Financial Risk Management

Finance 530Q, Spring 2020

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Team Assignment 1: The Risk of Two Mutual Funds

This assignment concerns the risk of two mutual funds. These are real life mutual funds. Their names are not provided. Just call them Fund X and Fund L. In the case of Fund X, we have its daily log returns from 2013 until 2017, as well as the fund holdings as of Oct 31, 2017. In the case of Fund L, we only have its fund holdings as of Dec 31, 2017. Our task is to provide estimates of their risk, in terms of VaR and ES.

Part 1: Mutual Fund X

Fund X began operating on Jan 31, 2013. Exhibit 1 provides the key parts of the fund's prospectus. The strategy of the fund is to invest in long ("purchased") and short ("written") positions in call and put options in the S&P 500 futures contract.

Exhibit 2 has the portfolio's investments as of Oct 31, 2017 (extracted from the fund's annual report). In addition to options, the fund has a cash position $628,226,078.

As risk managers, we know that the values of options depend of the price of the underlying S&P 500 futures contracts, as well as their implied volatilities. To access the risk of this mutual fund, we want to know, how much investors may lose if the S&P futures price changed, and if the implied volatilities of the options changed.

Ultimately, the question we want to answer is this: can investors lose 100% of their investments over a very short period of time (such as 1 day or 1 week)?

Directions:

Question 1: The file, MQM530-TeamAssignment1-logret.csv, contains the daily log returns of the fund from its inception date on Jan 31, 2013, until Oct 31, 2017. Analyze the log returns. What is your estimate of the 1-day 95% VaR and ES? Justify your answer.

Question 2: The fund holdings on Oct 31, 2017 are given in Exhibit 2, and in the file MQM530-TeamAssignment1-fund_holdings.csv. The last column, labelled 'r', is the tbill rate whose maturity date is closest to the option's maturity.

Determine the implied volatility of each option in Exhibit 2. You can use the R script in Exhibit 3 to calculate the prices and implied volatilities of these options, based on Black's pricing model for European-style options on futures contract. [For the purposes of this assignment, we will ignore the fact that the S&P 500 futures options are American-style.]

The CME futures prices of the S&P Index Futures contracts are in two files:

ESZ2017.csv contains the settlement prices for the Dec 2017 contract
ESH2018.csv contains the settlement prices for the Mar 2018 contract

Please note that each S&P futures option is written on 1 S&P futures contract. These S&P futures contract are the "full size" contracts, i.e., they are $250 times the S&P 500 index. [The "mini" S&P futures contract is 1/5 the size of the "full size" contract, i.e., $50 times the S&P 500 index.]

Is there a "volatility skew", i.e., do options at lower strike prices have higher implied volatilities than options at higher strike prices?

Question 3: Perform the following scenario analysis. Suppose the implied volatility of all options increase by 50%, 100%, 200%, or 300% on Nov 1, 2017, what happens to the value of the fund's investments, assuming everything else remains unchanged? How high will the implied volatilities have to rise to reduce the value of the fund (cash + market value of options) by 50%? Can you give any evidence regarding if this type of increase in implied volatility is possible? What other factor(s), besides the implied volatilities of options, would you take into consideration for your scenario analysis?

Exhibit 1: Fund Prospectus

Investment Objective: The Fund seeks capital appreciation and capital preservation with low correlation to the broader U.S. equity market.

Principal Investment Strategies: Under normal circumstances, the Fund invests primarily in purchased (aka "long") and sold (aka "short") call and put options on Standard & Poor's 500 Futures Index ("S&P").

The Fund seeks to achieve its investment objectives by capturing gains on options sold on S&P futures contracts that can be purchased ("closed") at a later date for a lower price than the price realized when originally sold. Excess cash is normally invested in a money market fund. In addition, the Fund may enter into overnight repurchase agreements with excess monies against which it pays interest to the Fund. In the aggregate, the Fund is typically "net short" in the portfolio of contracts that it holds, which means that the Fund holds more uncovered option contracts than covered. The definition of a covered option contract is when a purchased or "long" contract mitigates the exposure of a purely sold or "short" contract. The Fund will engage in active trading.

The Fund opportunistically invests where option pricing provide favorable risk/reward models and where gains can be attained independent of the direction of the broader U.S. equity market. The Fund uses quantitative models and analysis of historical portfolio profit and loss information to identify favorable option trading opportunities, including favorable call and put option spreads. The Fund's investment strategy also takes into account fundamental business and macroeconomic factors. However, the Fund employs a discretionary trading model, and outputs from these quantitative models influence but do not dictate investment decisions.

The Fund employs a variety of derivatives trading strategies to pursue its objectives, including buying (long) and selling (short) "out of the money" call and put options on S&P futures contracts. The Fund may employ additional call spreads during periods of S&P appreciation or additional put spreads during periods of S&P decline. The Fund's portfolio may include long or short S&P futures contracts to adjust risk exposure. In periods subsequent to significant gains in the S&P 500 cash markets, the Fund may assume greater risk through the selling of short call option premiums. The Fund aims to preserve capital, particularly in down markets (including major market drawdowns), through using put option spreads as a form of mitigation risk. Option positions are held until either they expire or are liquidated to either capture gains as option expirations approach or to adjust positions to reduce or prevent losses and to take other potentially profitable positions.

Quantitative Modeling. The Adviser uses mathematic analytics and modeling of equity index options relative to implied volatility; and models historical realized volatility against implied volatility to seek inefficiencies in options pricing. Quantitative modeling is useful in furthering understanding of volatility conditions and trends. The Adviser's quantitative model uses historical stock market volatility to serve as an input to determine relative value among call

and put options. As discussed above, all outputs from these quantitative models influence but do not dictate investment decisions.

The Fund employs a variety of derivatives trading strategies to pursue its objectives, including buying ("long") and selling ("short") "out of the money" call and put options on the S&P Futures Index. These strategies include:

- *S&P Bear Call Spreads*. A call option is "out of the money," when its strike price is higher than the market price of the underlying futures contract. A bear call spread consists of selling a call and buying another call, the second having a higher strike price is therefore being less expensive than the one sold. If a bear call spread is not closed prior to expiration, the trade will be profitable if the current price of the S&P is below the strike price of the sold call when the spread expires. If the S&P rises above the strike price of the sold call at expiration, the trade may produce a loss.
- *S&P Bull Call Spreads.* A call option is purchased nearer the S&P Futures Index and a second call option simultaneously sold further "out of the money". The cost of executing a bull call spread is the difference between the pricing of the long call contract which is purchased and the short call contract which is sold. The bull call spread profits if the S&P moves above the strike price of the purchased call, less the net cost of the spread. Profits are constrained to the difference between the strike prices of the long call and the short call, less the net cost of the spread.
- *S&P Bear Put Spreads.* A put option is purchased nearer the S&P Futures Index and a second put option simultaneously sold further "out of the money". The cost of executing a bear put spread is the difference between the pricing of the purchased put contract and the sold put contract. The bear put spread profits if the S&P falls below the strike price of the purchased put, less the net cost of the spread. Profits are constrained to the difference between the strike prices of the purchased put and the sold put, less the net cost of the spread. This trade is typically used to mitigate risk to falling equity markets.

- *S&P Bull Put Spreads*. A put option is "out of the money" when its strike price is below the market price of the underlying futures contract. A bull put spread consists of selling a put nearer the S&P Futures Index and simultaneously buying another put, which has a lower strike price and is therefore less expensive than the one sold. If a put spread is not closed prior to expiration, the trade will be profitable if the current price of the S&P is above the strike price of the sold put when the spread expires. If the S&P falls below the strike price of the sold put at expiration, the trade may produce a loss.
- *S&P Strangles.* An "out of the money" call contract and an "out of the money" put contract are simultaneously sold resulting in premium placed in the Fund's cash account. An S&P strangle profits when the S&P index, at expiration, closes between the strike prices of the short call and the short put, plus net premium collected. Losses are experienced if the S&P, at expiration, is higher than the call strike price plus premium collected, or, is below the put strike price less premium collected. Losses on S&P strangles are theoretically unlimited if the market moves higher than the call strike, and are limited to the difference between the put strike less and zero, less premium collected.
- *Uncovered ("Naked") Call Selling.* "Out of the money" S&P call contracts are sold. Profits are derived if the S&P index, at expiration, closes below the strike price plus net premium collected. Profits are constrained to total premium collected. Losses occur if the S&P market, at

expiration, closes above the strike price plus net premium collected. Losses are theoretically unlimited.

- *Uncovered ("Naked") Put Selling.* "Out of the money" S&P put option contracts are sold. Profits are derived if the S&P index, at expiration, closes above the strike price minus net premium collected. Profits are constrained to total premium collected. Losses occur if the S&P market, at expiration, closes below the strike price less net premium collected. Losses are limited to the difference between the strike price and zero (times the index multiplier) less premium received.
- *Purchase of Long Put contracts.* "Out of the money" S&P put contracts are purchased. Profits are derived if the S&P index, at expiration, closes below the strike price minus the net premium paid. Losses are constrained to the cost of the long put contracts.
- *Purchase of Long Call contracts.* "Out of the money" S&P call contracts are purchased. Profits are derived if the S&P index, at expiration, closes above the strike price minus the net premium paid. Losses are constrained to the cost of the long call contracts.

Fees and Expenses of the Fund:

Shareholder Fees (fees paid directly from your investment)	**Amount**
Maximum Sales Charge (Load) Imposed on Purchases (as a % of offering price)	None
Maximum Deferred Sales Charge (Load) (as a % of original purchase price)	None
Maximum Sales Charge (Load) Imposed On Reinvested Dividends and other Distributions	None
Redemption Fee (as a % of amount redeemed within 90 days of purchase)	1.00%
Annual Fund Operating Expenses (expenses that you pay each year as a percentage of the value of your investment)	
Management Fee	1.95%
Distribution and Service (12b-1) Fees	1.00%
Other Expenses	0.27%
Acquired Fund Fees and Expenses[1]	0.12%
Total Annual Fund Operating Expenses	3.34%
Fee Waiver and/or Reimbursement[2]	(0.10)%
Total Annual Fund Operating Expenses After Fee Waiver and or Reimbursement	3.24%

Exhibit 2. Portfolio of Investments, October 31, 2017

Constracts		Option Expiration Date	Exercise Price	Futures Maturity Month	Option Price	Market Value
	PUT OPTIONS PURCHASED					
245	S&P 500 Index Future	11/20/2017	2,545	Dec-17	9.60	588,000
250	S&P 500 Index Future	11/20/2017	2,535	Dec-17	8.10	506,250
250	S&P 500 Index Future	11/20/2017	2,525	Dec-17	6.90	431,250
249	S&P 500 Index Future	11/30/2017	2,555	Dec-17	16.60	1,033,350
251	S&P 500 Index Future	12/15/2017	2,535	Dec-17	19.20	1,204,800
257	S&P 500 Index Future	12/15/2017	2,525	Dec-17	17.40	1,117,950
252	S&P 500 Index Future	12/15/2017	2,515	Dec-17	15.80	995,400
253	S&P 500 Index Future	12/15/2017	2,505	Dec-17	14.30	904,475
400	S&P 500 Index Future	12/15/2017	2,435	Dec-17	7.90	790,000
250	S&P 500 Index Future	12/15/2017	2,485	Dec-17	12.00	750,000
244	S&P 500 Index Future	12/15/2017	2,475	Dec-17	11.10	677,100
200	S&P 500 Index Future	12/15/2017	2,495	Dec-17	13.00	650,000
510	S&P 500 Index Future	12/29/2017	2,425	Mar-18	10.10	1,287,750
	TOTAL PUT OPTIONS PURCHASED					10,936,325
	CALL OPTIONS PURCHASED					
249	S&P 500 Index Future	11/30/2017	2,595	Dec-17	9.90	616,275
260	S&P 500 Index Future	12/15/2017	2,575	Dec-17	28.10	1,826,500
254	S&P 500 Index Future	12/15/2017	2,605	Dec-17	12.80	812,800
254	S&P 500 Index Future	12/15/2017	2,615	Dec-17	9.40	596,900
255	S&P 500 Index Future	12/29/2017	2,625	Mar-18	10.20	650,250
255	S&P 500 Index Future	12/29/2017	2,635	Mar-18	7.70	490,875
255	S&P 500 Index Future	12/29/2017	2,645	Mar-18	5.80	369,750
	TOTAL CALL OPTIONS PURCHASED					5,363,350
	Cash					628,226,078
	PUT OPTIONS WRITTEN					
239	S&P 500 Index Future	11/20/2017	2,060	Dec-17	0.10	5,975
250	S&P 500 Index Future	11/20/2017	2,020	Dec-17	0.10	6,250
230	S&P 500 Index Future	11/20/2017	2,100	Dec-17	0.15	8,625
589	S&P 500 Index Future	11/20/2017	2,140	Dec-17	0.20	29,450
525	S&P 500 Index Future	11/20/2017	2,160	Dec-17	0.25	32,813
730	S&P 500 Index Future	11/20/2017	2,120	Dec-17	0.20	36,500
479	S&P 500 Index Future	11/20/2017	2,200	Dec-17	0.35	41,913
737	S&P 500 Index Future	11/20/2017	2,180	Dec-17	0.30	55,275
363	S&P 500 Index Future	11/20/2017	2,300	Dec-17	0.70	63,525
718	S&P 500 Index Future	11/20/2017	2,240	Dec-17	0.45	80,775

994	S&P 500 Index Future	11/20/2017	2,220	Dec-17	0.40	99,400
939	S&P 500 Index Future	11/20/2017	2,260	Dec-17	0.50	117,375
896	S&P 500 Index Future	11/20/2017	2,280	Dec-17	0.60	134,400
250	S&P 500 Index Future	11/20/2017	2,460	Dec-17	2.95	184,375
798	S&P 500 Index Future	11/20/2017	2,340	Dec-17	0.95	189,525
667	S&P 500 Index Future	11/20/2017	2,380	Dec-17	1.30	216,775
1,078	S&P 500 Index Future	11/20/2017	2,320	Dec-17	0.85	229,075
490	S&P 500 Index Future	11/20/2017	2,440	Dec-17	2.35	287,875
844	S&P 500 Index Future	11/20/2017	2,400	Dec-17	1.55	327,050
695	S&P 500 Index Future	11/20/2017	2,420	Dec-17	1.90	330,125
1,345	S&P 500 Index Future	11/20/2017	2,360	Dec-17	1.10	369,875
548	S&P 500 Index Future	11/30/2017	2,120	Dec-17	0.45	61,650
373	S&P 500 Index Future	11/30/2017	2,200	Dec-17	0.70	65,275
498	S&P 500 Index Future	11/30/2017	2,160	Dec-17	0.55	68,475
489	S&P 500 Index Future	11/30/2017	2,180	Dec-17	0.60	73,350
509	S&P 500 Index Future	11/30/2017	2,220	Dec-17	0.80	101,800
498	S&P 500 Index Future	11/30/2017	2,260	Dec-17	1.10	136,950
693	S&P 500 Index Future	11/30/2017	2,280	Dec-17	1.25	216,563
538	S&P 500 Index Future	11/30/2017	2,360	Dec-17	2.25	302,625
455	S&P 500 Index Future	11/30/2017	2,380	Dec-17	2.70	307,125
938	S&P 500 Index Future	11/30/2017	2,300	Dec-17	1.40	328,300
750	S&P 500 Index Future	11/30/2017	2,340	Dec-17	1.90	356,250
1,003	S&P 500 Index Future	11/30/2017	2,320	Dec-17	1.65	413,738
943	S&P 500 Index Future	11/30/2017	2,400	Dec-17	3.15	742,613
1,088	S&P 500 Index Future	11/30/2017	2,420	Dec-17	3.75	1,020,000
250	S&P 500 Index Future	12/15/2017	2,100	Dec-17	1.00	62,500
489	S&P 500 Index Future	12/15/2017	2,080	Dec-17	0.90	110,025
505	S&P 500 Index Future	12/15/2017	2,140	Dec-17	1.20	151,500
490	S&P 500 Index Future	12/15/2017	2,160	Dec-17	1.35	165,375
726	S&P 500 Index Future	12/15/2017	2,120	Dec-17	1.10	199,650
552	S&P 500 Index Future	12/15/2017	2,180	Dec-17	1.55	213,900
741	S&P 500 Index Future	12/15/2017	2,220	Dec-17	1.95	361,238
200	S&P 500 Index Future	12/15/2017	2,435	Dec-17	7.90	395,000
744	S&P 500 Index Future	12/15/2017	2,240	Dec-17	2.20	409,200
770	S&P 500 Index Future	12/15/2017	2,260	Dec-17	2.50	481,250
1,245	S&P 500 Index Future	12/15/2017	2,200	Dec-17	1.75	544,687
746	S&P 500 Index Future	12/15/2017	2,300	Dec-17	3.15	587,475
763	S&P 500 Index Future	12/15/2017	2,320	Dec-17	3.55	677,162
1,156	S&P 500 Index Future	12/15/2017	2,280	Dec-17	2.80	809,200
795	S&P 500 Index Future	12/15/2017	2,340	Dec-17	4.10	814,875
252	S&P 500 Index Future	12/29/2017	2,180	Mar-18	2.40	151,200
376	S&P 500 Index Future	12/29/2017	2,140	Mar-18	1.95	183,300
252	S&P 500 Index Future	12/29/2017	2,220	Mar-18	2.95	185,850
254	S&P 500 Index Future	12/29/2017	2,240	Mar-18	3.30	209,550
255	S&P 500 Index Future	12/29/2017	2,260	Mar-18	3.65	232,688

255	S&P 500 Index Future	12/29/2017	2,280	Mar-18	4.10	261,375
504	S&P 500 Index Future	12/29/2017	2,160	Mar-18	2.15	270,900
636	S&P 500 Index Future	12/29/2017	2,200	Mar-18	2.65	421,350
510	S&P 500 Index Future	12/29/2017	2,300	Mar-18	4.65	592,875
	TOTAL PUT OPTIONS WRITTEN					15,533,787
	CALL OPTIONS WRITTEN					
217	S&P 500 Index Future	11/20/2017	2,620	Dec-17	1.35	73,238
1,179	S&P 500 Index Future	11/20/2017	2,610	Dec-17	2.40	707,400
351	S&P 500 Index Future	11/30/2017	2,610	Dec-17	5.00	438,750
783	S&P 500 Index Future	11/30/2017	2,620	Dec-17	3.10	606,825
1,188	S&P 500 Index Future	11/30/2017	2,630	Dec-17	1.95	579,150
735	S&P 500 Index Future	12/15/2017	2,650	Dec-17	3.00	551,250
1,051	S&P 500 Index Future	12/15/2017	2,660	Dec-17	2.20	578,050
540	S&P 500 Index Future	12/15/2017	2,630	Dec-17	5.80	783,000
1,009	S&P 500 Index Future	12/15/2017	2,640	Dec-17	4.10	1,034,225
762	S&P 500 Index Future	12/29/2017	2,670	Mar-18	2.90	552,450
636	S&P 500 Index Future	12/29/2017	2,650	Mar-18	5.00	795,000
1,134	S&P 500 Index Future	12/29/2017	2,660	Mar-18	3.80	1,077,300
255	S&P 500 Index Future	12/29/2017	2,680	Mar-18	2.25	143,438
	CALL OPTIONS WRITTEN					7,920,075

Additional relevant information:

Each futures option is written on one S&P futures contract.

Each futures contract is 250 times the S&P 500 index.

Exhibit 3. Sample R scripts

Use the following R script to find the implied volatility of futures options

```
library(nloptr)

# F is the price of the underlying asset
# X is the strike price of the option
# t is the time to maturity (in years)
# r is the tbill rate (in decimal form)
# sigma is the volatility of the underlying asset
# BFC is the price of the call option
# BFP is the price of the put option
# IVC is the implied volatility of the call option
# IVP is the implied volatility of the put option

BFC <- function(F,X,t,r,sigma) {
  d1 <- log(F/X) + 0.5*sigma^2 *t
  d1 <- d1/(sigma*sqrt(t))
  d2 <- d1 - sigma*sqrt(t)
  N1 <- pnorm(d1)
  N2 <- pnorm(d2)
  C <- exp(-r*t) * (F * N1 - X * N2 )
  return(C)
}

BFP <- function(F,X,t,r,sigma) {
  d1 <- log(F/X) + 0.5*sigma^2 *t
  d1 <- d1/(sigma*sqrt(t))
  d2 <- d1 - sigma*sqrt(t)
  NM1 <- pnorm(-d1)
  NM2 <- pnorm(-d2)
  P <- exp(-r*t) * (X * NM2 - F * NM1 )
  return(P)
}

IVC <- function(F,X,t,r,Call) {
  eval_f_C <- function(sigma) {
    return ( (Call-BFC(F,X,t,r,sigma))^2 )
  }
  opts <- list("algorithm"="NLOPT_LN_COBYLA",
               "xtol_rel"=1.0e-8)
  xs <- 0.10
  es <- nloptr( x0=xs,
                eval_f=eval_f_C,
                opts=opts)
  return(es$solution)
}
```

```
IVP <- function(F,X,t,r,Put) {
  eval_f_P <- function(sigma) {
    return ( (Put-BFP(F,X,t,r,sigma))^2 )
  }
  opts <- list("algorithm"="NLOPT_LN_COBYLA",
               "xtol_rel"=1.0e-8)
  xs <- 0.10
  es <- nloptr( x0=xs,
                eval_f=eval_f_P,
                opts=opts)
  return(es$solution)
}
```

Part 2: Mutual Fund L

Fund L has 15 stocks in its portfolio. The tickers and weights are given in the file:

MQM530-TeamAssignment1-Q2.R

This file also contains R code to generate the daily log returns of this portfolio from 12/31/2012 until 12/31/2017.

Use this daily log return series to answer the following questions:

Question 4: Is the unconditional distribution of the daily log return normal?

Question 5: Is there evidence of conditional volatility?

Question 6: Fit an AR(1)-GARCH(1,1)-t model to the daily log return series. What is the VaR and ES at the 95% level? For this simulation, use:

set.seed(123789)

[Note: if you are using R 3.6.0 or higher, please insert the following command BEFORE the set.seed() command:

RNGkind(sample.kind="Rounding")]

Submission:

Your submission consists of two files uploaded to Canvas.

File 1: PDF file with powerpoint slides.
Slide 1: Your team number and members
Slide 2: Your answer to Question 1, plus a brief explanation.
Slide 3: Your answer to Question 2, plus a brief explanation.
Slide 4: Your answer to Question 3, plus a brief explanation.
Slide 5: Your answers to Questions 4, 5, and 6.

We will discuss randomly selected slide submissions in class.

File 2: One R script with all your calculations for the entire assignment. Please provide comments for each part. For example:
Part 1 – R code for Question 1
Part 2 – R code for Question 2
Part 3 – R code for Question 3
Part 4 – R code for Questions 4, 5, and 6