SPL: Fama French Factor Model

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Structure

1. Model
2. Data
3. Results

1. Model

- CAPM $R_i - R_F = \beta \cdot (R_M - R_F)$
- Fama and French (1993) 3 Factors
  $R_i - R_F = \beta_M \cdot (R_M - R_F) + \beta_S \cdot SMB + \beta_V \cdot HML$
- Fama and French (2015) 5 Factors
  $R_i - R_F = \beta_M \cdot (R_M - R_F) + \beta_S \cdot SMB + \beta_V \cdot HML + \beta_P \cdot RMW + \beta_I \cdot CMA$

2. Data

- Model factors including the estimated market return and the risk-free rate from Kenneth French's data library: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

- S&P 500 stock prices downloaded with `BatchGetSymbols` library.

```
library(BatchGetSymbols)
Companies <- GetSP500Stocks()
Stocks<- BatchGetSymbols(tickers = Companies$tickers,
                         first.date = "2010-01-01",
                         last.date = "2017-12-31")
```

2. Data: S&P 500

- `GetSP500Stocks()` returns company info like name and sector.

- Downloaded stock data contains two dataframes:
  df.control descriptive info. e.g. whether the download for the ticker is successful.
  df.tickers downloaded price data, stacked in rows.

- `BatchGetSymbols()` function **keeps** stocks with 75% or more price points compared to the benchmark.
  We took *3M Company*'s dates as they are complete.

```
good.tickers <- Stocks$df.control$
    ticker[Stocks$df.control$threshold.decision=="KEEP"]

SP500.data<-data.frame(date = Stocks$df.tickers$
              ref.date[Stocks$df.tickers$ticker=="MMM"])
```

2. Data: S&P 500

- Loop over the downloaded data **df.tickers**.
- Subset each company by its ticker.
- Rename `colname` of the price series to the ticker symbol.
- Merge to the existing dataframe by matching dates.

```
for(i in 1:length(good.tickers))
{
  X <- data.frame(date =
    Stocks$df.tickers$
      ref.date[Stocks$df.tickers$ticker==good.tickers[i]],
    Stocks$df.tickers$
      price.adjusted[Stocks$df.tickers$ticker
                                  ==good.tickers[i]])

  colnames(X)[2] <- Stocks$df.tickers$
        ticker[Stocks$df.tickers$ticker==good.tickers[i]]

  SP500.data <- merge.data.frame(SP500.data, X,
                                  by = "date", all.x = TRUE)
}
```

2. Data: from Daily Price to Monthly Return

quantmod::monthlyReturn() requires non-NA daily prices in **xts** format.

```
Stock.Prices.Daily <-
  xts(Stock.Prices.Daily[,-1],
        order.by = as.POSIXct(Stock.Prices.Daily$date))

Stock.Prices.Daily <-
  Stock.Prices.Daily[!is.na(Stock.Prices.Daily)]

Stock.Prices.Monthly <- monthlyReturn(Stock.Prices.Daily)
```

How to chose?

- **Remove stocks with NA** ensures remaining stocks have same number of observations.
- **Remove NAs in each series** results in a larger sample size.

Price data with NAs in the middle might result in strange monthly returns.
("BHY" Brighthouse Financial Inc. removed for 2015-2017 runs)

2. Data: Linear Regression

- Linear Regression in R

```
y <- lm(rirf ~ rmrf + smb + hml);
round(summary(y)$coefficients, digits = 4)
```

```
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -0.3818     0.1075 -3.5504    4e-04
## rmrf          1.0349     0.0264 39.2255    0e+00
## smb           1.3985     0.0393 35.6070    0e+00
## hml          -0.2979     0.0440 -6.7676    0e+00
```

- We can read out the regression summary from the `coefficients` matrix.

- Similarly R^2 from `summary(y)$r.squared` and standard errors from `summary(y)$sigma`.

3. Results

Overview:

- Replicating Fama and French (1993)
- Regression over S&P500 stocks
- 3 Factors vs. 5 Factors
- Stock selection?

3.1 Results: Replicating the 3 Factors Model

b	LOW	2	3	4	HIGH
SMALL	1.03	0.97	0.94	0.89	0.95
2	1.10	1.02	0.96	0.97	1.07
3	1.10	1.02	0.97	0.97	1.06
4	1.06	1.07	1.04	1.03	1.15
BIG	0.96	1.02	0.96	1.01	1.03

t(b)	LOW	2	3	4	HIGH
SMALL	39.23	50.60	58.42	57.99	57.76
2	53.20	58.56	59.98	62.77	63.25
3	59.68	56.81	53.35	58.93	51.14
4	57.16	52.61	50.34	51.30	46.30
BIG	57.20	56.98	42.80	55.04	37.70

s	LOW	2	3	4	HIGH
SMALL	1.40	1.27	1.16	1.10	1.19
2	1.00	0.94	0.83	0.71	0.85
3	0.70	0.63	0.54	0.45	0.65
4	0.30	0.27	0.25	0.22	0.36
BIG	(0.20)	(0.19)	(0.27)	(0.19)	(0.04)

t(s)	LOW	2	3	4	HIGH
SMALL	35.61	44.82	48.65	48.10	48.63
2	32.62	36.36	34.80	30.78	33.82
3	25.53	23.41	20.04	18.46	21.03
4	10.92	8.75	8.06	7.49	9.64
BIG	(8.10)	(7.08)	(7.99)	(6.91)	(1.05)

h	LOW	2	3	4	HIGH
SMALL	(0.30)	0.08	0.27	0.38	0.62
2	(0.48)	0.03	0.23	0.47	0.70
3	(0.43)	0.04	0.31	0.50	0.71
4	(0.44)	0.03	0.30	0.56	0.74
BIG	(0.44)	(0.02)	0.20	0.56	0.76

t(h)	LOW	2	3	4	HIGH
SMALL	(6.77)	2.43	9.92	14.93	22.43
2	(13.93)	0.88	8.73	18.32	24.74
3	(14.04)	1.39	10.27	18.28	20.34
4	(14.24)	0.79	8.77	16.68	17.79
BIG	(15.96)	(0.68)	5.25	18.41	16.65

3.1 Results: Replicating the 3 Factors Model

Results from Fama and French (1993):

Table 6

Regressions of excess stock and bond returns (in percent) on the excess market return ($RM-RF$) and the mimicking returns for the size (SMB) and book-to-market equity (HML) factors: July 1963 to December 1991, 342 months.[a]

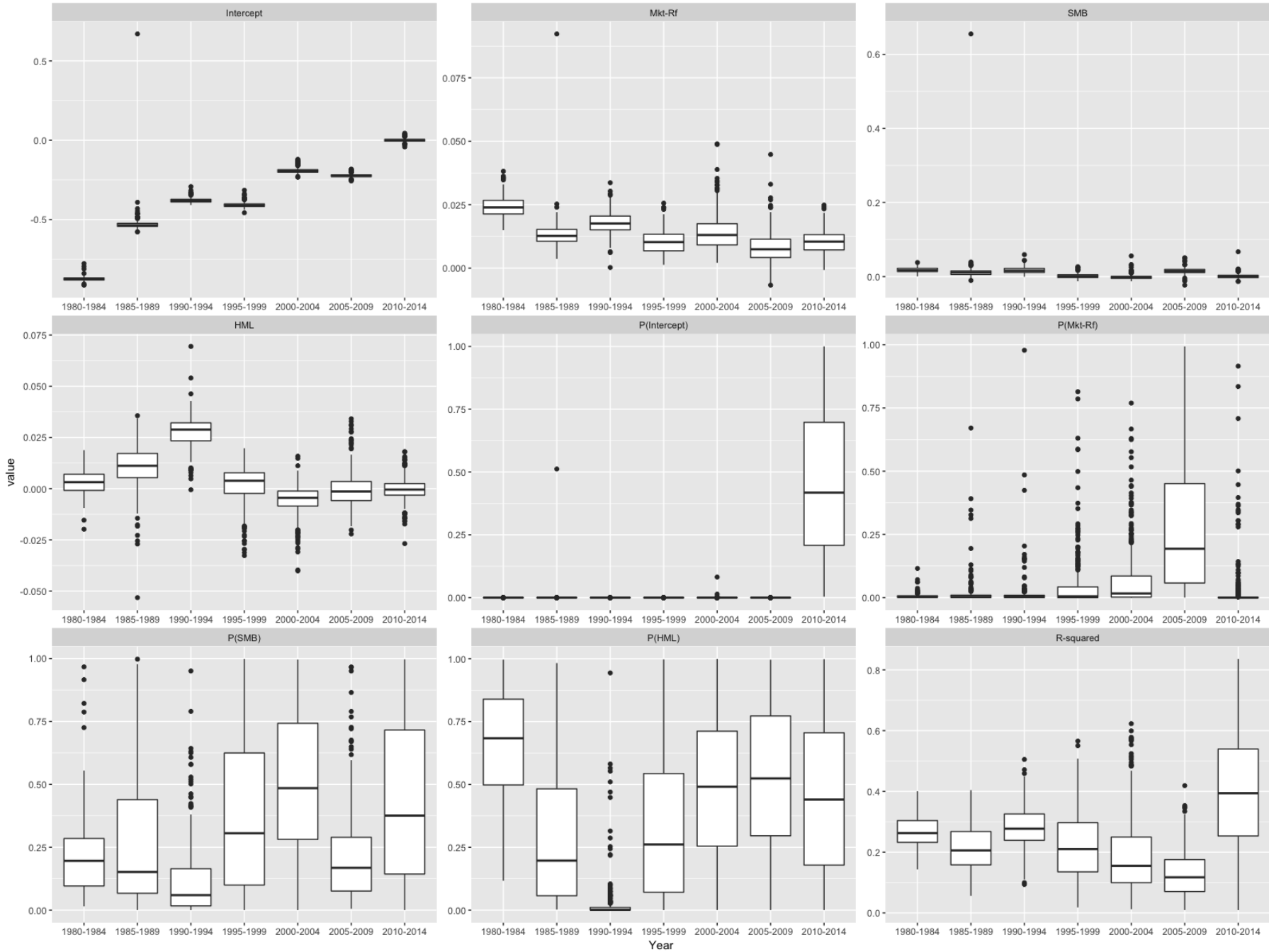
$$R(t) - RF(t) = a + b[RM(t) - RF(t)] + sSMB(t) + hHML(t) + e(t)$$

Dependent variable: Excess returns on 25 stock portfolios formed on size and book-to-market equity

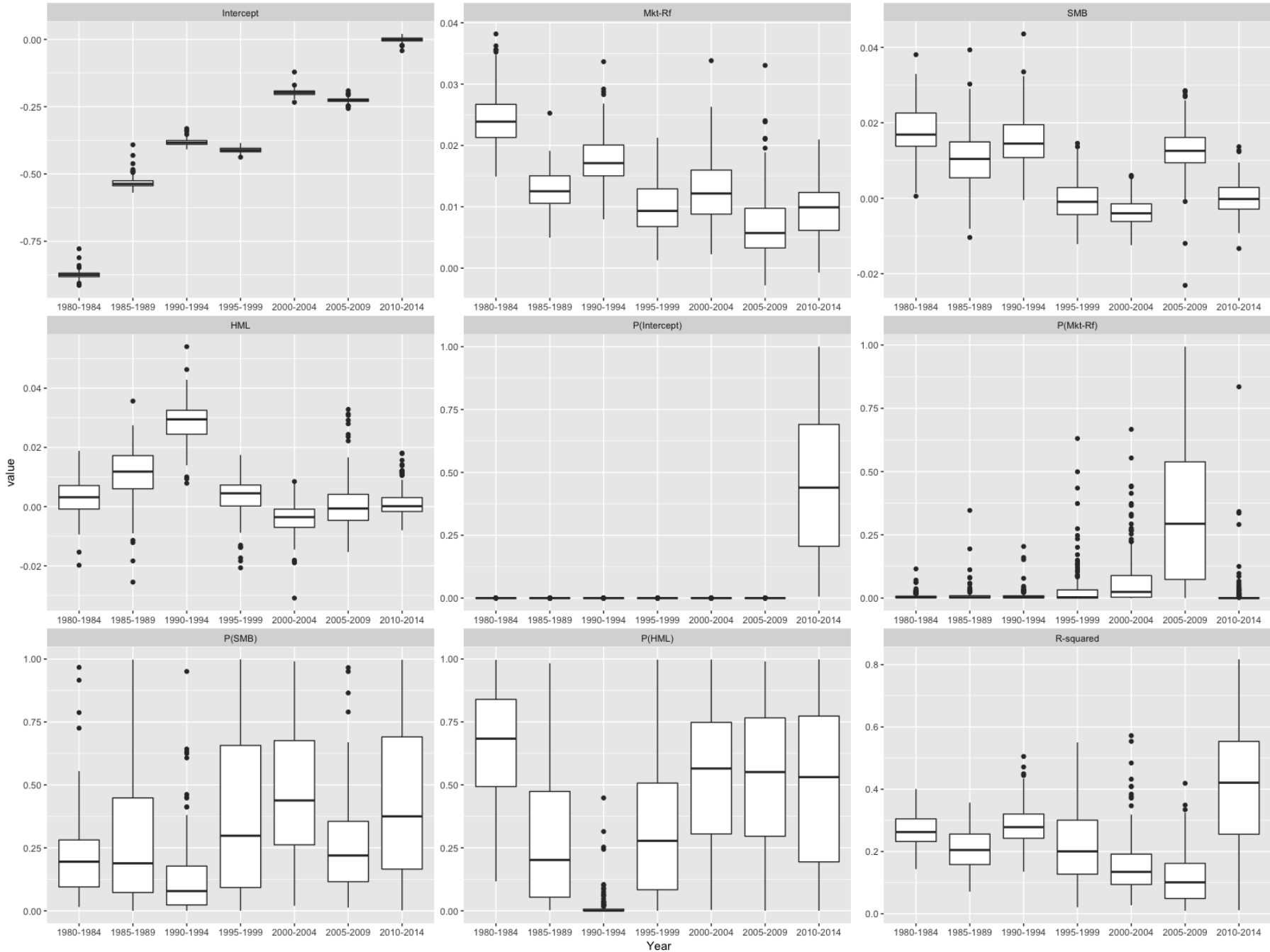
Size quintile	Book-to-market equity (BE/ME) quintiles									
	Low	2	3	4	High	Low	2	3	4	High
	b					$t(b)$				
Small	1.04	1.02	0.95	0.91	0.96	39.37	51.80	60.44	59.73	57.89
2	1.11	1.06	1.00	0.97	1.09	52.49	61.18	55.88	61.54	65.52
3	1.12	1.02	0.98	0.97	1.09	56.88	53.17	50.78	54.38	52.52
4	1.07	1.08	1.04	1.05	1.18	53.94	53.51	51.21	47.09	46.10
Big	0.96	1.02	0.98	0.99	1.06	60.93	56.76	46.57	53.87	38.61
	s					$t(s)$				
Small	1.46	1.26	1.19	1.17	1.23	37.92	44.11	52.03	52.85	50.97
2	1.00	0.98	0.88	0.73	0.89	32.73	38.79	34.03	31.66	36.78
3	0.76	0.65	0.60	0.48	0.66	26.40	23.39	21.23	18.62	21.91
4	0.37	0.33	0.29	0.24	0.41	12.73	11.11	9.81	7.38	11.01
Big	− 0.17	− 0.12	− 0.23	− 0.17	− 0.05	− 7.18	− 4.51	− 7.58	− 6.27	− 1.18
	h					$t(h)$				
Small	− 0.29	0.08	0.26	0.40	0.62	− 6.47	2.35	9.66	15.53	22.24
2	− 0.52	0.01	0.26	0.46	0.70	− 14.57	0.41	8.56	17.24	24.80
3	− 0.38	- 0.00	0.32	0.51	0.68	− 11.26	0.05	9.75	16.88	19.39
4	− 0.42	0.04	0.30	0.56	0.74	− 12.51	1.04	8.83	14.84	17.09
Big	− 0.46	0.00	0.21	0.57	0.76	− 17.03	0.09	5.80	18.34	16.24

E.F. Fama and K.R. French, Common risk factors in stock and bond returns

3.2 Regression over S&P 500 stocks (All)

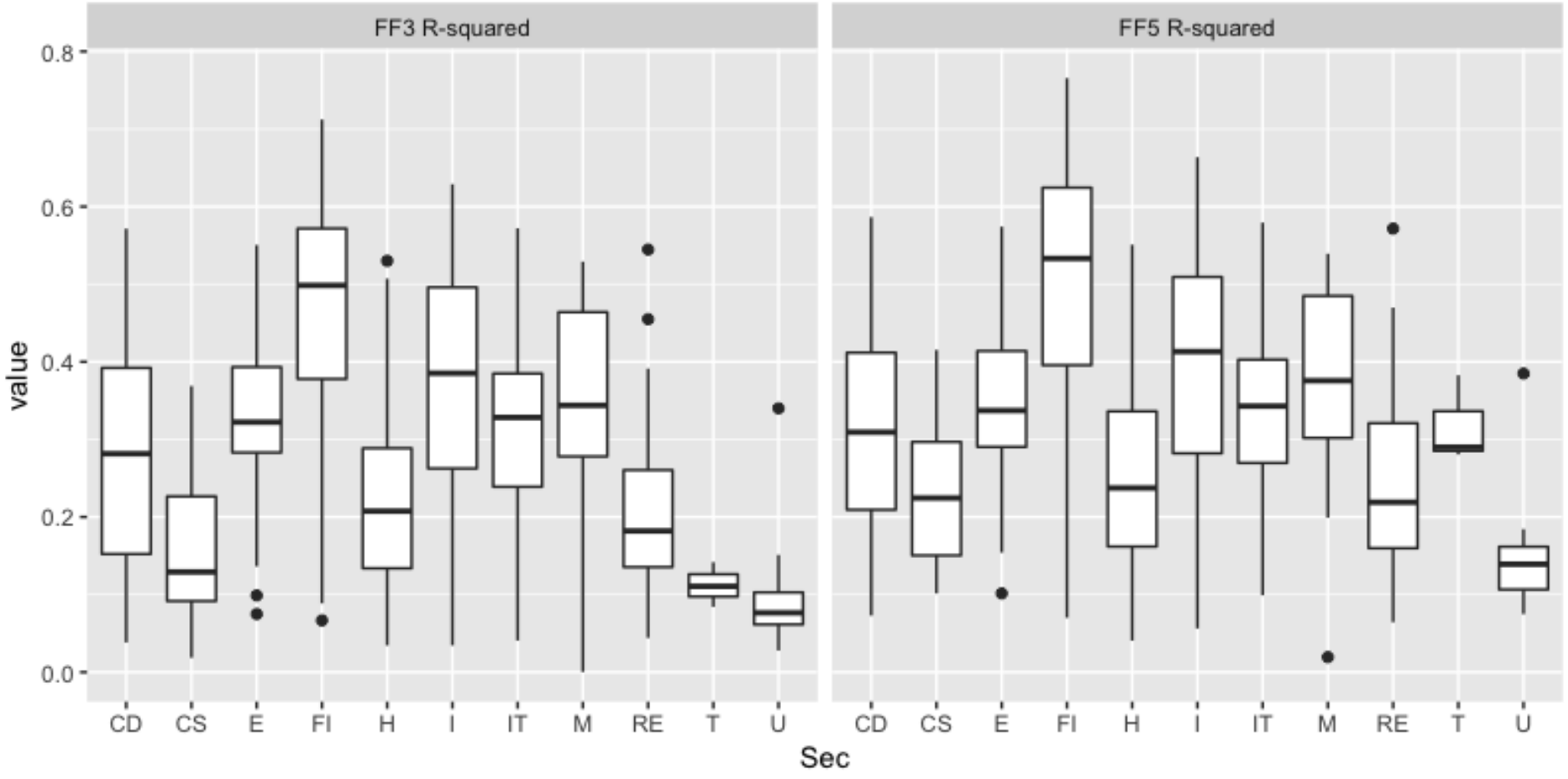


3.2 Regression over S&P 500 stocks (Survivors)



3.3 3 Factors vs. 5 Factors

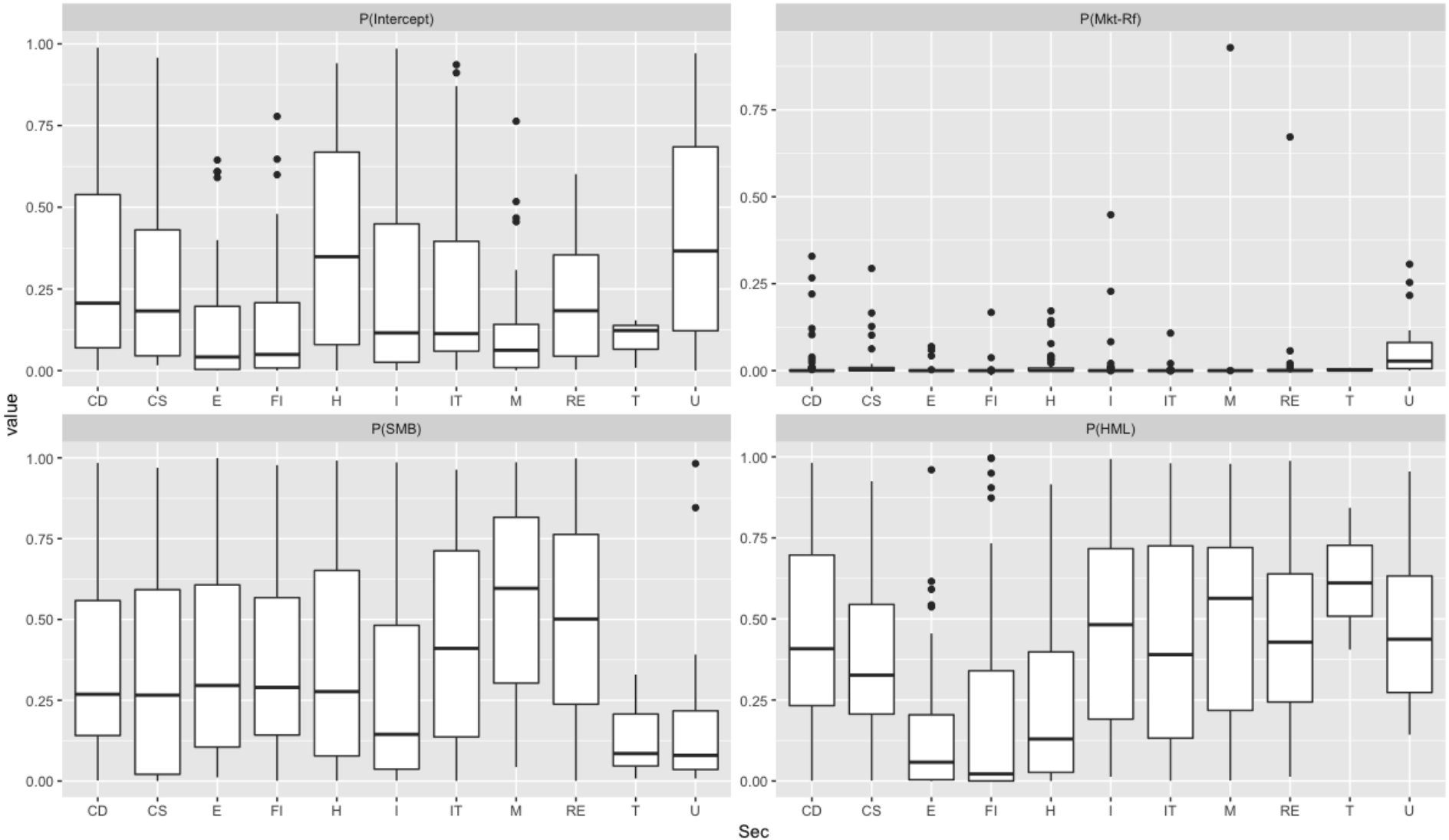
- R^2 Comparison



CD: Consumer Discretionary, CS: Consumer Staples, E: Energy, FI: Financials, H: Health Care, I: Industrials, IT: Information Technology, M: Materials, RE: Real Estate, T: Telecommunication Services, U: Utilities

3.3 3 Factors vs. 5 Factors

- P-Values: 3 Factors



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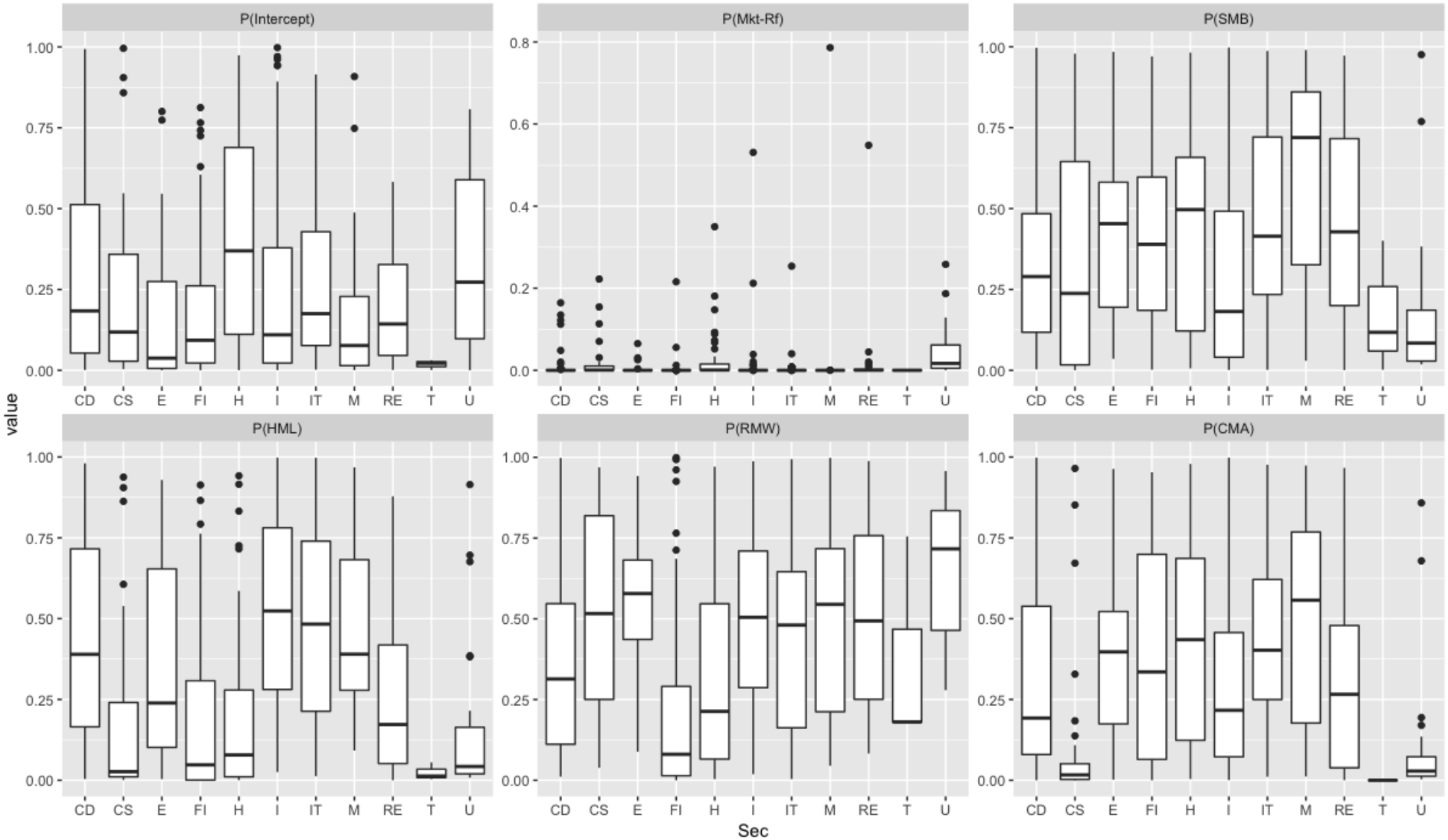
- P-Values: 5 Factors



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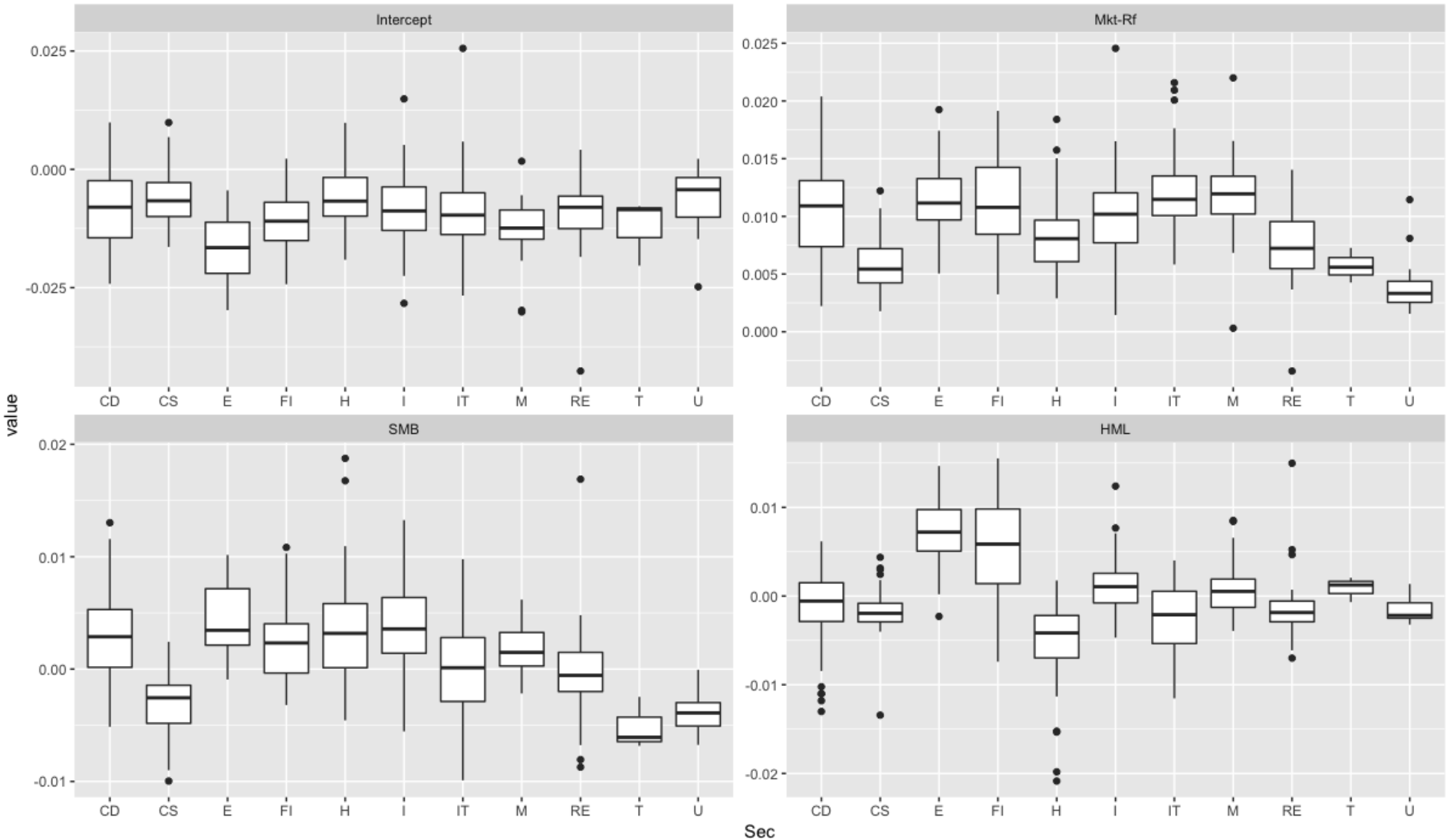
3.3 3 Factors vs. 5 Factors

- Regressed Coefficients: 3 Factors



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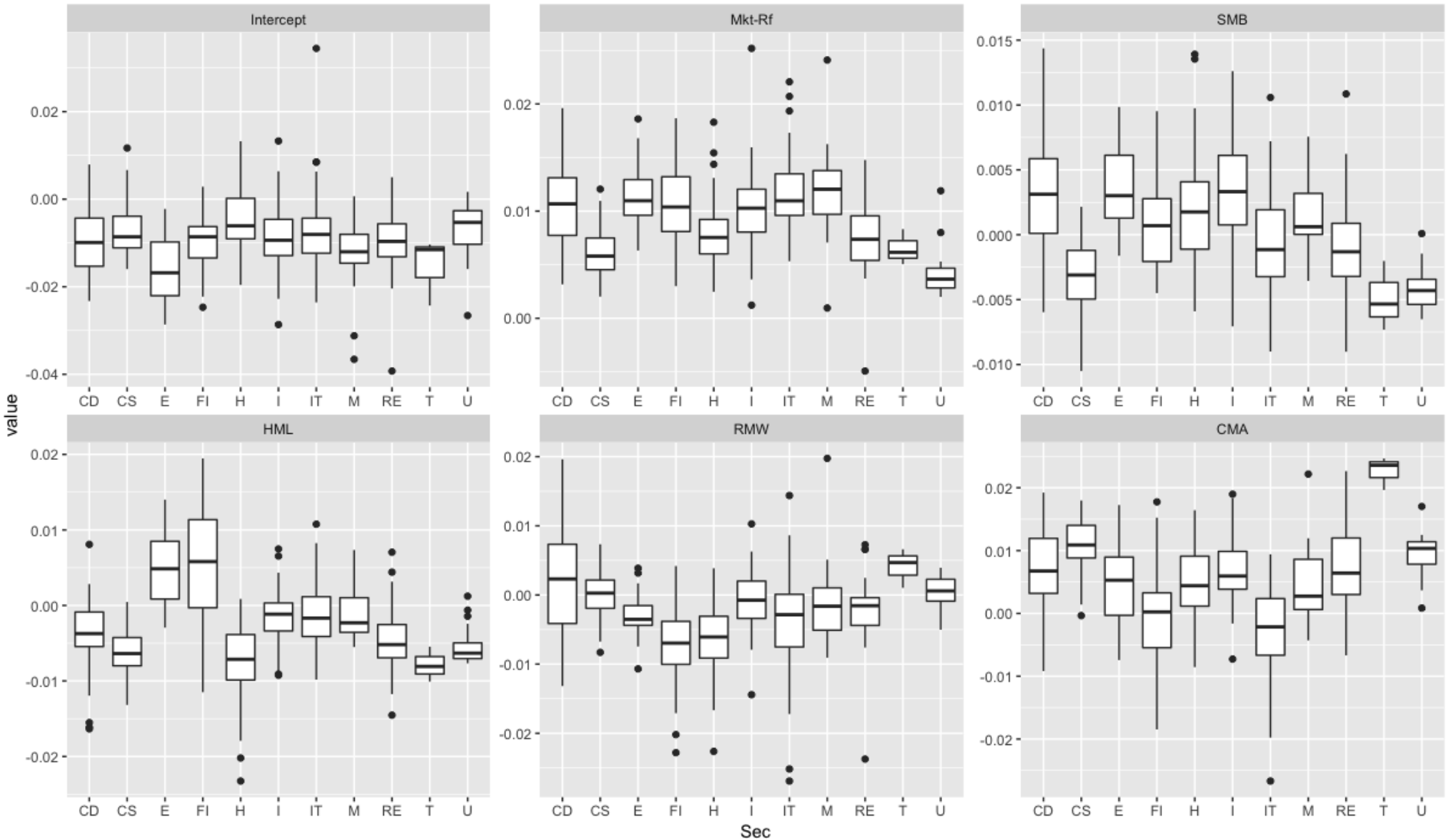
3.3 3 Factors vs. 5 Factors

- Regressed Coefficients: 5 Factors



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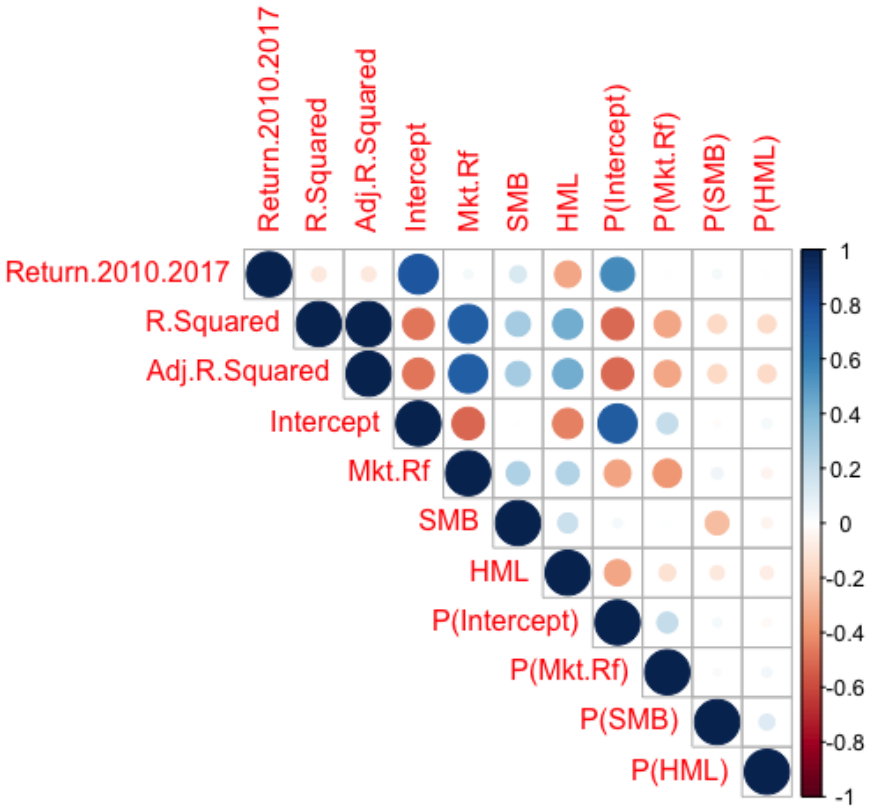
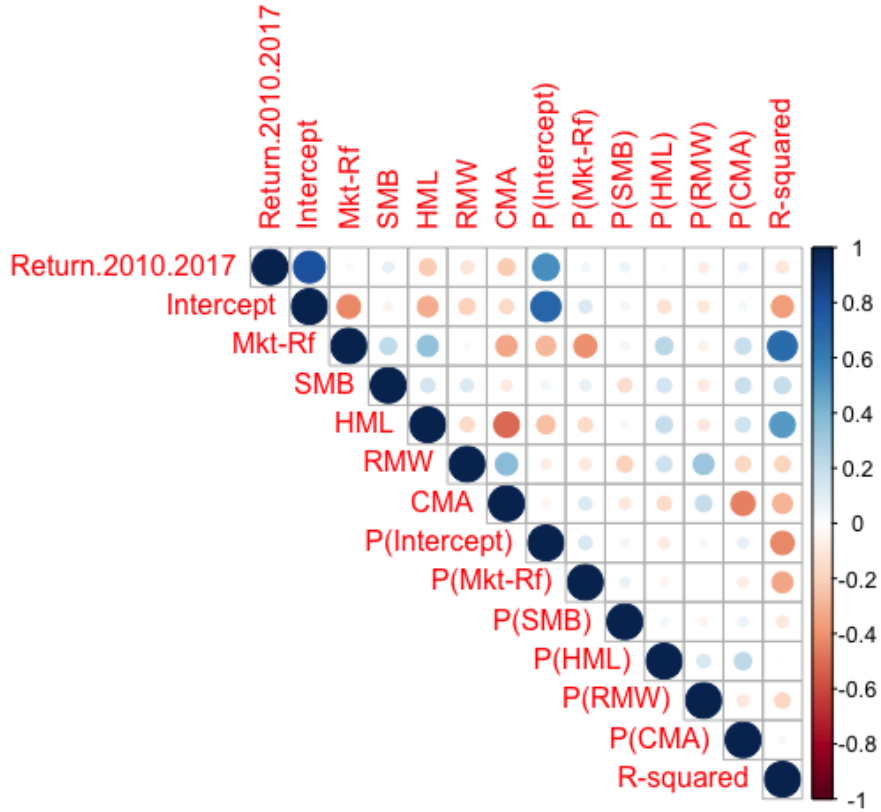
3.4 Stock Selection?

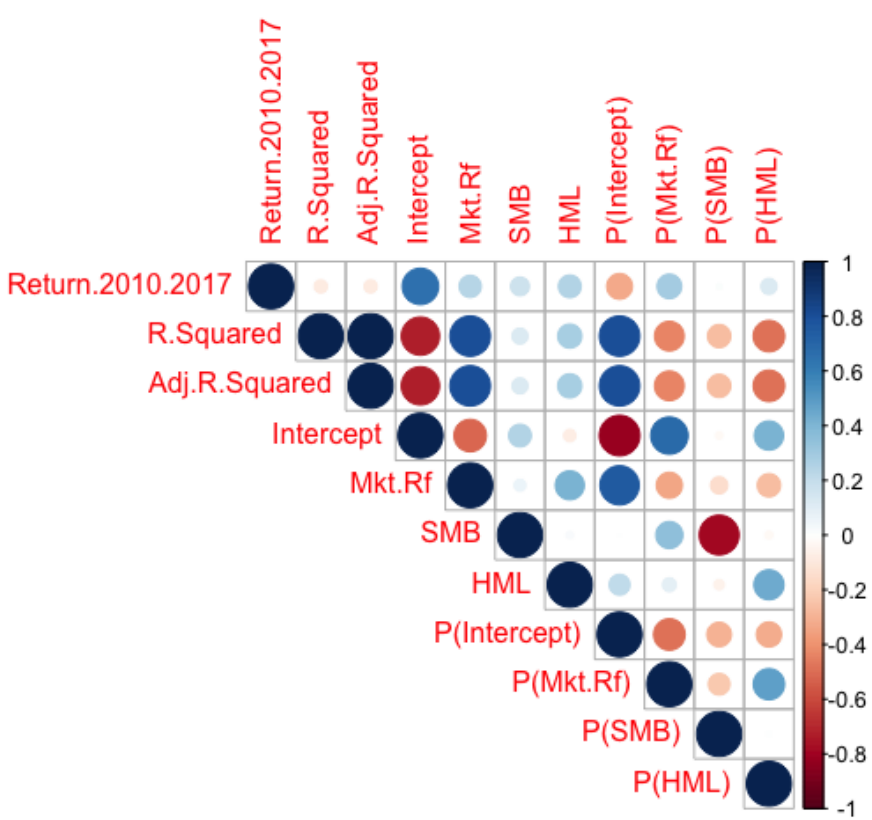
- Stock returns from Jan. 2010 to Dec. 2017.
  Corr. plot of the stock returns and the regressed coefficients.
- *alpha* or *Intercept* highly correlated to stock returns.
- Positive corr. to SMB: Small cap premium.
  Negative corr. to HML: Market seemed to favor **Growth** stocks (instead of **Value**) in the bullish years.
- Negative corr. to RMW and CMA.

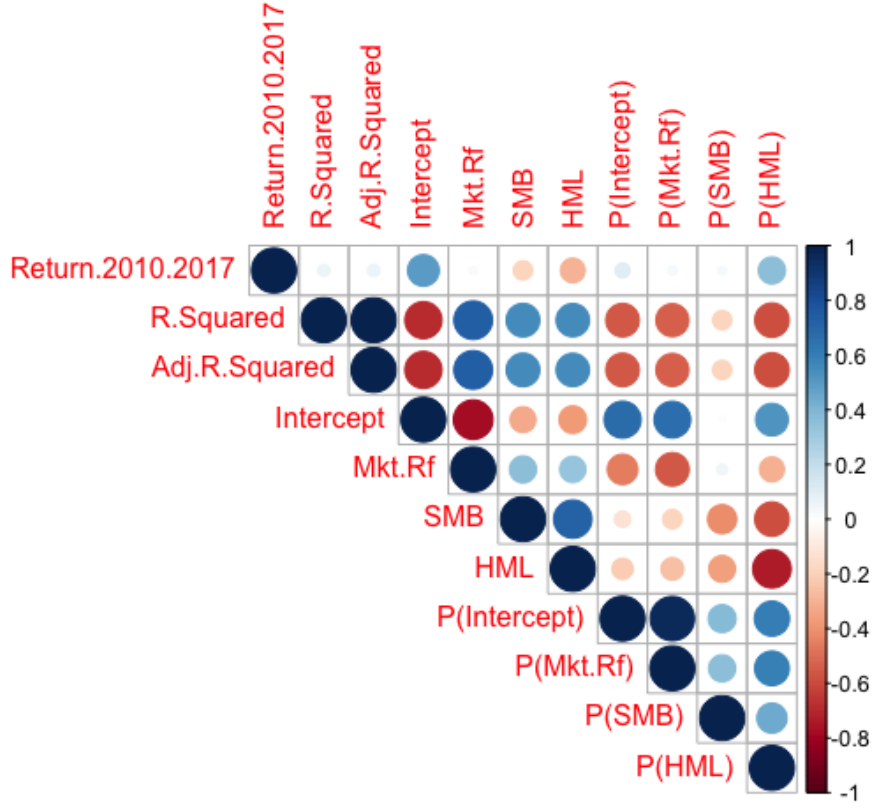




3.4 Stock Selection: 3 Factor / Top and Bottom 20s

- Winners have positive correlations to both *SMB* and *HML*, while losers have negative correlations.
- Small Cap and Value premiums work at the extremes.

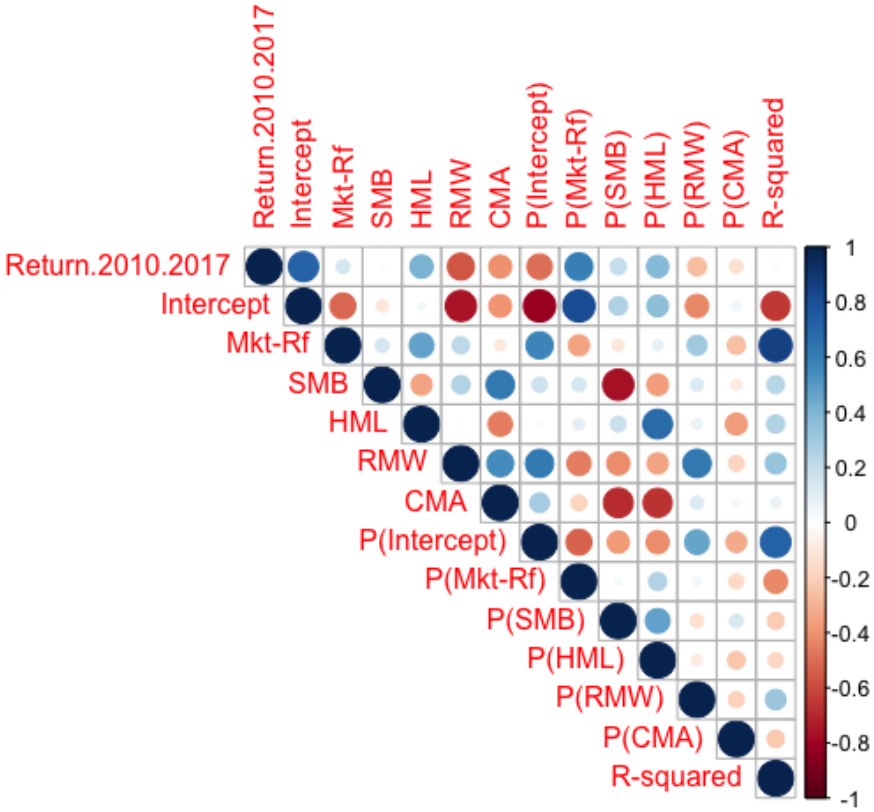


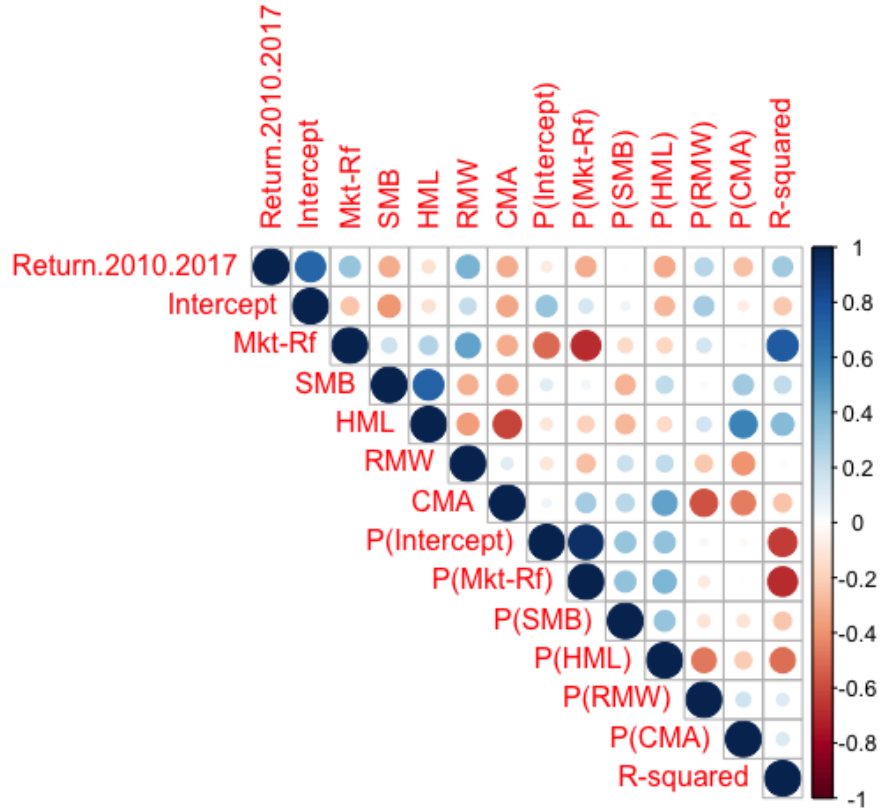


Although the overall winner, *NETFLIX*, is clearly neither *small cap* nor *value*.

3.4 Stock Selection: 5 Factor / Top and Bottom 20s

- Recall: the regressed coefficient for the **Profitability** factor *RMW* have different signs for different industry sectors. It is difficult to interpret based on positive / negative corr.
- **Investment** factor *CMA* is negatively correlated to the returns of both winners and losers: both winners and losers invest aggressively [?].





Thank You!

Below are backup slides

Melt and Plotting

- Regression results in dataframe `Results`.
- `reshape::melt()` prepares the data for plots.
- Each Fama French factor will have 1 sub-plot comparing different sectors

```
df.melt <- melt(
  Results[,c("Intercept", "Mkt-Rf", "SMB", "HML", "RMW", "CMA", "Sec")],
  "Sec"
)
```

- Boxplot with the melted data

```
ggplot(df.melt, aes(x=Sec, y=value))
  + geom_boxplot()
  + facet_wrap(~ variable, scales='free')
```

Helper functions

- Resizing the regression output from an 1 dimensional vector to the same format as in the papers with rows for *SMB* and columns for *HML*.

```
resize <- function(x)
{
  return(
    matrix(x, nrow=5, byrow = TRUE,
        dimnames = list(
          c("SMALL", "2", "3", "4", "BIG"),
          c("LOW", "2", "3", "4", "HIGH")
        )
    )
  )
}
```

Descriptions copied from K.French's Website

Description of the factors: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/f-f_5_factors_2x3.html

- SMB (Small Minus Big) is the average return on the nine small stock portfolios minus the average return on the nine big stock portfolios.
- HML (High Minus Low) is the average return on the two value portfolios minus the average return on the two growth portfolios.
- RMW (Robust Minus Weak) is the average return on the two robust operating profitability portfolios minus the average return on the two weak operating profitability portfolios.
- MA (Conservative Minus Aggressive) is the average return on the two conservative investment portfolios minus the average return on the two aggressive investment portfolios.

Descriptions copied from K.French's Website (cont.)

- Rm-Rf, the excess return on the market, value-weight return of all CRSP firms incorporated in the US and listed on the NYSE, AMEX, or NASDAQ that have a CRSP share code of 10 or 11 at the beginning of month t, good shares and price data at the beginning of t, and good return data for t minus the **one-month Treasury bill rate** (from Ibbotson Associates).

References

Fama, Eugene F., and Kenneth R. French. 1993. "Common risk factors in the returns on stocks and bonds." *Journal of Financial Economics* 33 (1): 3–56. doi:10.1016/0304-405X(93)90023-5.

———. 2015. "A five-factor asset pricing model." *Journal of Financial Economics* 116 (1). Elsevier: 1–22. doi:10.1016/j.jfineco.2014.10.010.