

## Factor Models

### CAPM

Hypothetical Portfolio of AMZN, TSLA, IBM & MSFT

```
names <- c("AMZN", "MSFT", "TSLA", "IBM")
date.from <- "2010-12-31"; date.to <- "2013-12-31"

getMonthlyReturns <- function(name, from = date.from, to = date.to) {
  prices <- getSymbols(name, from = date.from, to = date.to, auto.assign = F)
  monthly <- to.monthly(prices)
  returns <- Delt(monthly[, 6])[-1]

  ret.data <- data.table(Month = index(returns), Company = name, Return = returns[, 1])
  colnames(ret.data) <- c("Month", "Company", "Return")

  return(ret.data)
}

returns <- data.table::rbindlist(lapply(names, getMonthlyReturns))
```

'getSymbols' currently uses auto.assign=TRUE by default, but will use auto.assign=FALSE in 0.5-0. You will still be able to use 'loadSymbols' to automatically load data. getOption("getSymbols.env") and getOption("getSymbols.auto.assign") will still be checked for alternate defaults.

This message is shown once per session and may be disabled by setting options("getSymbols.warning4.0"=FALSE). See ?getSymbols for details.

```
portfolio <- dcast(returns, Month ~ Company, value.var = c("Return"))

port.return <- data.table(Month = portfolio$Month, Return = rowMeans(portfolio[, 2:4]))
```

### S&P500

```
SPX <- getMonthlyReturns("^GSPC")

rf.data <- data.table::fread(file.path(data.dir, "DGS3MO.csv"))
rf.data$DATE <- as.Date(rf.data$DATE)
rf.data$DGS3MO <- as.numeric(rf.data$DGS3MO)
```

Warning: NAs introduced by coercion

```
rf <- rf.data[DATE >= date.from & DATE <= date.to]

rfm <- to.monthly(rf)
```

Warning in to.period(x, "months", indexAt = indexAt, name = name, ...): missing values removed from data

```
options(scipen="100")
rf.monthly <- (1 + rfm[, 1]/100) ^ (1/12) - 1
colnames(rf.monthly) <- c("RiskFreeRate")
rf.monthly <- rf.monthly[-1]

risk.free <- data.table(index(rf.monthly), Return = rf.monthly$RiskFreeRate)
colnames(risk.free) <- c("Month", "Return")

consolidated <- merge(port.return[, .(Month, Portfolio = Return)],
                      SPX[, .(Month, Market = Return)],
                      by = "Month")
consolidated <- merge(consolidated, risk.free[, .(Month, RiskFree = Return)],
                      by = "Month")

consolidated[, ':='(ExcessReturn = Portfolio - RiskFree,
                    ExcessMarket = Market - RiskFree) ]

consolidated
```

	Month	Portfolio	Market	RiskFree	ExcessReturn
1: Jan 2011	0.0132794123	0.022645574	0.000124914145	0.0131544981	
2: Feb 2011	-0.0036913993	0.031956564	0.000124914145	-0.0038163134	
3: Mar 2011	0.0006840647	-0.001047313	0.000116591872	0.0005674728	
4: Apr 2011	0.0513253768	0.028495380	0.000058314626	0.0512670622	
5: May 2011	-0.0098445165	-0.013500953	0.000041657121	-0.0098861736	
6: Jun 2011	0.0315833871	-0.018257461	0.000041657121	0.0315417300	
7: Jul 2011	0.0673526326	-0.021474426	0.000016665139	0.0673359674	
8: Aug 2011	-0.0354580712	-0.056791107	0.000083295163	-0.0355413663	
9: Sep 2011	-0.0141406939	-0.071761988	0.000016665139	-0.0141573591	
10: Oct 2011	0.0377137981	0.107723039	0.000016665139	0.0376971330	
11: Nov 2011	-0.0364122562	-0.005058715	0.000008332951	-0.0364205891	
12: Dec 2011	-0.0356187107	0.008532764	0.000008332951	-0.0356270437	
13: Jan 2012	0.1027408082	0.043583062	0.000016665139	0.1027241430	
14: Feb 2012	0.0104923704	0.040589464	0.000049986255	0.0104423841	
15: Mar 2012	0.0679901798	0.031332315	0.000066642235	0.0679235376	
16: Apr 2012	0.0433881906	-0.007497453	0.000066642235	0.0433215484	
17: May 2012	-0.0762875615	-0.062650726	0.000074969080	-0.0763625305	
18: Jun 2012	0.0447912002	0.039554982	0.000058314626	0.0447328855	
19: Jul 2012	-0.0042968287	0.012597574	0.000083295163	-0.0043801239	
20: Aug 2012	0.0384608969	0.019763370	0.000083295163	0.0383776017	
21: Sep 2012	0.0182133896	0.024236154	0.000083295163	0.0181300945	
22: Oct 2012	-0.0625128777	-0.019789410	0.000074969080	-0.0625878468	
23: Nov 2012	0.0013367371	0.002846717	0.000074969080	0.0012617680	

24: Dec 2012	0.0021619407	0.007068230	0.000083295163	0.0020786455
25: Jan 2013	0.0487211236	0.050428097	0.000066642235	0.0486544814
26: Feb 2013	0.0032114708	0.011060649	0.000049986255	0.0031614846
27: Mar 2013	0.0332097537	0.035987724	0.000091620484	0.0331181332
28: Apr 2013	0.0196372581	0.018085768	0.000066642235	0.0195706159
29: May 2013	0.0514266848	0.020762812	0.000049986255	0.0513766986
30: Jun 2013	-0.0200225169	-0.014999302	0.000041657121	-0.0200641741
31: Jul 2013	0.0090428675	0.049462080	0.000033327224	0.0090095403
32: Aug 2013	-0.0238695484	-0.031298019	0.000033327224	-0.0239028756
33: Sep 2013	0.0416831168	0.029749523	0.000016665139	0.0416664516
34: Oct 2013	0.0653793902	0.044595753	0.000016665139	0.0653627251
35: Nov 2013	0.0580907722	0.028049472	0.000033327224	0.0580574450
36: Dec 2013	0.0049302797	0.019525801	0.000041657121	0.0048886225

	Month	Portfolio	Market	RiskFree	ExcessReturn
ExcessMarket					
1:		0.022520660			
2:		0.031831650			
3:		-0.001163905			
4:		0.028437066			
5:		-0.013542610			
6:		-0.018299118			
7:		-0.021491091			
8:		-0.056874403			
9:		-0.071778653			
10:		0.107706373			
11:		-0.005067048			
12:		0.008524431			
13:		0.043566397			
14:		0.040539478			
15:		0.031265672			
16:		-0.007564095			
17:		-0.062725695			
18:		0.039496668			
19:		0.012514279			
20:		0.019680075			
21:		0.024152859			
22:		-0.019864379			
23:		0.002771748			
24:		0.006984935			
25:		0.050361454			
26:		0.011010663			
27:		0.035896103			
28:		0.018019126			
29:		0.020712825			
30:		-0.015040959			

```

31:  0.049428753
32: -0.031331346
33:  0.029732858
34:  0.044579087
35:  0.028016144
36:  0.019484143
    ExcessMarket

```

```
CAPM <- lm(ExcessReturn ~ ExcessMarket, data = consolidated)
```

```
summary(CAPM)
```

Call:

```
lm(formula = ExcessReturn ~ ExcessMarket, data = consolidated)
```

Residuals:

	Min	1Q	Median	3Q	Max
	-0.056862	-0.018265	-0.005936	0.025061	0.074152

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	0.007583	0.005552	1.366	0.180956
ExcessMarket	0.670012	0.152960	4.380	0.000108 ***

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.03169 on 34 degrees of freedom

Multiple R-squared: 0.3607, Adjusted R-squared: 0.3419

F-statistic: 19.19 on 1 and 34 DF, p-value: 0.0001075

```
beta <- summary(CAPM)$coefficients[2]
```

```
beta
```

```
[1] 0.6700119
```

```
beta.pval <- summary(CAPM)$coefficients[8]
```

```
beta.pval
```

```
[1] 0.0001075304
```

## Market Model

```
reg <- lm(Portfolio ~ Market, data = consolidated)
```

```
beta.mktmod <- summary(reg)$coefficients[2]
```

```
adj.beta.mktmod <- (2/3)*beta.mktmod+(1/3)*1  
adj.beta.mktmod
```

```
[1] 0.7798934
```

## Rolling Window Regression

### AMZN vs. SPX

```
AMZN <- getSymbols("AMZN", from = date.from, to = date.to, auto.assign = F)  
SPX <- getSymbols("^GSPC", from = date.from, to = date.to, auto.assign = F)
```

```
AMZN.ret <- diff(log(AMZN$AMZN.Close))  
SPX.ret <- diff(log(SPX$GSPC.Adjusted))
```

```
returns <- cbind(AMZN.ret, SPX.ret)  
colnames(returns) <- c("AMZN", "SPX")
```

```
coeffs <- rollapply(returns, width = 252,  
  FUN = function(X){  
    roll.reg <- lm(AMZN ~ SPX,  
      data = as.data.frame(X))  
    return(roll.reg$coef)  
  },  
  by.column = F)
```

```
coeffs <- na.omit(coeffs)
```

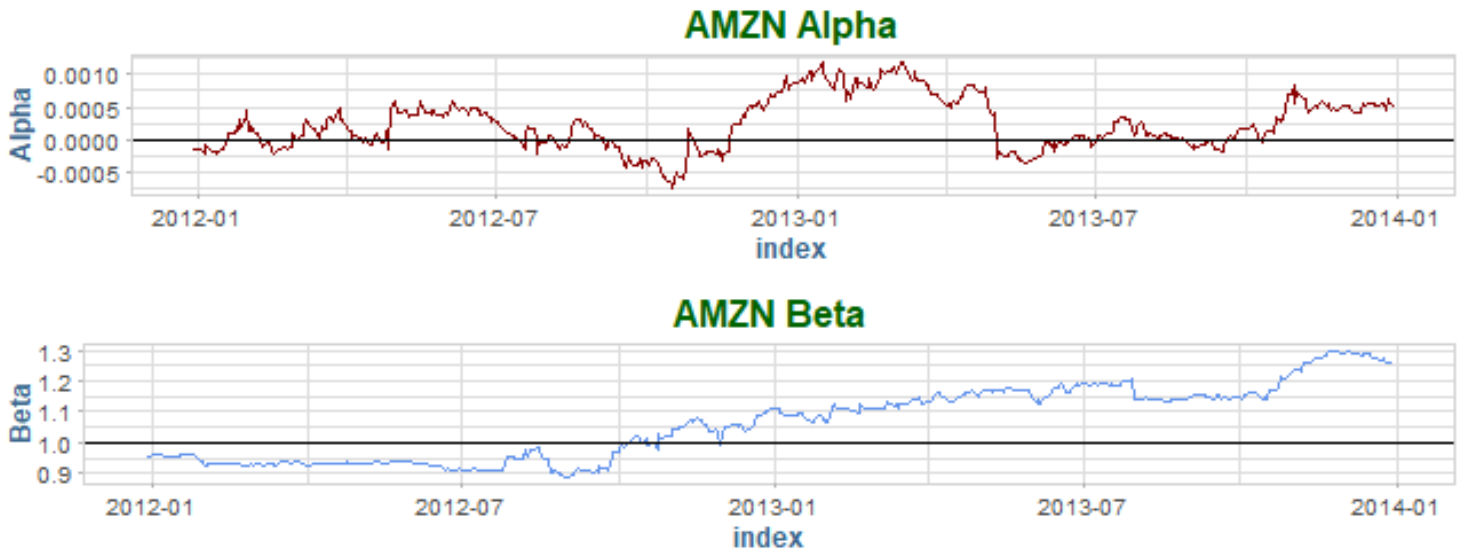
```
names(coeffs) <- c("Alpha", "Beta")
```

```
coeffs <- as.data.table(coeffs)
```

```
p1 <- ggplot(coeffs) +  
  geom_line(aes(index, Alpha), col = "darkred") +  
  geom_hline(yintercept = 0) +  
  labs(title = "AMZN Alpha")
```

```
p2 <- ggplot(coeffs) +  
  geom_line(aes(index, Beta), col = "cornflowerblue") +  
  geom_hline(yintercept = 1) +  
  labs(title = "AMZN Beta")
```

```
grid.arrange(p1, p2, nrow = 2)
```



## Fama-French Three Factor

```
ff.data <- data.table::fread(file.path(data.dir, "F-F_Research_Data_Factors.CSV"))
```

Warning in data.table::fread(file.path(data.dir, "F-F\_Research\_Data\_Factors.CSV")): Stopped early on line 1128. Expected 5 fields but found 0. Consider fill=TRUE and comment.char=. First discarded non-empty line: <<Annual Factors: January-December >>

```
ff.data$Date <- as.yearmon(parse_date(as.character(ff.data$V1), format = "%Y%m"))
ff.data$V1 <- NULL
```

```
factor.data <- ff.data[, .(Month = Date, RmxRF = `Mkt-RF` / 100, SMB = SMB / 100, HML = HML / 100, Rf = Rf)]
```

```
FF <- factor.data[Month >= "2011-1-1" &
  Month <= "2013-12-31"][, .(Month, RmxRF, SMB, HML, Rf)]
```

```
FF.data <- merge(port.return, FF, by = "Month")[, Excess := Return - Rf]
```

```
FF.reg <- lm(Excess ~ RmxRF + SMB + HML, data = FF.data)
```

```
summary(FF.reg)
```

Call:

```
lm(formula = Excess ~ RmxRF + SMB + HML, data = FF.data)
```

Residuals:

Min	1Q	Median	3Q	Max
-----	----	--------	----	-----

-0.045893 -0.023246 -0.005154 0.021982 0.070282

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	0.005182	0.005849	0.886	0.382240
RmxRF	0.752255	0.184050	4.087	0.000274 ***
SMB	-0.231712	0.386026	-0.600	0.552567
HML	-0.538316	0.368993	-1.459	0.154346

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.03187 on 32 degrees of freedom

Multiple R-squared: 0.392, Adjusted R-squared: 0.335

F-statistic: 6.878 on 3 and 32 DF, p-value: 0.001051

```
betas <- rbind(
  cbind(summary(FF.reg)$coefficient[2],
        summary(FF.reg)$coefficient[14],
        summary(FF.reg)$adj.r.squared),
  cbind(summary(CAPM)$coefficient[2],
        summary(CAPM)$coefficient[8],
        summary(CAPM)$adj.r.squared))

colnames(betas) <- paste(c("Beta", "p-Value", "Adj. R-Squared"))
rownames(betas) <- paste(c("Farma-Frech", "CAPM"))

betas
```

	Beta	p-Value	Adj. R-Squared
Farma-Frech	0.7522554	0.0002739225	0.3350455
CAPM	0.6700119	0.0001075304	0.3419441

## Event Studies

```
date.from <- "2012-7-20"; date.to <- "2013-7-24"

NFLX <- getSymbols("NFLX", from = date.from, to = date.to, auto.assign = F)
SPX <- getSymbols("^GSPC", from = date.from, to = date.to, auto.assign = F)

firm.data <- merge(NFLX$NFLX.Adjusted, SPX$GSPC.Adjusted)
colnames(firm.data) <- c("Firm", "Mkt")

firm.returns <- data.table(Date = index(firm.data)[-1],
                          apply(firm.data, 2, function(x) diff(log(x)) * 100))
```

```

N <- nrow(firm.returns)
actual <- firm.returns[N]

mkt.model <- lm(Firm ~ Mkt, data = firm.returns[1:N-1])

summary(mkt.model)

```

```

Call:
lm(formula = Firm ~ Mkt, data = firm.returns[1:N - 1])

```

Residuals:

Min	1Q	Median	3Q	Max
-29.134	-1.847	-0.507	1.472	34.845

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	0.3768	0.2908	1.296	0.19620
Mkt	1.0138	0.3820	2.654	0.00847 **

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.567 on 248 degrees of freedom

Multiple R-squared: 0.02761, Adjusted R-squared: 0.02369

F-statistic: 7.042 on 1 and 248 DF, p-value: 0.008474

```

event.window <- data.table(actual)
event.window$Pred <- predict(mkt.model, newdata = data.table(Mkt = actual$Mkt))
event.window$Ab.Ret <- event.window$Firm - event.window$Pred
event.window$tStat <- event.window$Ab.Ret / summary(mkt.model)$sigma
event.window$pval <- 2 * (1 - pt(abs(event.window$tStat), df = nrow(firm.data) - 2))

event.window

```

	Date	Firm	Mkt	Pred	Ab.Ret	tStat	pval
1:	2013-07-23	-4.569143	-0.1853653	0.1889223	-4.758065	-1.041777	0.2985214

```
NFLX.df <- as.data.table(NFLX)
```

```

ggplot(NFLX.df, aes(index, NFLX.Adjusted)) +
  geom_line(col = "cornflowerblue") +
  labs(title = "NFLX July '12 - July - '13")

```





```
NFLX.df <- subset(NFLX.df, index >= "2013-1-1")
```

```
ggplot(NFLX.df, aes(index, NFLX.Adjusted)) +  
  geom_line(col = "cornflowerblue") +  
  labs(title = "NFLX July '12 - July - '13")
```



```
head(subset(firm.returns, Date >= "2013-1-1"), 20)
```

	Date	Firm	Mkt
1:	2013-01-02	-0.6283867	2.5086116281
2:	2013-01-03	4.8577969	-0.2087795541
3:	2013-01-04	-0.6335390	0.4853300262
4:	2013-01-07	3.2998177	-0.3128003221
5:	2013-01-08	-2.0778940	-0.3247639705

```

6: 2013-01-09 -1.2948894  0.2652345964
7: 2013-01-10  2.1557269  0.7568699709
8: 2013-01-11  3.3020211 -0.0047514919
9: 2013-01-14  2.1100685 -0.0931104825
10: 2013-01-15 -1.7159396  0.1128033221
11: 2013-01-16 -4.2281771  0.0196972467
12: 2013-01-17  0.2254361  0.5627060187
13: 2013-01-18  1.4933990  0.3397492337
14: 2013-01-22 -1.3808748  0.4418332215
15: 2013-01-23  5.4223297  0.1506341924
16: 2013-01-24 35.2229644  0.0006614196
17: 2013-01-25 14.3727089  0.5430708897
18: 2013-01-28 -4.4931742 -0.1851334124
19: 2013-01-29  4.2333423  0.5093003708
20: 2013-01-30 -0.8431806 -0.3907244749

```

Remove the huge jump in Jan

```

firm.subset <- firm.returns[Date >= "2013-1-28"]

N <- nrow(firm.subset)
actual <- firm.subset[N]

mkt.model2 <- lm(Firm ~ Mkt, data = firm.subset[1:N-1])

summary(mkt.model2)

```

Call:

```
lm(formula = Firm ~ Mkt, data = firm.subset[1:N - 1])
```

Residuals:

	Min	1Q	Median	3Q	Max
	-7.4803	-1.7454	-0.4618	1.0089	20.5409

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	0.2544	0.2951	0.862	0.39046
Mkt	1.0341	0.3838	2.694	0.00807 **

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 3.233 on 120 degrees of freedom

Multiple R-squared: 0.05704, Adjusted R-squared: 0.04918

F-statistic: 7.259 on 1 and 120 DF, p-value: 0.008068

```
event.window <- data.table(actual)
event.window$Pred <- predict(mkt.model2, newdata = data.table(Mkt = actual$Mkt))
event.window$Ab.Ret <- event.window$Firm -event.window$Pred
event.window$tStat <- event.window$Ab.Ret/summary(mkt.model2)$sigma
event.window$pval <- 2 * (1 - pt(abs(event.window$tStat), df = nrow(firm.data)-2))

event.window
```

	Date	Firm	Mkt	Pred	Ab.Ret	tStat	pval
1:	2013-07-23	-4.569143	-0.1853653	0.06266365	-4.631807	-1.43288	0.1531414