fukushima – are classified into two groups: expectable events and force majeure events. The classification is carried out on the basis of the capability of market participants to foresee the event, enabling them to adjust their expectations and market exposure before the event had occurred, or the impossibility of suspecting that it would happen, leaving their expectations prior to the event unchanged. Altogether, 12 volatility plots, 12 risk-neutral density function plots, 12 subjective density function plots and 36 pricing kernel plots are shown in the thesis.

The empirical results show that there are indeed differences not only between the pre- and post-event empirical pricing kernels, but also between the evolution of the volatility smiles from the first to the second cross-section and the shapes of the risk-neutral density functions retrieved from the option prices. The 12 volatility smiles show differences in the steepness of their slopes as well as in their overall volatility level. Generally speaking, the overall implied volatility level of the first cross-section options is higher for the expectable events but only exhibits a minor increase as a result of the event compared to the increase in volatility exhibited by the force majeure events. Conversely, the changes in the slope of the smiles are biggest for the force majeure events. Their post-event volatility smiles decrease faster for increasing levels of moneyness. The differences between the risk-neutral density functions are that the pre-event functions of the expectable events exhibit less excess-kurtosis than the pre-event functions of the force majeure events, which are almost symmetrical. The development of the risk-neutral density functions is also distinct. For the force majeure events, the excess-kurtosis decreases, the modes are shifted to the right and the probabilities in the far left tail increase. In contrast, the locations of the modes of the post-event functions of the expectable events are almost unchanged and nearly the whole area under the curve on the left side of the mode increases. Virtually all the first cross-section pricing kernels derived in the thesis show the same course as can be found in the literature. For wealth levels between 0.7 and 1.2, they decrease globally but exhibit a concave part whose apex is located around the current level of wealth. However, the shapes of the pricing kernels develop differently for the two groups. The post-event kernels of the force majeure events are still similar in shape after the occurrence of the respective event. The apexes of the concave parts are shifted to the right and the steepness of the slopes for low levels of wealth increased. On the other side, the changes in the shapes of the pricing kernels of the other group include a decrease in the implied marginal utility of the representative agent for low levels of wealth and the disappearance of the concave parts in two cases.

To summarize, the empirical results suggest that if investors are aware of the possibility of a market downturn, they adjust their expectations and with it the prices of traded options before the meltdown happens. Furthermore, the post-event pricing kernels imply that their reaction to the new information released by the event is different. In addition, our findings reveal that the externally controllable estimation procedure of the subjective density function is very sensitive to the inputs of the operator and strongly influences the shape of the empirical pricing kernel.