What happened during the 2007-09 financial crisis?

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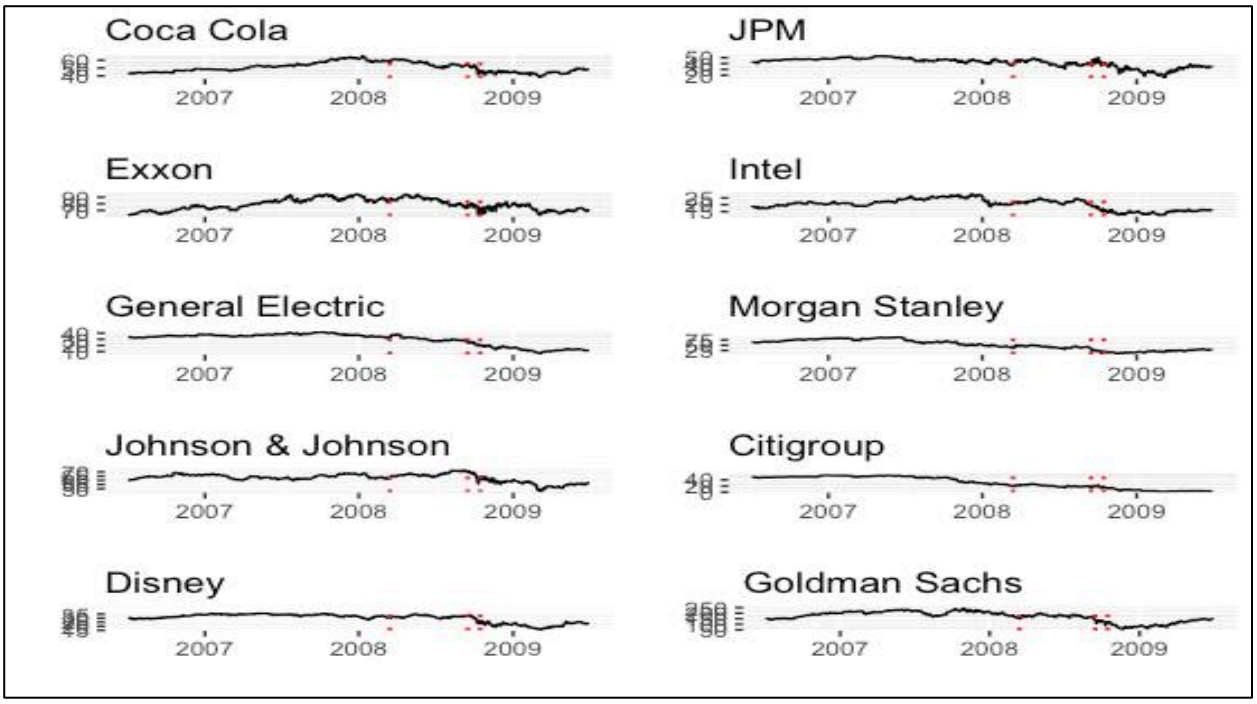
Contents

1. Introduction

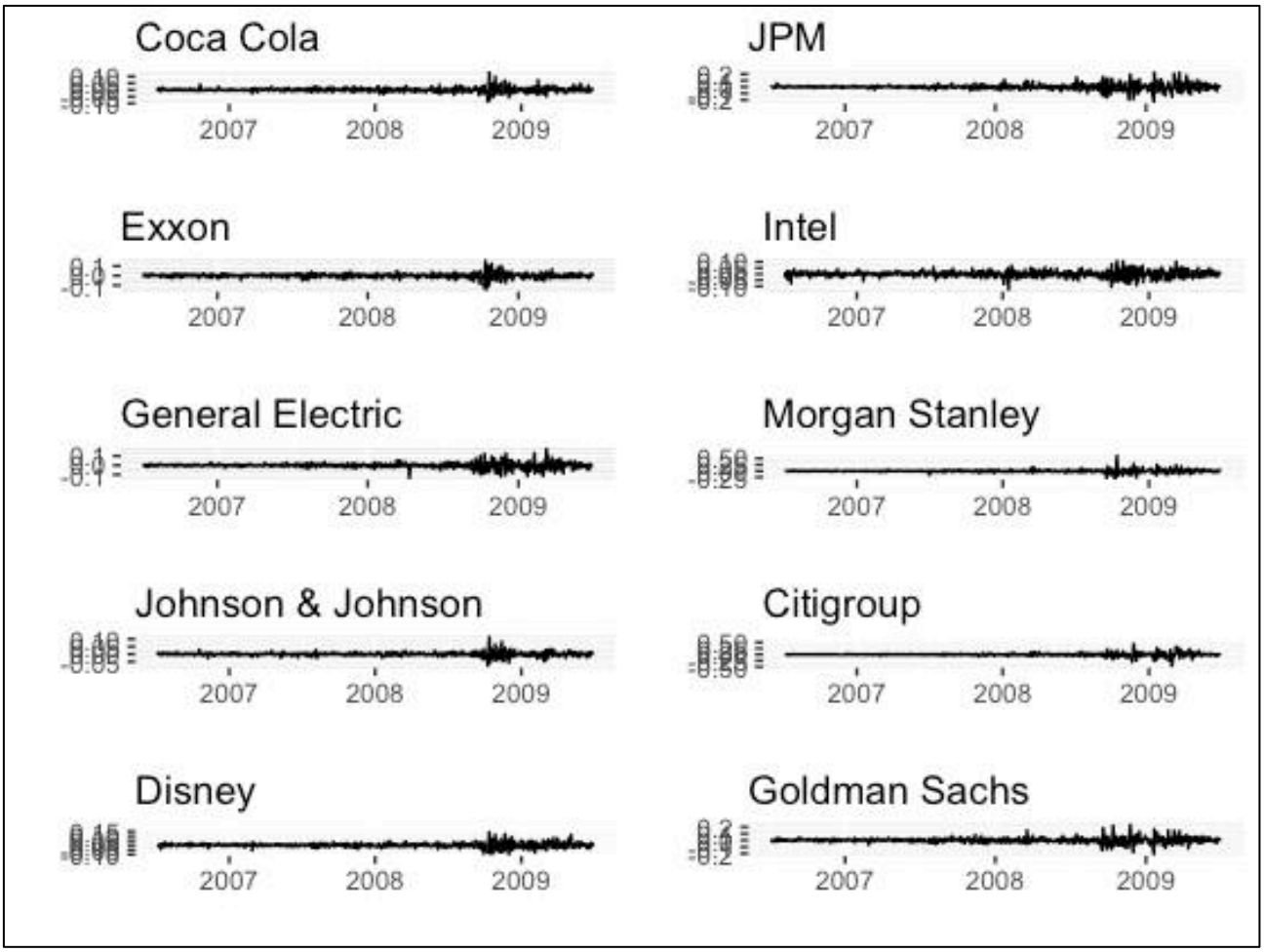
The 2007-09 global financial crisis had far-ranging consequences within the global money and capital markets. The crisis, characterized by the extensive failures of large-scale investment banks and unprecedented mortgage delinquencies, caused US equity market declines of more than 50 percent from peak (October 2007) to trough (March 2009) and had a notable impact on increasing cross-correlations among different stocks. Moreover, as indicated by the CBOE Volatility Index (VIX), US equity market volatility increased almost ten-fold, from as low as 9.6 in December 2006 to 89.5 in October 2008. This paper assesses how the 2007-2009 global financial crisis impacted the market risks associated with a representative sample of ten Standard and Poor's 500 (S&P 500) firms – both financial and non-financial – by evaluating the returns and cross-correlations of their common stocks.

2. Market Overview

The S&P 500 is the most widely used benchmark for portfolio performance, and companies listed within this index were used to analyze these matters of interest. The period runs from 2006 through 2009. It encompasses both bear and bull markets, and offers the opportunity to examine the risk of specific companies before and during the crisis. The following two graphs provide insight into their stock price dynamics, the causes of notable events that shaped the trajectory of returns and cross-correlations among stocks, and the log returns of S&P 500 firms before and during the 2007-09 financial crisis.



Graph A: Stock price dynamics



Graph B: Log returns

From these graphs we can see evidence of major market events on 15 September 2008, October 2008 and, to a lesser extent, 14 March 2008.

On 14 March 2008, news came that Bear Stearns was seeking emergency short-term funding from JPMorgan and the New York Federal Reserve to prevent its collapse. Bear was among several systemically important investment banks and securities trading/brokerage firms that had material exposure to collateralized debt obligations (CDO) – derivatives based on residential mortgage-backed securities (RMBS). Once home price peaked in July 2006 and began declining, these assets started losing value. Poorly diversified, highly leveraged banks were most at risk. As these securities lost value, investors began pulling their money, further amplifying losses.

By Q4 2007, Bear announced its first loss in more than 80 years stemming from a write-down of its subprime RMBS portfolio (WSJ, 2007). This triggered a credit downgrade from S&P.

By March 2008, once the Fed announced its Term Securities Lending Facility program to promote financial market liquidity, the market interpreted this as a warning signal that credit and capital market conditions were deteriorating more broadly. Bear was hit with another credit downgrade and clients began pulling their capital in the form of investments and deposits. Other banks recalled their repurchase agreements and refused to continue to enter into collateralized

lending arrangements with Bear due to a lack of confidence stemming from its exposure to toxic RMBS assets. This led to the first stench that a liquidity crisis could be brewing wherein banks refused to lend to each other as part of spreading uncertainty over the health of the financial system.

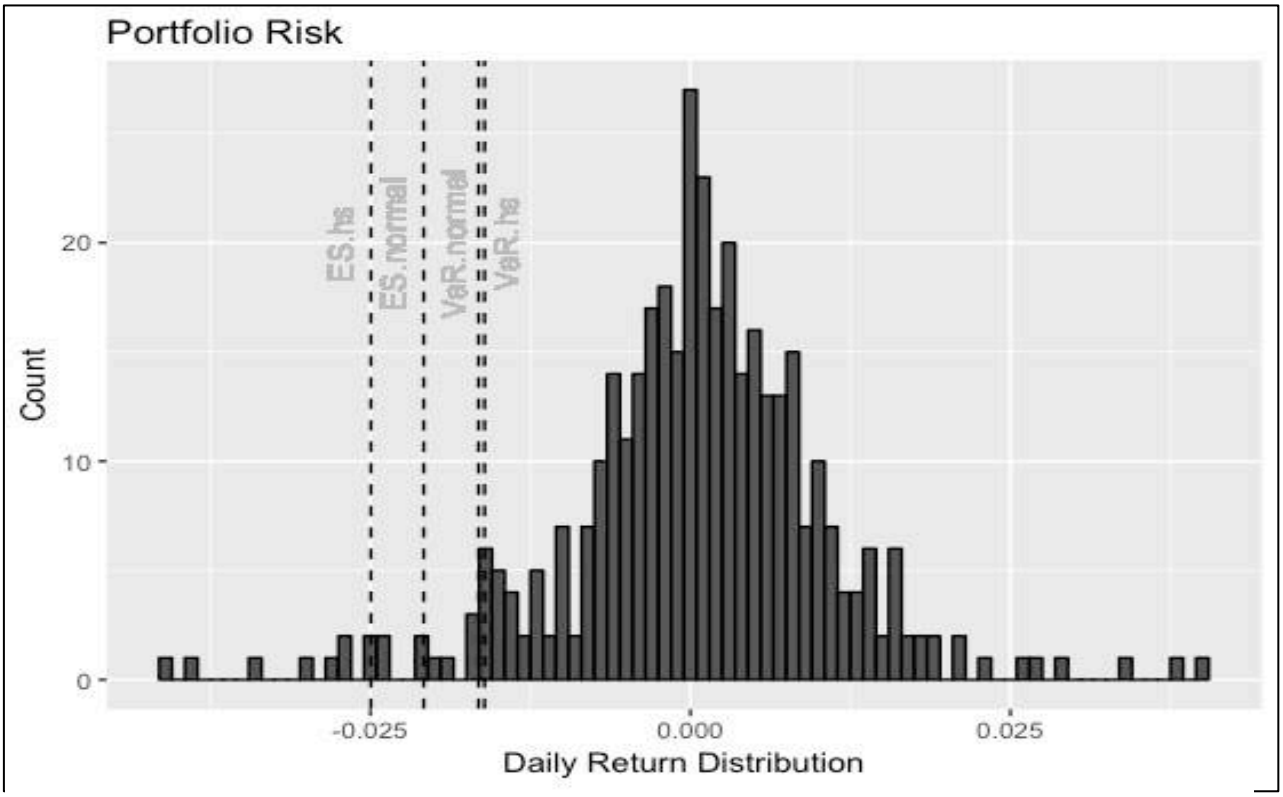
Lehman Brothers filed for bankruptcy on 15 September 2008, which coincided with a drop of the S&P of 4.7% that same day, upon the implication that it was defaulting on more than $600 billion worth of liabilities, the largest filing in history. Lehman also had exceptional exposure to the RMBS markets and real estate assets. Moreover, it was heavily involved in mortgage origination and was leveraged by a factor of 30-to-1 ($680 billion in assets backed by only $23 billion in capital) (US Securities and Exchange Commission, 2008). This rendered it particularly vulnerable to a reversal in prices. Under this leveraging structure, merely a 3%-4% deterioration in the value of its assets would wipe out its equity entirely.

Lehman's failing signaled how much bad debt was in the economy and what that meant for future write-offs and coerced asset liquidations. This caused nearly all stocks to drop contemporaneously after news hit the market.

In October 2008, there was a run on money market mutual funds, which are largely comprised of safe assets such as US Treasury bills and commercial paper (generally used for purposes of short-term financing for corporate operations). When this market suffered a run, companies had difficulty rolling over their short-term debt, leading to a temporary freeze up in corporate bond markets. Naturally because this pressured companies' ability to carry out their operations, this exacerbated the ongoing equity market sell-off. These events led to a profusion of adverse capital market ramifications. Risk aversion was magnified, collateralization requirements (on the basis of quality or amount) were increased, liquidity mismatches ballooned, deposit runs emerged, loan-funding sources dissipated, counterparties' credit default risks were amplified, and illiquid assets were marked down, all leading to a crisis of confidence and strangulated capital markets.

3. Before the financial crisis

This section examines the market risk from 1 July 2006 to 31 December 2007 using standard portfolio risk measurement techniques. The portfolio invests $1000 in each of the aforementioned stocks at the beginning of the period. Risk computations are performed by taking the Value at Risk ("VaR") and the Expected Shortfall ("ES") at the 95% level using both an empirical distribution and parametric approach on the basis of daily portfolio returns.



Graph C: VaR and ES

The negative return at the 95th percentile (i.e., 5% chance that the daily loss will exceed this level) for the non-parametric VaR estimate comes to (-0.0161). The parametric VaR (-0.0166) is more precise in estimating the actual value given financial returns tend to have fatter tails than those specified by the normal distribution. But using parametric VaR risks imprecision if the assets follow a return distribution that materially varies from normality.

In contrast, the expected shortfall attempts to measure the magnitude of the average loss exceeding the VaR. The portfolio's calculated ES`s using both the historical approach and parametric method yield (-0.0250) and (-0.0208), respectively. The mathematical definition of VaR as the negative value of a quantile as well as the mathematical definition of ES as the negative value of extreme losses will usually produce a positive number. However, in practice, VaR and ES denote losses and thus will be expressed as negative numbers.

4. During the Financial Crisis

The computed VaR can be back-tested by counting VaR violations per year. In contrast, the ES is difficult to back-test given estimates of expected shortfall depend on the full shape of the tail of the distribution, which is typically unknown. In other words, one would need a very large horizon to estimate the tail losses, but tail risk might change over time. The 1996 BIS amendment requires the one-day ($\alpha = 99\%$) VaR to be back-tested over a period of 250 days. When the losses are larger than the VaR, an “exception” is recorded. In this paper, the VaR is back-tested by counting VaR violations over the period from 1 January 2008 to 30 June 2009.

The back-test results are summarized in the following table:

VaR	Historic	Parametric
Number of Violations	86	83
Violations in %	22.81 %	22.02 %

Table 1: VaR Violations

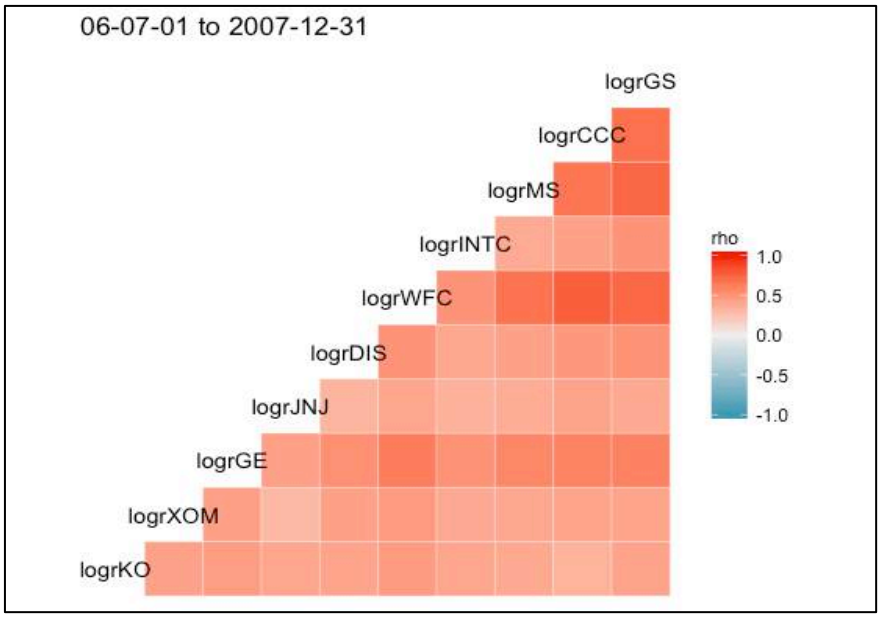
The high percentage of VaR violations illustrates that the VaR prediction greatly underestimated the actual risk. Our VaR calculation is based on data between 1 July 2006 and 31 December 2007. As observed from the second graph, this period was characterized by low volatility. This issue highlights an important point and can be transferred to a general problem of many VaR models and consequently to risk management practices before the crisis. To compute the Market Risk Charge (MRC), the VaR was often computed with a historical simulation of a window of 1-4 years. The 2003-2006 period often saw low financial market volatility. Thus, risk was underestimated and MRC was "too low". During the credit crisis, it became clear that the computation of market risk should be amended for the sake of greater robustness in its assessment. These changes are referred to as Basel II.5 and mainly consists of three parts:

1. The computation of stressed VaR (sVaR)
2. The new incremental risk charge (IRC)
3. A comprehensive risk charge (CompRC) for instruments dependent on credit correlations

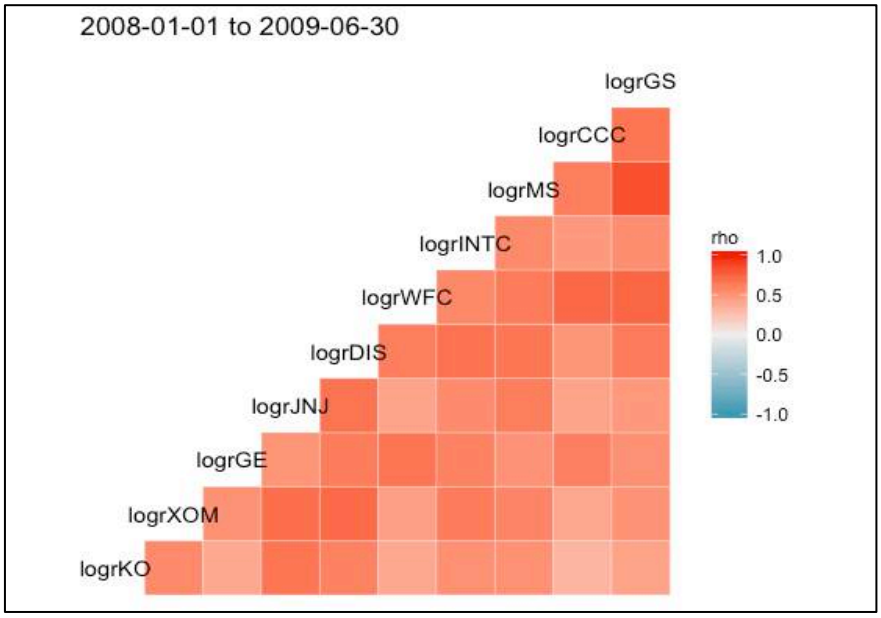
Therefore Basel II.5 greatly increased the MRC that banks have to hold:

$$MCR = MRC_{\text{Basel II}} + IRC + CompRC$$

Less emphasized, generally, is the impact on the correlations of equity returns. During the financial crisis, the average correlation coefficient between S&P 500 stocks rose dramatically and virtually all other risky assets moved in lockstep. As support for this observation, the following two graphs show the correlation matrices for the log returns of our portfolio before and during the financial crisis.



Graph D: Correlation matrix I



Graph E: Correlation matrix II

In these situations, with the covariance in returns increasing, investors are confronted with two challenges. First, the difficulty of building equity portfolios with significant alphas increases. Second, and arguably more important, the ability to diversify across equity investments, a centerpiece of modern portfolio theory (MPT), becomes limited. As argued in the financial media (Koh and Spremann, 2008; Ferry and Foster, 2010), the theoretical robustness of MPT during the financial crisis largely broke down when financial advisors, portfolio managers, and investors could have most benefited from the merits of diversification to defray risk. Furthermore, research has shown that stock investments are much more strongly correlated in market downturns than upturns (Silvapulle and Granger, 2001; Ang and Chen, 2002; Hong et al., 2007; Chua et al., 2009; Ennis, 2009).

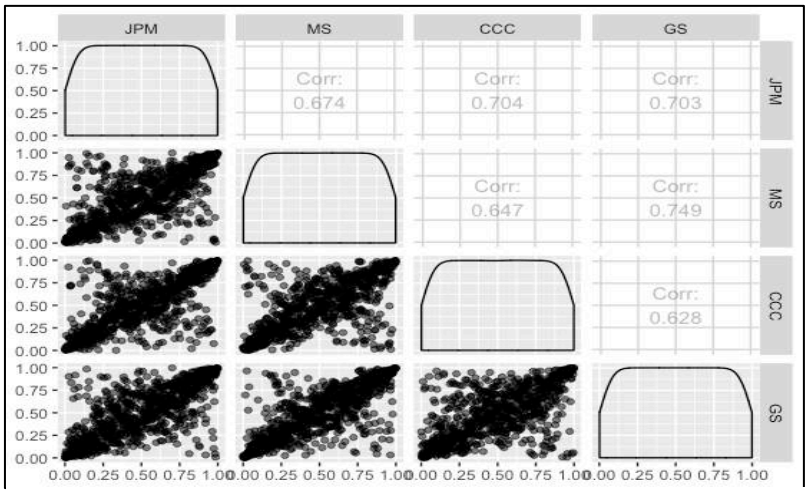
The drawbacks of the VaR model can be summarized in the following table:

VaR historical	VaR parametric
- Ignores the severity of losses below VaR "That $50M (VaR) wasn't just the most you could lose 99% of the time. It was the least you could lose 1 percent of the time." (NY Times)	- The model assumes that dependencies between risk factors are adequately described by a covariance matrix - Correlations are measures of linear dependencies only
- Estimation from historical data may be a bad proxy for a future-oriented risk measurements	- The assumption of normally distributed value changes is often not justified
- Poor VaR estimate if only a short window of data is available - Data from the non-recent past may not accurately reflect current risk	- Only applicable for positions with linear dependencies on the driving risk factors

Table 2: Drawbacks of VaR

5. Copulas

Focusing on the financial stocks (Goldman Sachs, Citigroup, Morgan Stanley, Wells Fargo), this chapter will analyze their dependence using the t-copula, Gauss-copula, and the clay-copula. Copulas describe the dependence at a deeper level than correlation. For example, two random variables can be uncorrelated but still dependent. The origin of the word copula is the Latin word `copulare´, which means `join together´. In many cases of statistical modeling, it is essential to obtain the Probability Density Function (pdf) between multiple random variables. Even though the marginal distribution of each of the random variables are known, their joint distribution may not be easy to obtain from these marginal distributions. Knowing the scale-free measure of dependence between random variables, copulas can be used to obtain their joint distribution. Thus, copulas are functions that join multiple distributions to their joint distribution function. They facilitate a bottom-up approach: Generally, the marginal behavior of individual risk factors is better understood than their dependence structure. Copulas express dependence on a quantile scale, which is especially useful for describing the dependence of extreme outcomes. They are distribution functions whose one-dimensional margins are uniform. In order to find the best function (i.e., the copula) for our empirical data we first constructed a pseudo copula from our data and then fitted our three copulas in question. The following graph shows all the data pairs generated from the Empirical Distribution Function (edf).



Graph F: Correlation of financial stocks

As observed from the graph, many data points are clustered in the tails. Therefore, it is not surprising that the t-copula best fits our data. The maximum likelihoods of the t-copula, Gauss-copula and the clay-copula are summarized in the following table.

	t copula	Gauss copula	clay copula
Maximum Likelihood	**1801.982**	1009.453	874.2564

6. Conclusion

The VaR method failed to provide an accurate picture of the true market risk. Nonetheless, models were generally computed with a historical simulation of a window of merely one to four years. The period between 2003 and 2006 was especially characterized by low financial market volatility. Thus, market risk was materially underestimated and consequently the MRC was insufficient. Moreover, the average correlation coefficient between stocks in the S&P 500 rose significantly during the 2007-09 financial crisis. Investors should be aware that equity portfolio risk reduction during major crises could be hard to achieve since the average correlation coefficient between stock returns may rise dramatically, crimping the efficacy of diversification. However, because the study solely focuses on only one specific period of time, researchers should be cautious in generalizing the results to the post-crisis period and whatever predictive value they may offer with respect to future market conditions.

Lastly, copulas can be used to model dependencies. Where the correlation only measures some kind of dependency, copulas capture all dependencies. Copulas are functions that join multiple distributions to their joint distribution function. The joint distribution function contains the marginal behavior of individual risk and their dependence structure. Since copulas describe dependence on a quantile scale, they describe dependencies in extreme events such as the 2007-09 financial crisis much better than traditional Value at Risk models.

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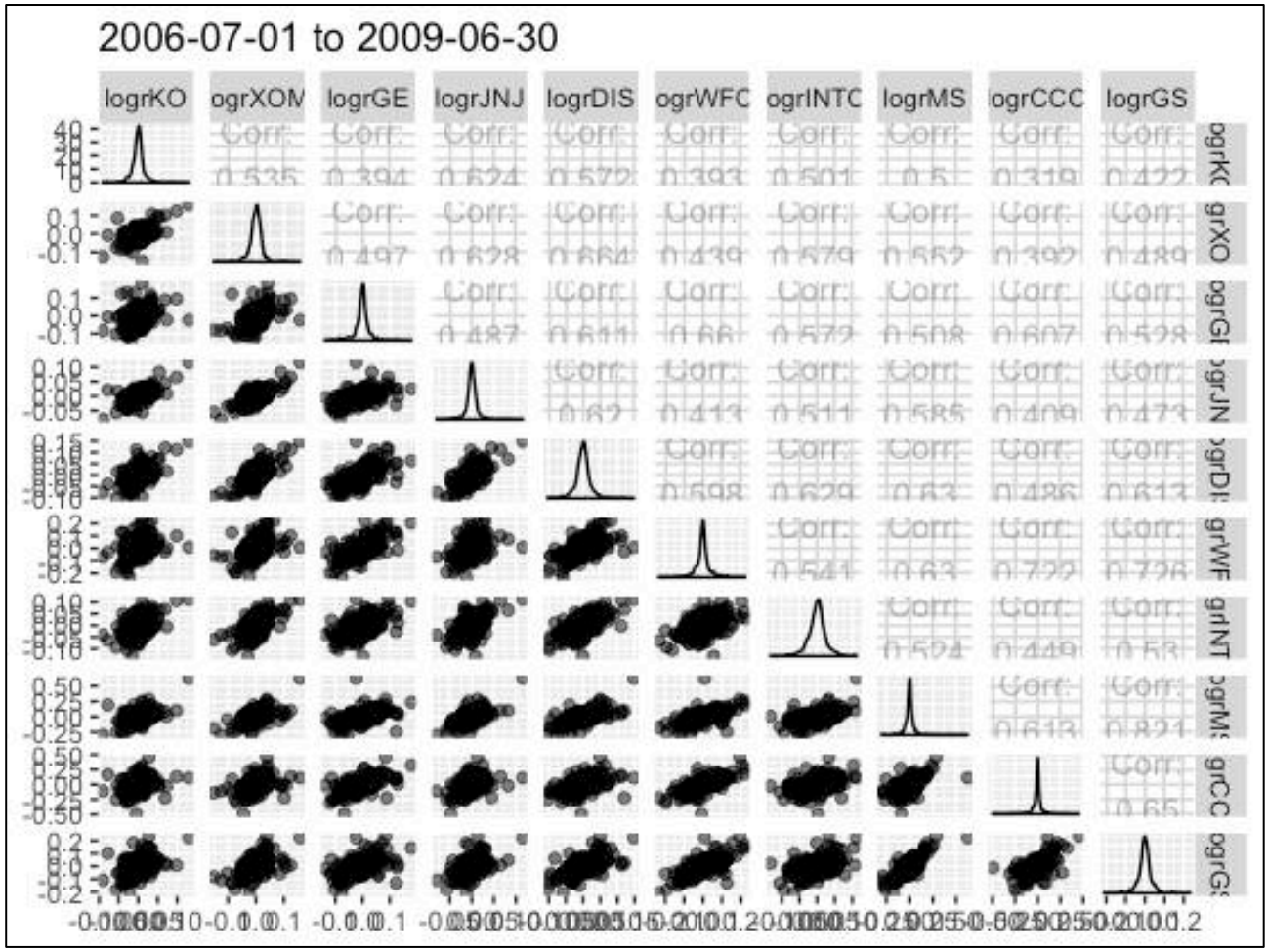
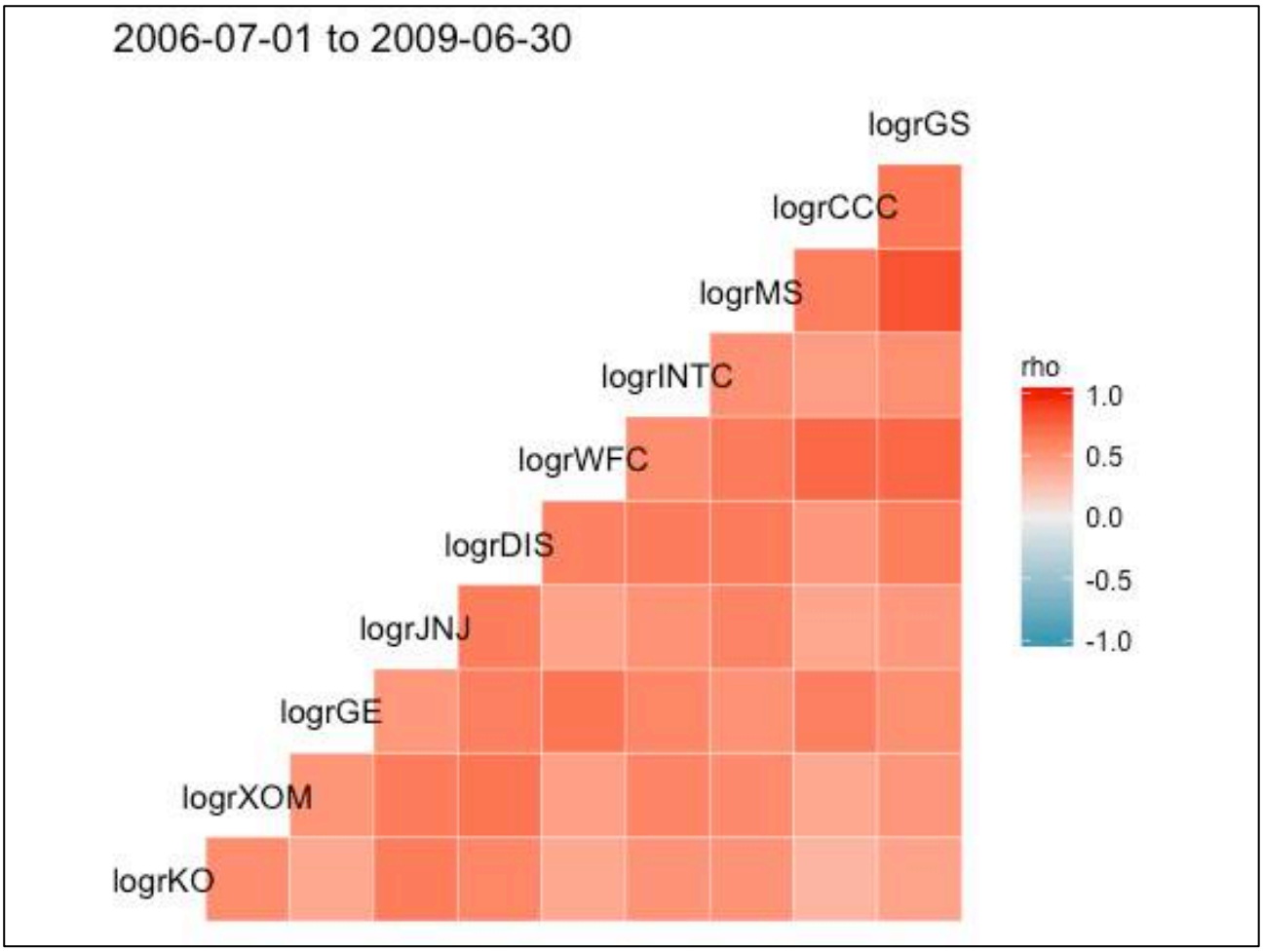
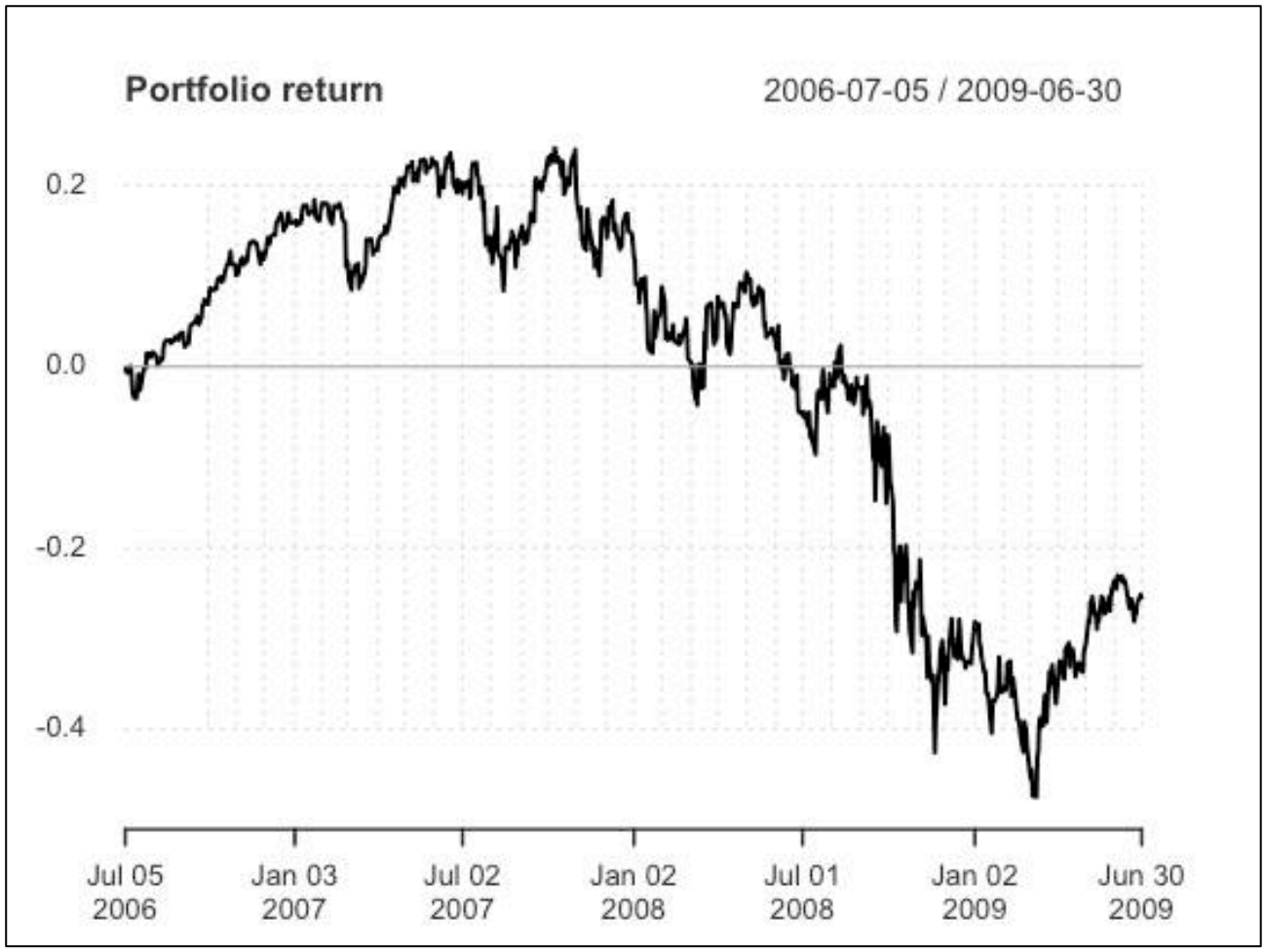
Appendix

- Total Period (2006-07-01 to 2009-06-30)




2006-07-01 to 2009-06-30
logrGS
logrCCC
logrMS
logrINTC
logrWFC
logrDIS
logrJNJ
logrGE
logrXOM
logrKO
rho
1.0
0.5
0.0
-0.5
-1.0


Portfolio return
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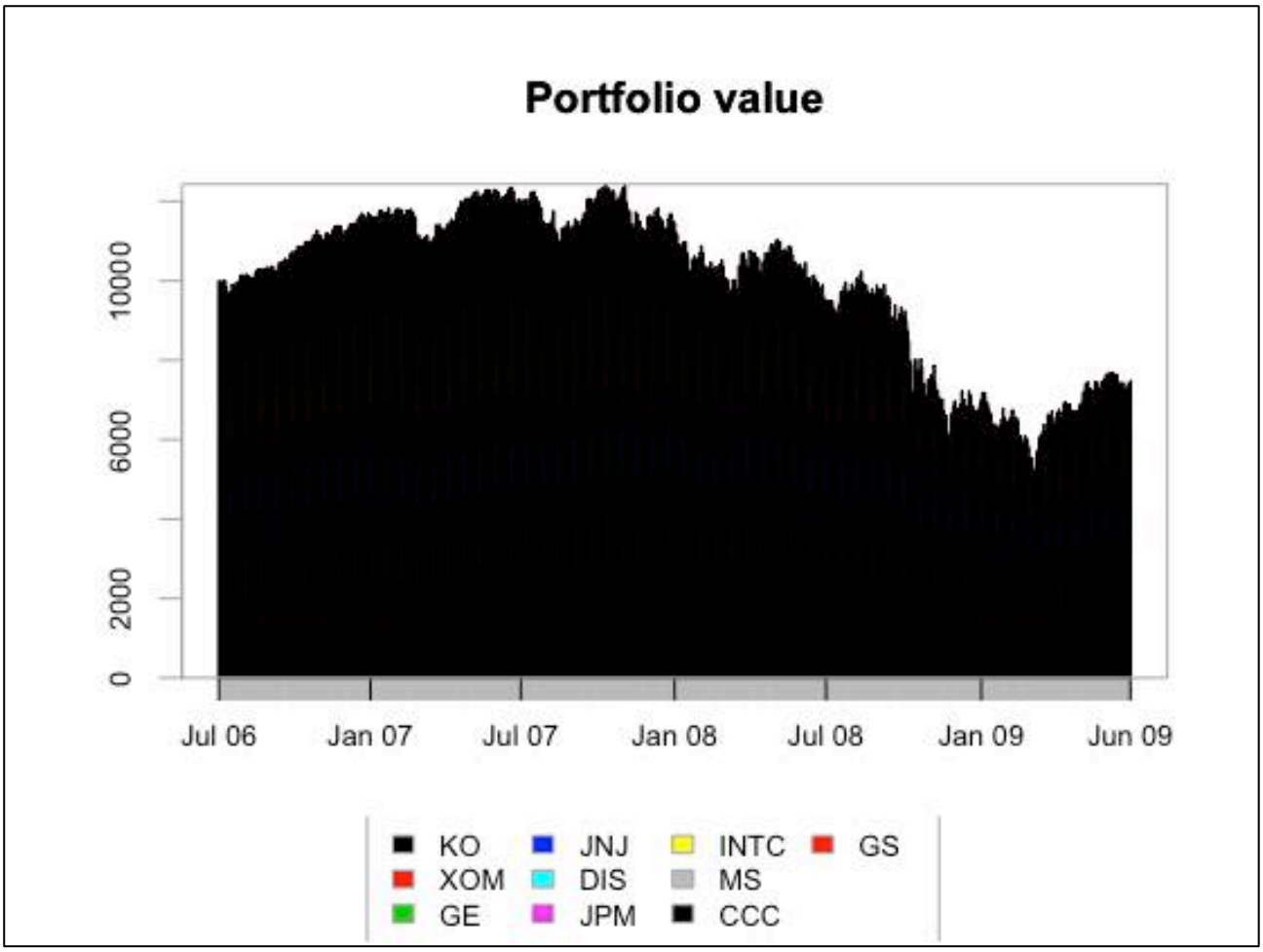
0.0
-0.2
-0.4
Jul 05
2006
Jan 03
2007
Jul 02
2007
Jan 02
2008
Jul 01
2008
Jan 02
2009
Jun 30
2009


Portfolio value
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2000
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Jul 06
Jan 07
Jul 07
Jan 08
Jul 08
Jan 09
Jun 09
KO
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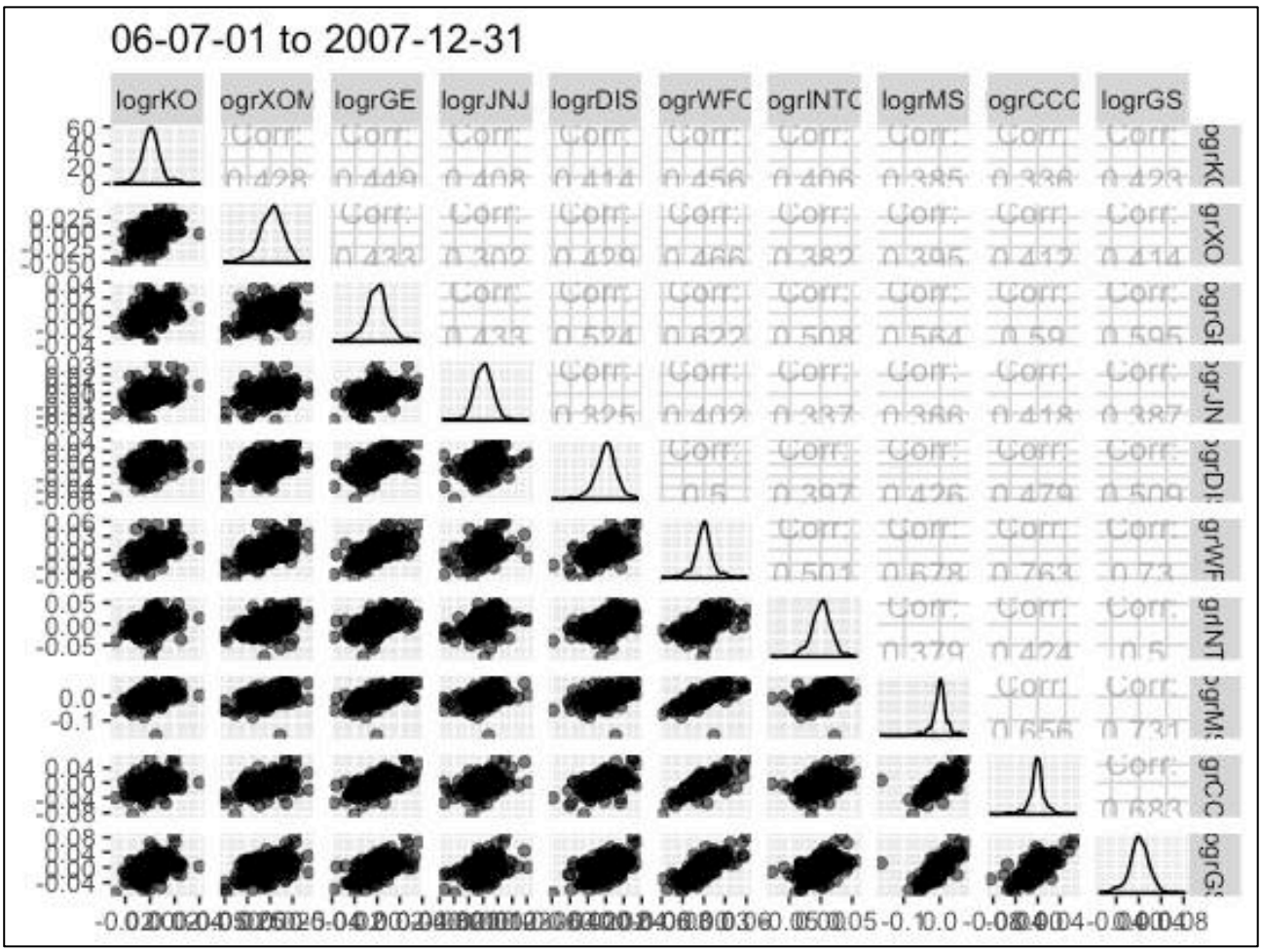
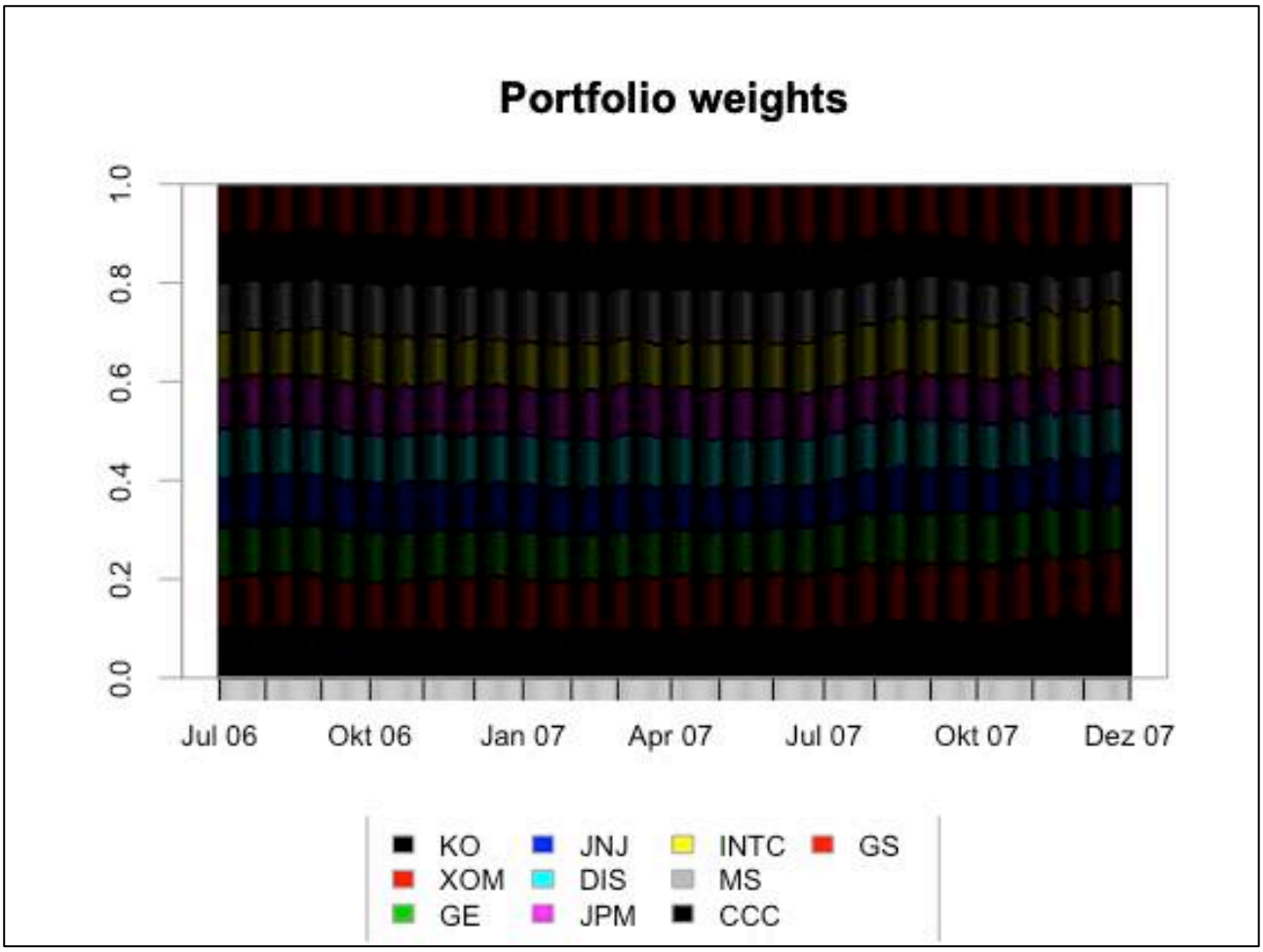
GS
XOM
DIS
MS
GE
JPM
CCC

- Period before the crisis (2006-07-01 to 2007-12-31)




Portfolio return
2006-07-05 / 2007-12-31
0.20
0.15
0.10
0.05
0.00
Jul 05
2006
Okt 02
2006
Jan 03
2007
Apr 02
2007
Jun 01
2007
Sep 04
2007
Dez 03
2007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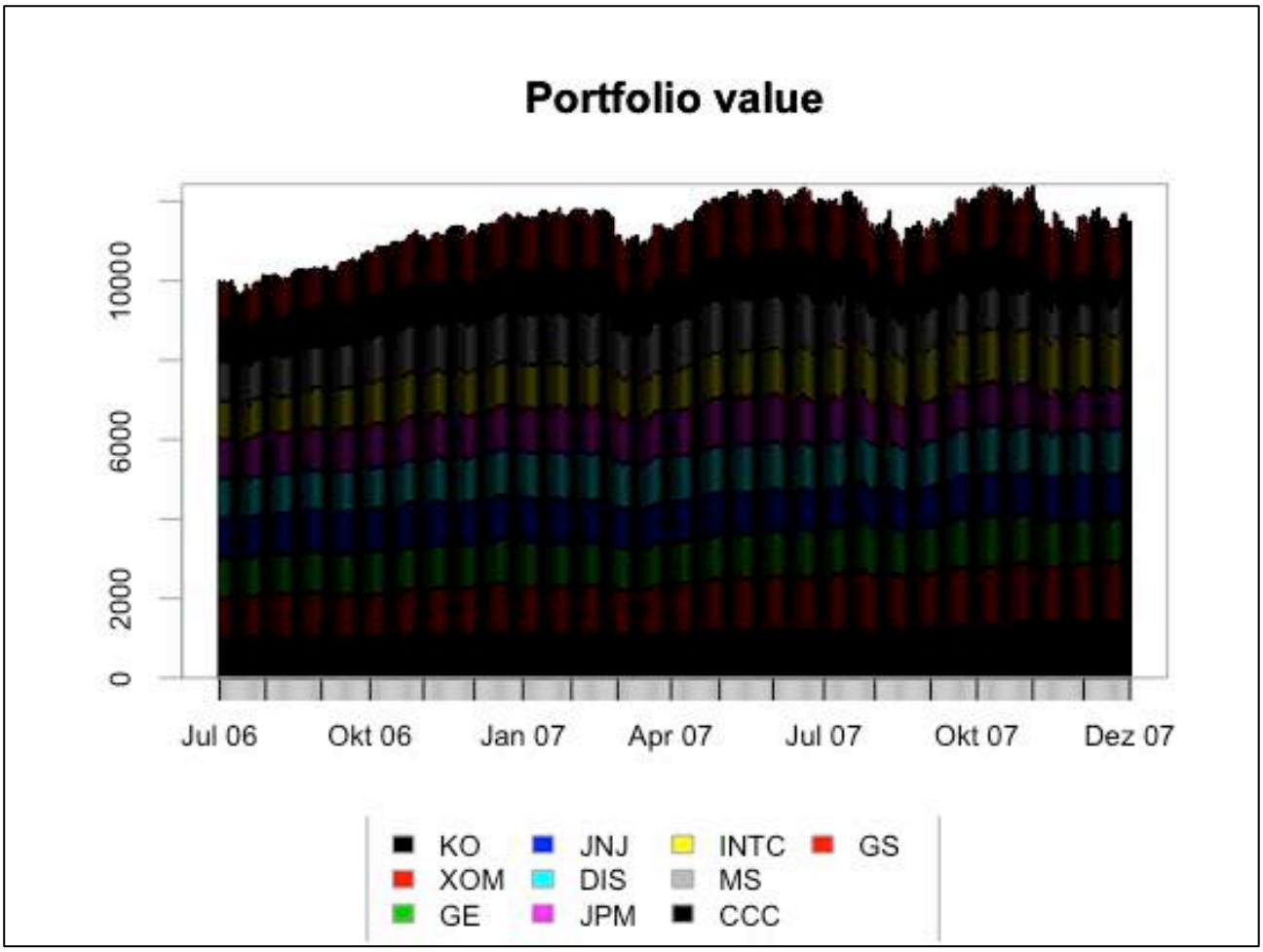
DIS
MS
GE
JPM
CCC


Portfolio value
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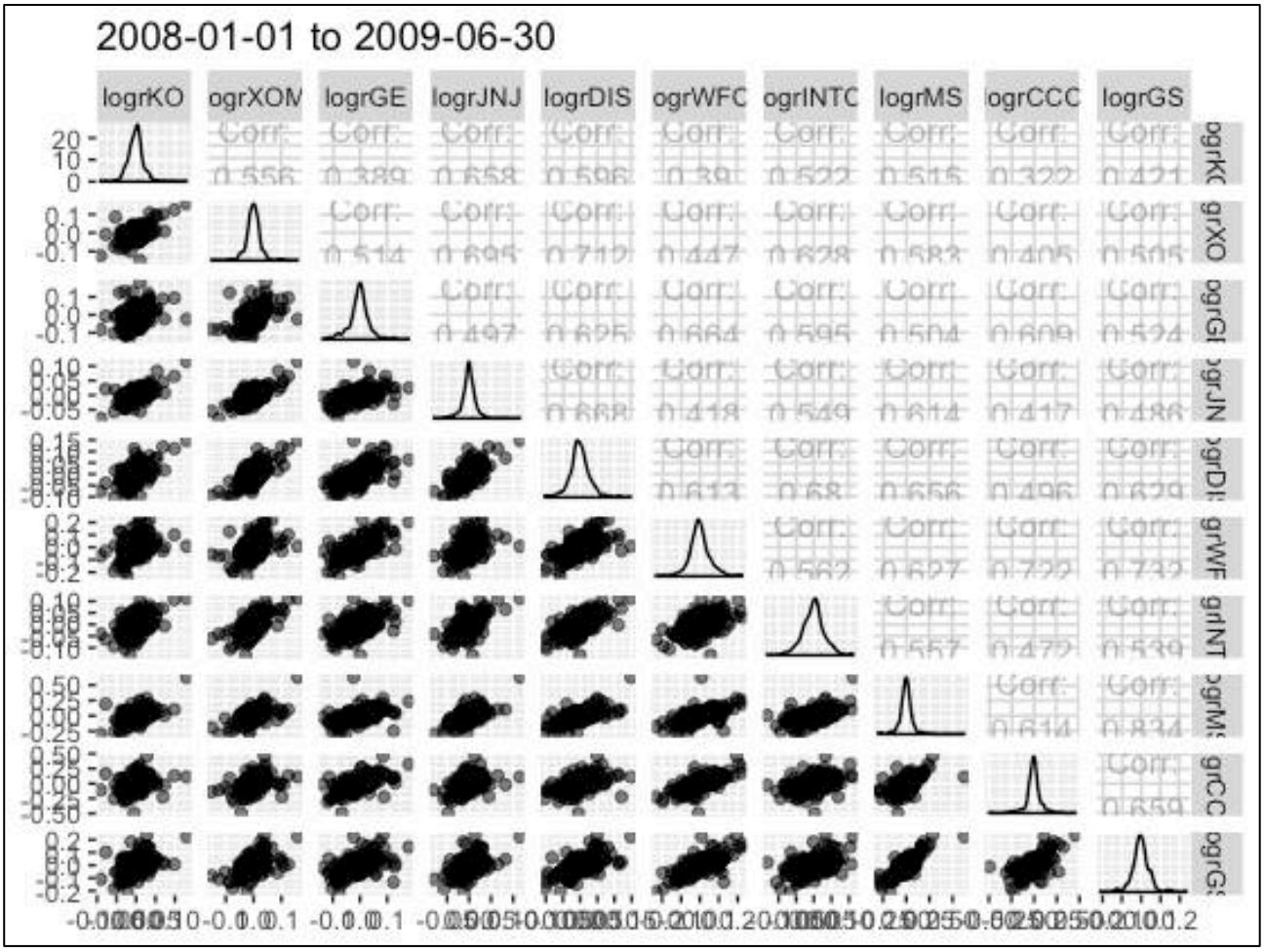
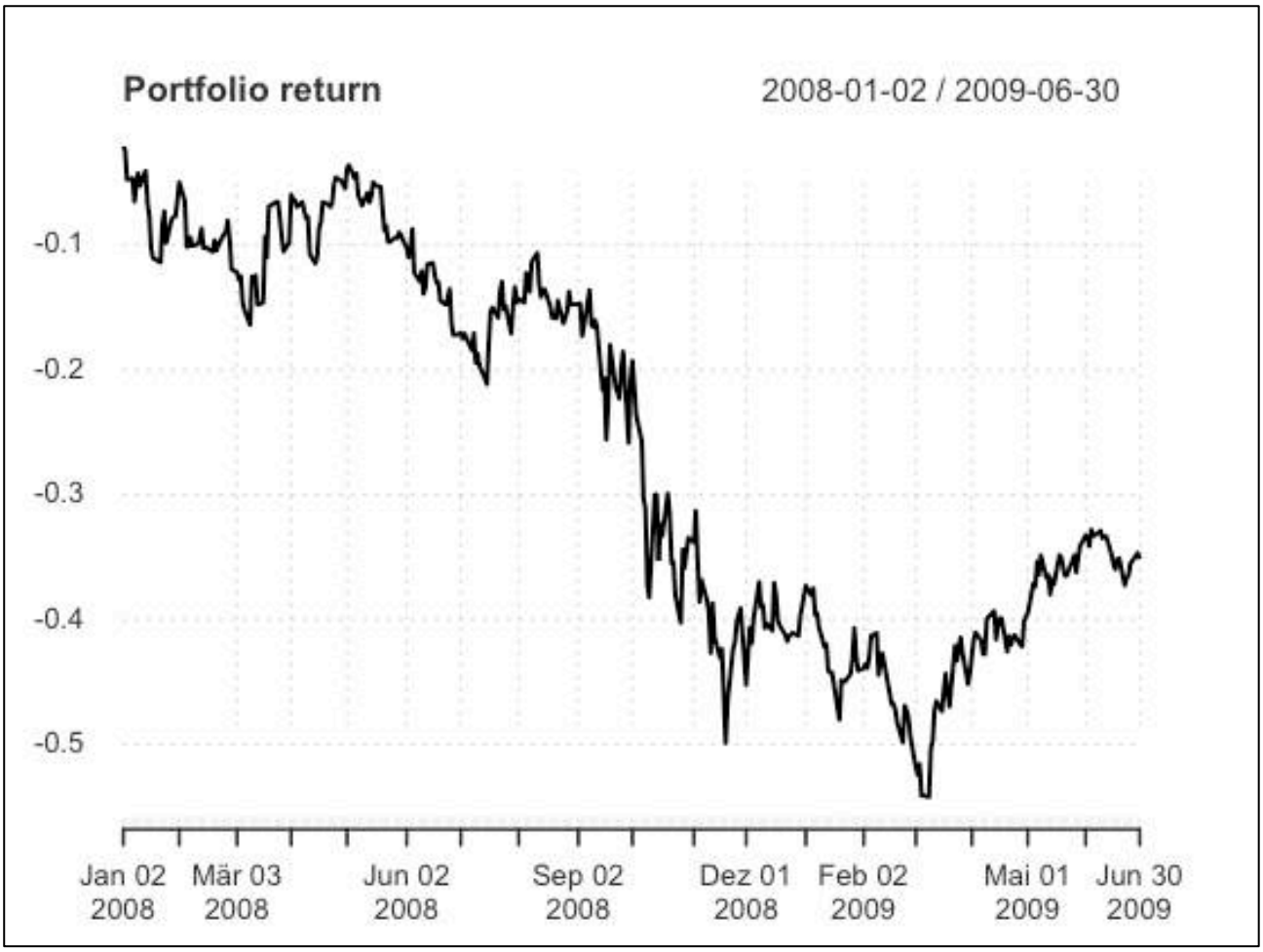
CCC

- Period during the crisis (2008-01-01 to 2009-06-30)




Portfolio return
2008-01-02 / 2009-06-30
-0.1
-0.2
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-0.4
-0.5
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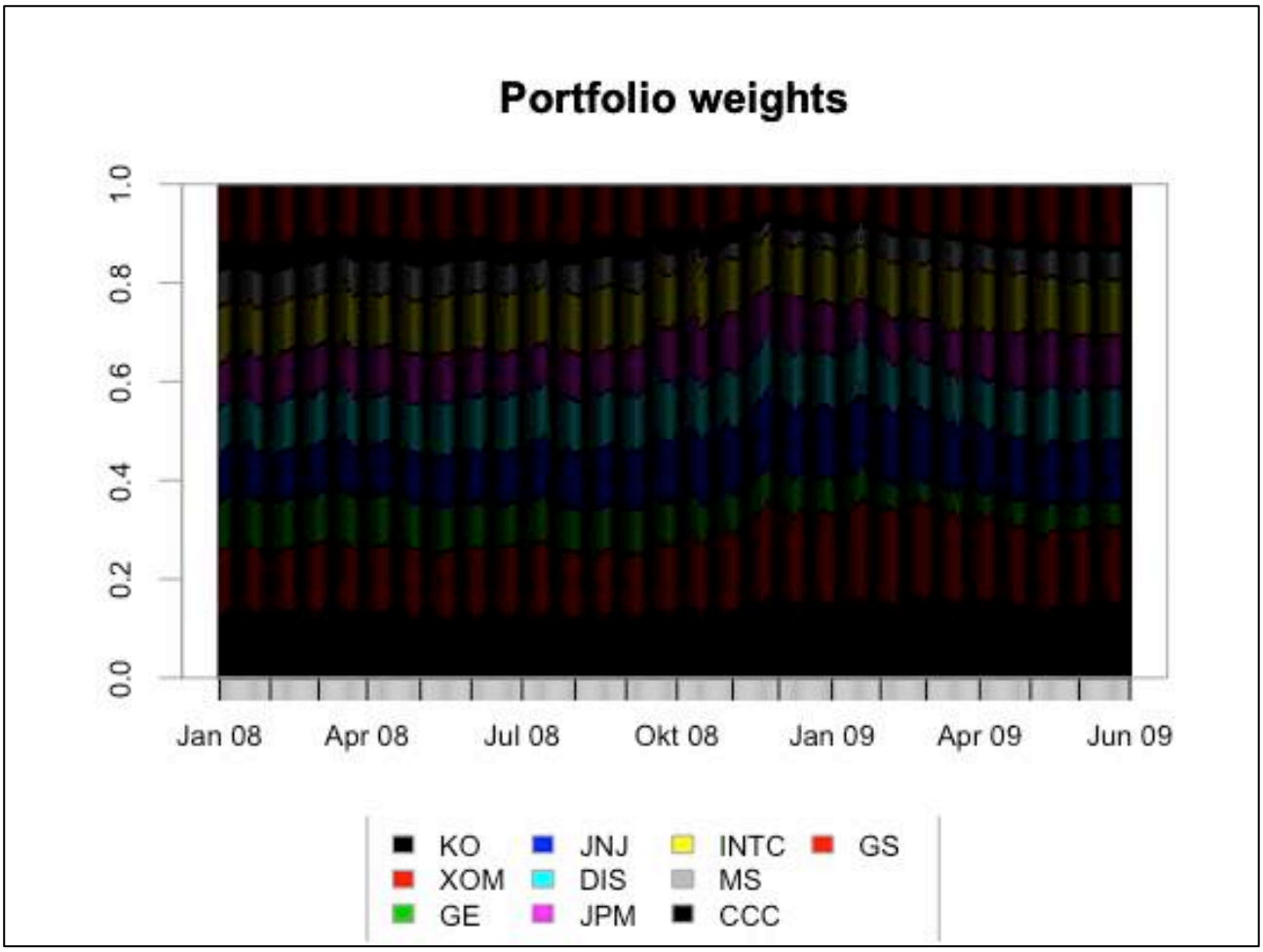
Mär 03 2008
Jun 02 2008
Sep 02 2008
Dez 01 2008
Feb 02 2009
Mai 01 2009
Jun 30 2009


Portfolio weights
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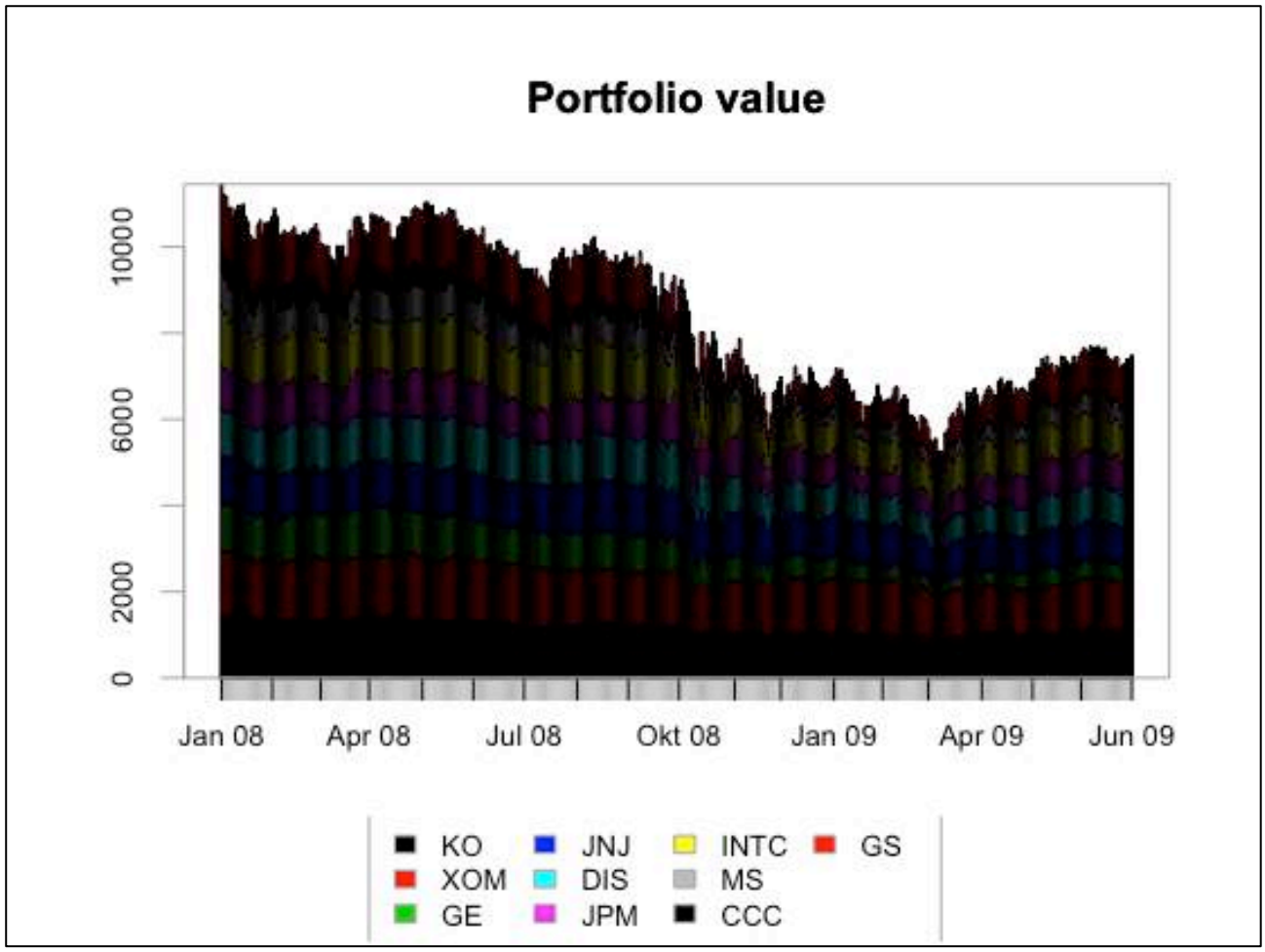
Portfolio value
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