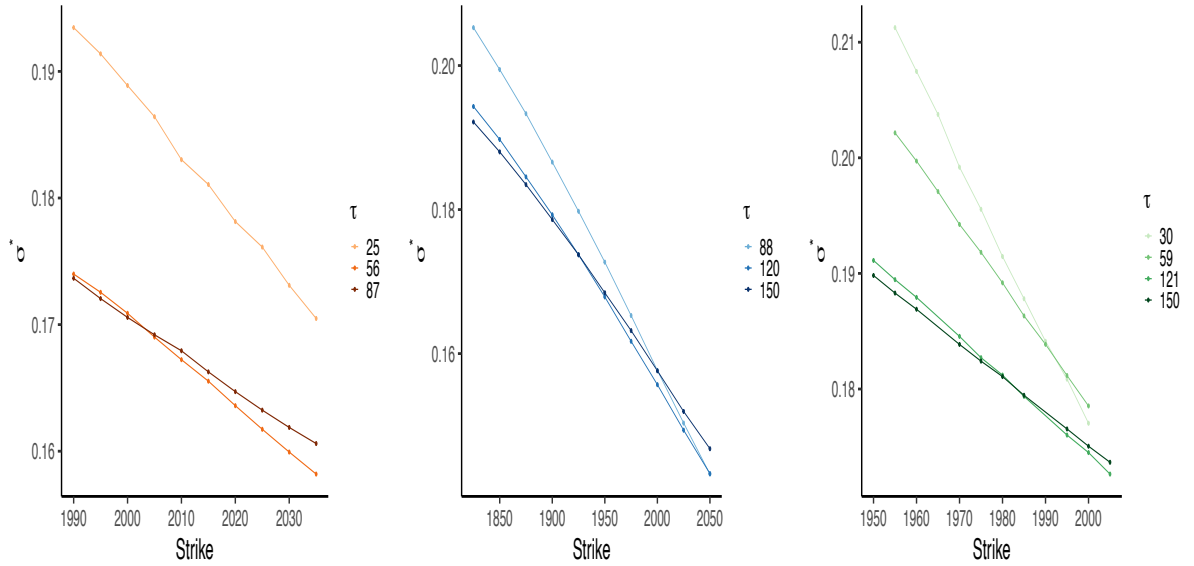
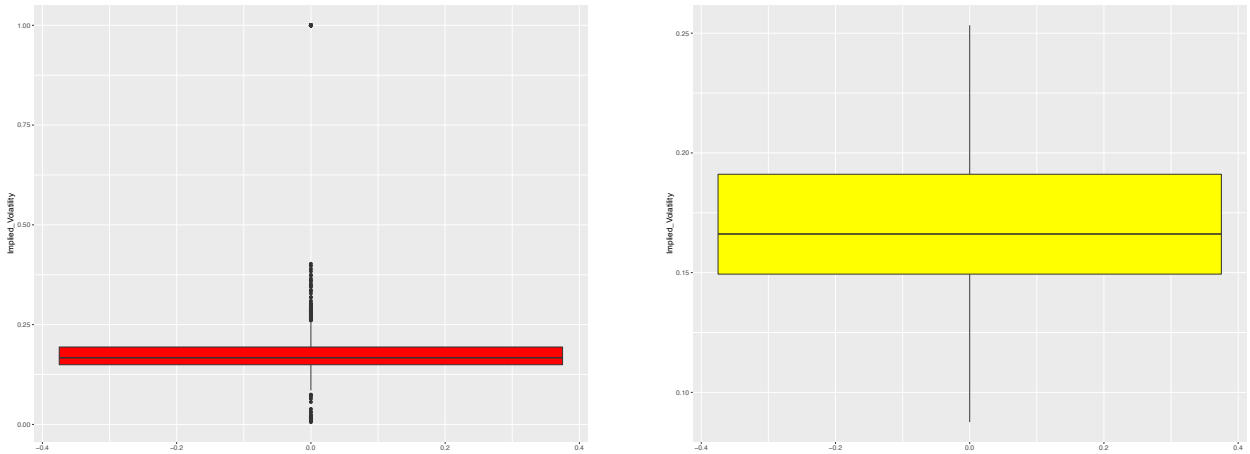
A FIGURES: S&P 500



(a) Skew as of Jan. 04 **(b)** Skew as of Feb. 01 **(c)** Skew as of Mar. 01

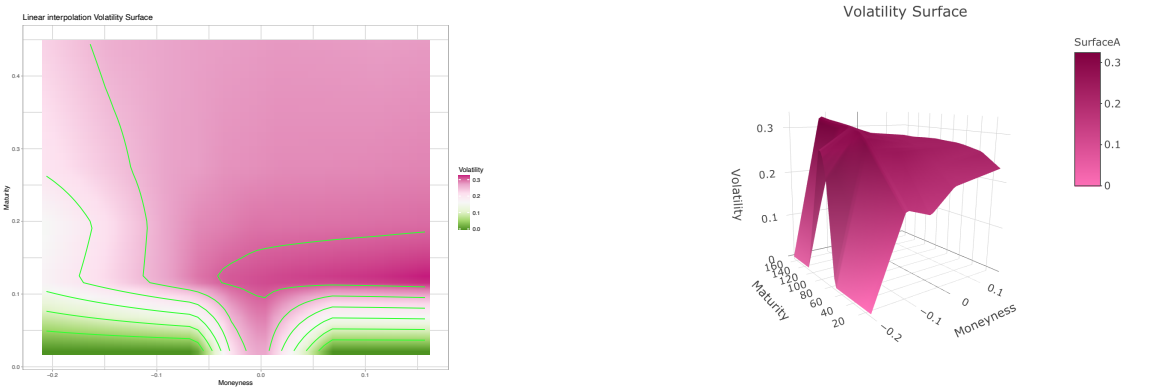
Figure A.1: Different volatility skews for the S&P500



(a) With outliers **(b)** Without outliers

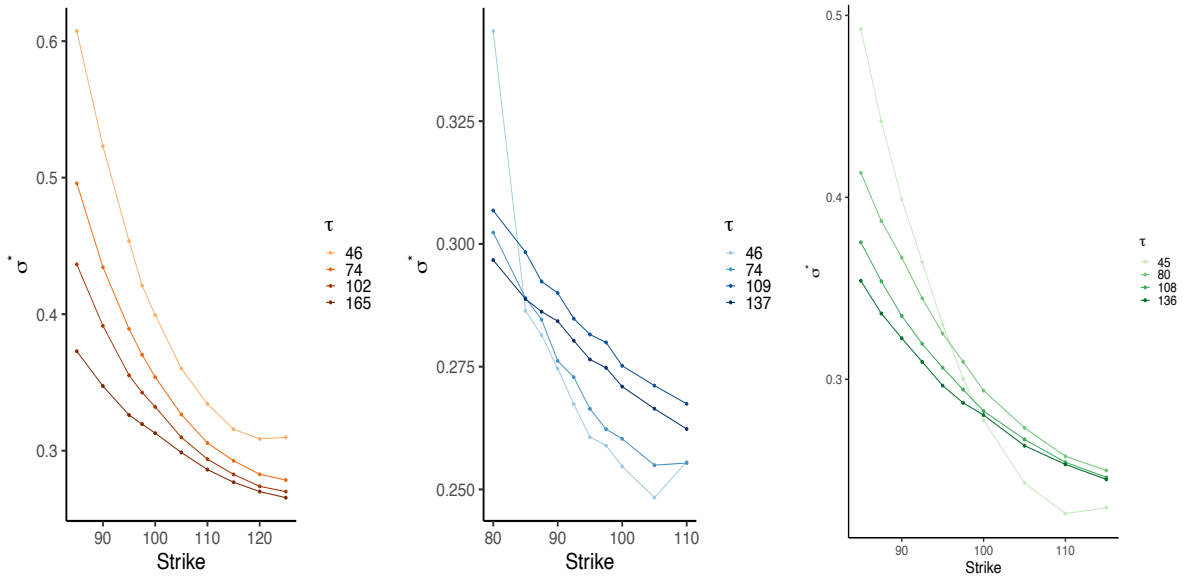
Figure A.2: Handgling outliers comparison

B FIGURES: APPLE



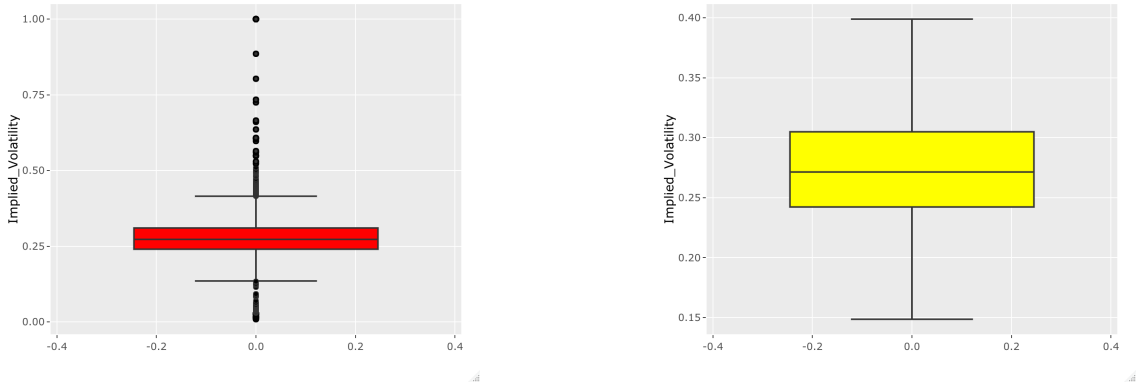
(a) Volatility Surface Contour plot **(b)** Volatility Surface 3D plot

Figure B.1: Volatility Surface: No moneyness adjustment



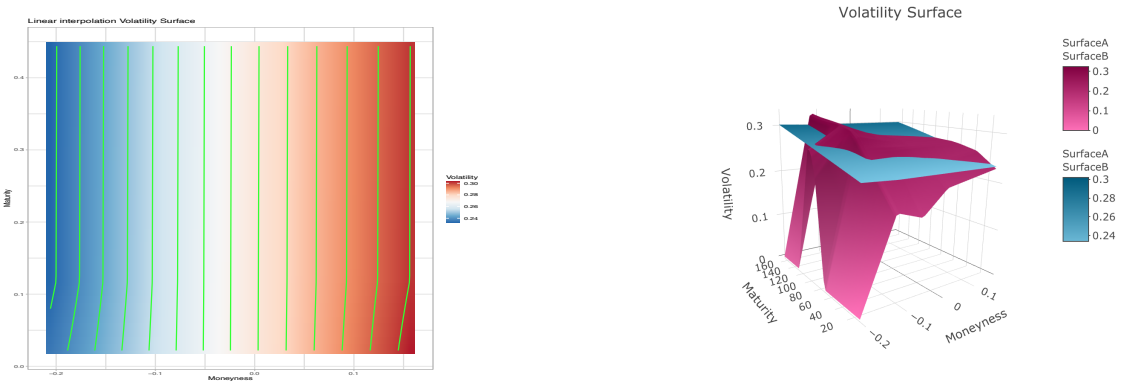
(a) Skew as of Jan. 04 **(b)** Skew as of Feb. 01 **(c)** Skew as of Mar. 01

Figure B.2: Different volatility skews for the S&P500



(a) With outliers **(b)** Without outliers

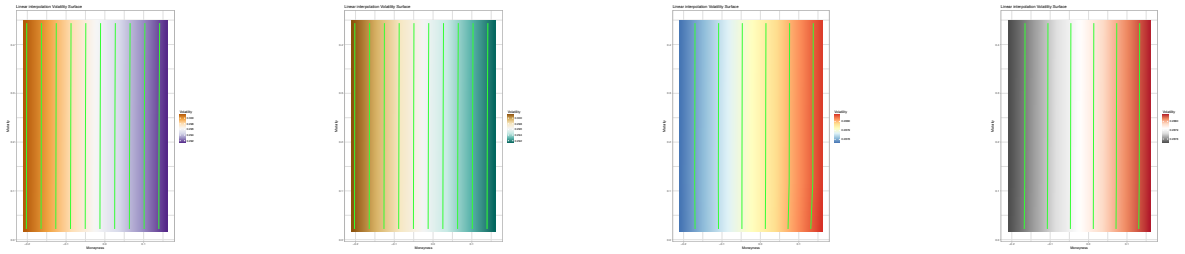
Figure B.3: Handling outliers comparison



(a) Volatility Surface: Moneyness Adjusted

(b) Volatility Surface 3D Comparison

Figure B.4: Moneyness adjusted volatility surface comparison



(a) OLS: P=0 **(b)** SUR: P=0 **(c)** OLS: P=2.75 **(d)** SUR: P=2.75

Figure B.5: Comparison of the volatility surfaces

C OTHER FIGURES

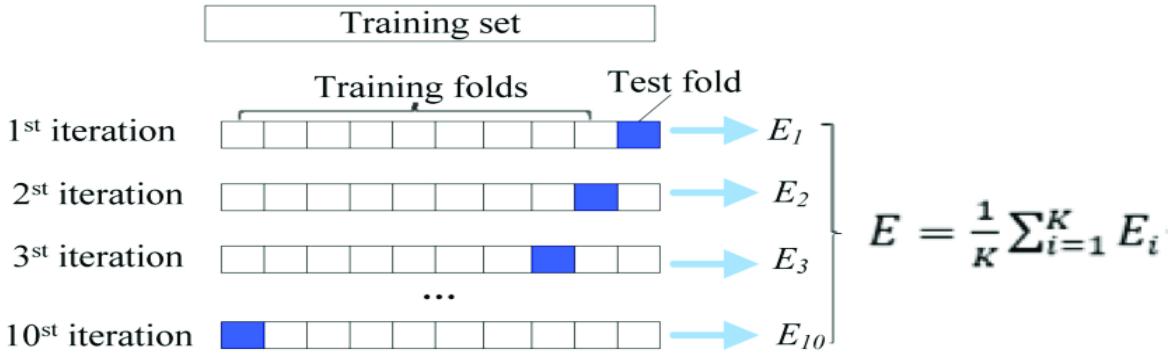


Figure C.1: 10-Fold Cross Validation [19]

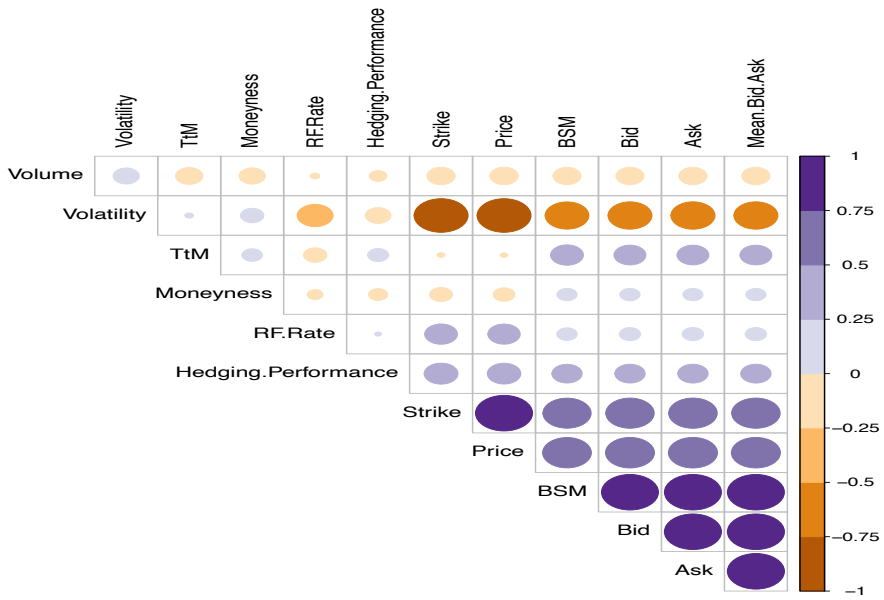
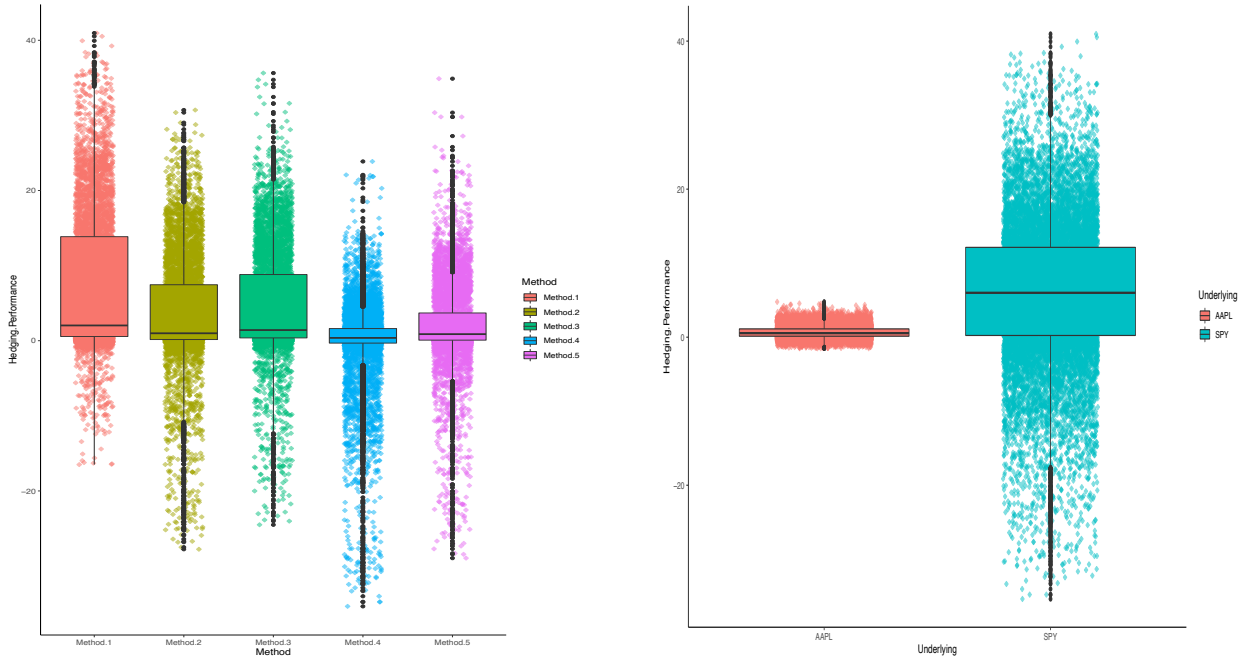


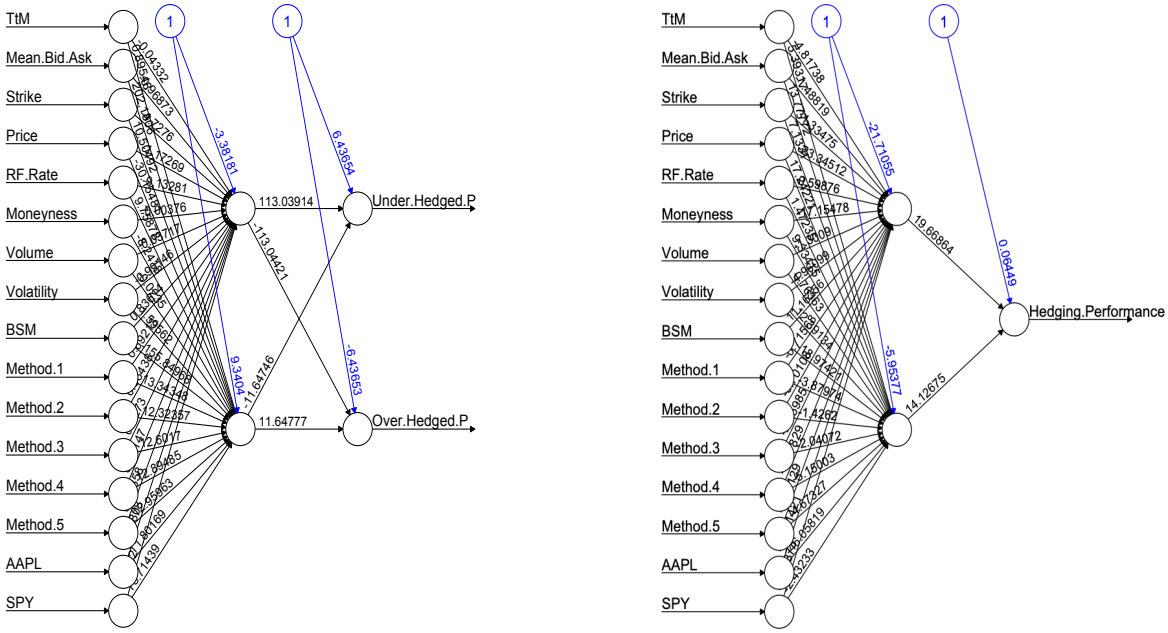
Figure C.2: Correlogram

[19] Niu, M., Li, Y., Wang, C. & Han, K. (2018). RFAmyloid: A Web Server for Predicting Amyloid Proteins. *International journal of molecular sciences.* 19.



(a) Methods **(b)** Underlying

Figure C.3: Boxplots of ε_T for the method and the underlying used.



(a) Categorical prediction **(b)** Continuous prediction

Figure C.4: Representation of artificial neural network for categorical and continuous independent variable prediction.

D ADDITIONAL EQUATIONS

$$MSE = \frac{\sum_{i=1}^{k}\sum_{j=1}^{n_i}(Y_{ij} - \overline{Y})^2 - \sum_{i=1}^{k} n_i(\overline{Y}_{i\bullet} - \overline{Y})^2}{n-k} \quad \textbf{Equation D.1a.}$$

$$MST = \frac{\sum_{i=1}^{k} n_i(\overline{Y}_{i\bullet} - \overline{Y})^2}{k-1} \quad \textbf{Equation D.1b.}$$

Given 2 variables X_1 and X_2, the pearson correlation coefficient is given by:

$$\rho(X_1, X_2) = \frac{Cov(X_1, X_2)}{\sigma_{X_1}\sigma_{X_2}} \quad \textbf{Equation D.2.}$$

Where $Cov(X_1, X_2)$ is the covariance between X_1 and X_2 and where σ_{X_i} is the standard deviation of the considered variable.

Given a set of estimated variable $\hat{y}$ and a set of corresponding independent variable y, both of length n, the mean square error and the root mean square error are given by the following equations:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2 \quad \textbf{Equation D.3a.}$$

$$RMSE = \sqrt{MSE} \quad \textbf{Equation D.3b.}$$

Following [24], scaling data is the same as transforming a random variable Y into a standard normal random variable Z using the following equation:

$$Z = \frac{Y - \mu}{\sigma} \quad \textbf{Equation D.4.}$$

Where μ is the sample mean and σ is the sample standard deviation.

E ADDITIONAL TABLES

	TtM	Bid	Ask	Mean.Bid.Ask	Strike	Price	RF.Rate	Moneyness	Volume	Volatility	BSM	HP
TtM	1	0.308	0.306	0.307	-0.018	-0.016	-0.164	0.125	-0.224	0.021	0.327	0.133
Bid	0.308	1	0.999	0.999	0.717	0.734	0.135	0.122	-0.238	-0.589	0.997	0.279
Ask	0.306	0.999	1	0.999	0.721	0.738	0.137	0.12	-0.239	-0.593	0.997	0.279
Mean.Bid.Ask	0.307	0.999	0.999	1	0.719	0.736	0.136	0.121	-0.238	-0.591	0.997	0.279
Strike	-0.018	0.717	0.721	0.719	1	0.999	0.325	-0.156	-0.241	-0.893	0.711	0.348
Price	-0.016	0.734	0.738	0.736	0.999	1	0.32	-0.142	-0.243	-0.892	0.728	0.341
RF.Rate	-0.164	0.135	0.137	0.136	0.325	0.32	1	-0.076	-0.026	-0.39	0.125	0.012
Moneyness	0.125	0.122	0.12	0.121	-0.156	-0.142	-0.076	1	-0.209	0.164	0.121	-0.111
Volume	-0.224	-0.238	-0.239	-0.238	-0.241	-0.243	-0.026	-0.209	1	0.204	-0.238	-0.092
Volatility	0.021	-0.589	-0.593	-0.591	-0.893	-0.892	-0.39	0.164	0.204	1	-0.584	-0.198
BSM	0.327	0.997	0.997	0.997	0.711	0.728	0.125	0.121	-0.238	-0.584	1	0.277
HP	0.133	0.279	0.279	0.279	0.348	0.341	0.012	-0.111	-0.092	-0.198	0.277	1

Table E.1: Correlation matrix (HP = Hedging Performance)

Nodes	Threshold					
	0.05	0.06	0.07	0.08	0.09	0.1
1	83.25%	83.25%	83.15%	83.04%	83.04%	83.04%
2	84.31%	83.52%	83.83%	83.73%	82.78%	85.16%
3	84.26%	83.41%	87.97%	85.21%	86.65%	84.84%
4	89.03%	87.92%	88.71%	86.27%	87.92%	88.07%
5	86.16%	86.00%	90.04%	NC	89.56%	87.44%

Table E.2: Accuracy for the hyper parameter optimization

Where a bad accuracy (below 85%) is in light red, a fair accuracy is in orange (between 85% and 87%) and a good accuracy is in green (higher than 87%).

Nodes	Threshold					
	0.05	0.06	0.07	0.08	0.09	0.1
1	1’50"	1’24"	1’22"	1’13"	0’32"	1’09"
2	5’44"	3’38"	1’29"	2’20"	0’54"	2’23"
3	3’09"	1’34"	7’03"	2’22"	4’23"	0’19"
4	8’34"	15’28"	13’04"	5’37"	55’13"	20’52"
5	1’8"	13’46"	5’7"	3:52’12"	20’35"	4’29"

Table E.3: Time taken for the algorithm to print a result

Where a good time is below 5 minutes in green, between 5 minutes and 10 minutes in orange and higher than 10 minutes in light red.

Given the fact that growing the training size would increase the time consumption exponentially for a lot of nodes in the hidden layer, we decided to select the pair (2,0.1).

	k-Fold									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Accuracy	83.19%	84.24%	84.46%	84.46%	83.31%	84.43%	84.77%	84.94%	84.02%	83.97%
TtR	31’20"	32’19"	38’56"	44’19"	33’36"	50’01"	47’43"	28’36"	34’32"	25’39"

Table E.4: 10-fold cross validation for *Hedge.Type* prediction

Where *TtR* is the time to run the algorithm.

	k-Fold									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MSE	24.53	27.48	26.55	28.31	25.70	22.63	25.75	24.74	27.27	28.63
RMSE	4.95	5.24	5.15	5.32	5.07	4.76	5.07	4.97	5.22	5.35
TtR	1:45’36"	1:05’24"	54’40"	1:21’36"	1:01’48"	2:51’36"	1:28’12"	1:22’48"	18’55"	1:24’36"

Table E.5: 10-fold cross validation for *Hedging.Performance* prediction

F R PACKAGES DESCRIPTION

In order to plot numerous of our graphs, we wrote a code in the R software. The advantage of this software is the fact that it is open source and that people can write functions in built-in packages. We will here list the packages we used as well as the functions of each package we used that are not included in the basic R software.

- *ggplot2*: Package used to plot all our graphs. The package can be found in the following link: `https://www.rdocumentation.org/packages/ggplot2`.
- *cowplot* : Package used to plot several graphs to get a clearer view. The package can be found in the following link: `https://www.rdocumentation.org/packages/cowplot`.
- *plotly* : Package used to plot interactive graphs such as the ones in the greeks application. The package can be found in the following link: `https://www.rdocumentation.org/packages/plotly`.
- *gridExtra* : Package used to serve the same purpose as the *cowplot* package. The package can found in the following link: `https://www.rdocumentation.org/packages/gridExtra`.
- *reshape2*: Package used for the *melt* function, that converts a high dimensional data frame into a lower dimensional data frame. The package can be found in the following link: `https://www.rdocumentation.org/packages/reshape2`.
- *moments*: Package used to compute the kurtosis and skewness of a data set. The package can be found in the following link: `https://www.rdocumentation.org/packages/moments`.
- *quantmod*: Package used in order to retrieve financial data from Yahoo Finance through the *getSymbols()* function. The package can be found in the following link: `https://www.rdocumentation.org/packages/quantmod`.
- *NlcOptim*: Package used to compute the optimization for the implied volatility. The package can be found in the following link: `https://www.rdocumentation.org/packages/NlcOptim`.
- *readxl*: Package used to read excel files in R. The package can be found in the following link: `https://www.rdocumentation.org/packages/readxl`.

- *svMisc*: Package used to show a progress bar in some for loops of the code. The package can be found in the following link: `https://www.rdocumentation.org/packages/svMisc`.
- *inflection*: Package used to compute the inflection point of a set of points. The package can be found in the following link: `https://www.rdocumentation.org/packages/inflection`.
- *Hmisc*: Package used to get a subplot of the current plot. The package can be found in the following link: `https://www.rdocumentation.org/packages/Hmisc`.
- *dplyr*: Package used for numerous data manipulation. The package can be found in the following link: `https://www.rdocumentation.org/packages/dplyr`.
- *stats*: Package used for computing the quantiles for outliers handling. The package can be found in the following link: `https://www.rdocumentation.org/packages/stats`.
- *DescTools*: Same purpose as the *stats* package. The package can be found in the following link: `https://www.rdocumentation.org/packages/DescTools`.
- *tseries*: Package used to build time series data. The package can be found in the following link: `https://www.rdocumentation.org/packages/tseries`.
- *corrplot*: Package used for the correlogram. The package can be found in the following link: `https://www.rdocumentation.org/packages/corrplot`.
- *RColorBrewer*: Package used for the degraded colors in some plots. The package can be found in the following link: `https://www.rdocumentation.org/packages/RColorBrewer`.
- *neuralnet*: Package used for the *neuralnet* function that computed the artifical neural network algorithm. The pacakge can be found in the following link: `https://www.rdocumentation.org/packages/neuralnet`.
- *viridis*: Package used for the 3D plotting. The package can be found in the following link: `https://www.rdocumentation.org/packages/viridis`.
- *systemfit*: Package used for computing the SUR. The package can be found in the following link: `https://www.rdocumentation.org/packages/systemfit/versions/1.1-24`