Quantessentials

R advice – Tidy data science with the tidyverse

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The tidyverse and its philosophy

The tidyverse is a collection of packages that provide tools for data science in R, ranging from importing, cleaning and manipulating data, to data visualisation and functional programming. Solving complex problems in the tidyverse involves combining small, simple pieces, each of which is easy to understand in isolation. This strategy of taking one step at a time reduces the scope for error and increases readability, while the consistent interface of the tidyverse allows the user to focus on the questions at hand, rather than the coding.

Data manipulation with dplyr

Following our recent Quantessentials note on *data.table* – an excellent tool for data manipulation, we look at its main competitor: *dplyr*. We introduce the core functions (verbs) of the package and show how to join them together to solve common data wrangling tasks.

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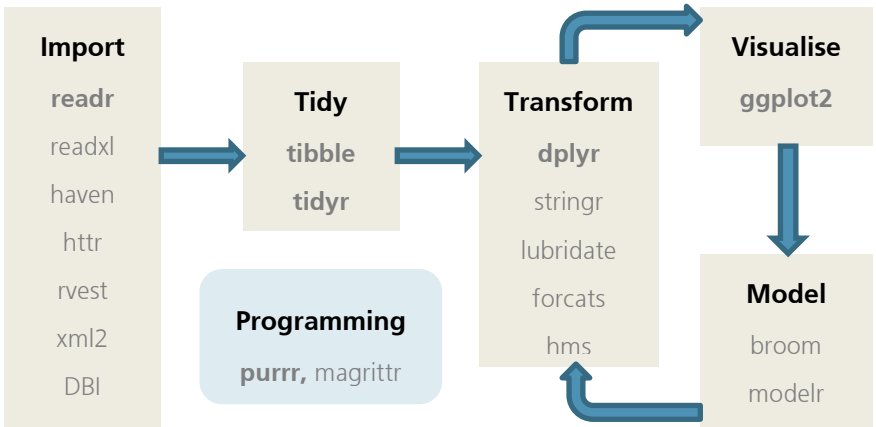
The philosophy of the tidyverse

The *tidyverse* is a set of packages for doing data science, which share a common philosophy about data and R programming. It loads six "core" libraries that provide tools for importing (readr, which was reviewed in our R and Excel note), tidying (tidyr, tibble), manipulating (dplyr) and visualising (ggplot2) data, as well as support for functional programming (purrr).

At the heart of the tidyverse is the idea of solving complex problems by combining simple pieces that are easy to understand in isolation. What makes this strategy possible is the use of a uniform data structure (*tidy data*) and "consistent" functions[1], which are joined together with the pipe operator **%>%** from the magrittr package.

Figure 1: The tidyverse ecosystem



Source: UBS Quant. The six core packages are identified in bold.

Why get into the tidyverse ecosystem?

Although most data-related tasks can arguably be achieved with the functionality of base R, there are several reasons why one should learn the tidyverse:

- Consistent, user-friendly syntax
  Tidyverse functions are simple, have explicit names (verbs) and uniform syntax (e.g. data is always the first argument). This allows the user to focus on the problem at hand, rather than the programming, thus reducing coding time and increasing readability.

- Speed
  According to the creator of the tidyverse, Hadley Wickham, "*the bottleneck in most data analysis is thinking time, not computing time*"[2]. Although speed is not its main focus, tidyverse solutions to data problems are much faster than base R and for medium sized datasets its performance is comparable to that of data.table.

- It provides a new data structure for R – the *tibble* – a special type of data frame that makes your datasets easier to look at and work with. The key

[1] "Consistent" here refers not only to syntax, but also function's behaviour; every function does one thing, without mixing side-effects with transformations.
[2] https://cran.r-project.org/web/packages/tidyverse/vignettes/manifesto.html

differences between the tibble and the base R data frame are outlined in Figure 2 and demonstrated in Figure 3.

Figure 2: Key differences between tibbles and standard data frames

	tibble	data.frame
Creation	`tibble(…)`	`data.frame(…)`
Coercion	`as_tibble(…)`	`as.data.frame(…)`
Printing	Prints first ten rows and a number of variables that fit on screen; shows column types	Tries to print all the data
Subsetting	"[" always returns another tibble; Partial matching not supported	"[" returns a vector or a data.frame; Supports partial matching
Input modification	Does not change any aspects of the underlying data	Strings are converted to factors; Variable names, containing special symbols are modified

Source: UBS Quant. The table outlines the main differences between the default behaviour of tibble and data.frame objects.

Tibbles are data frames with better behaviour around printing, subsetting and treatment of factors

Figure 3: tibble vs data.frame

```
# load/install the tidyverse
if (!require(tidyverse)) {
  install.packages("tidyverse")
  require(tidyverse)
}

# data.frame silently modifies input ------------------------------------
df_example <- data.frame("abc" = 1:3, "123" = c("a", "b", "c"))
str(df_example)
## 'data.frame':    3 obs. of  2 variables:
##  $ abc : int  1 2 3
##  $ X123: Factor w/ 3 levels "a","b","c": 1 2 3
tbl_example <- tibble("abc" = 1:3, "123" = c("a", "b", "c"))
str(tbl_example)
## Classes 'tbl_df', 'tbl' and 'data.frame':    3 obs. of  2 variables:
##  $ abc: int  1 2 3
##  $ 123: chr  "a" "b" "c"

# Subsetting and partial matching ---------------------------------------
class(df_example[, 1])
## [1] "integer"
class(df_example[, 1, drop = FALSE]) # to keep original structure
## [1] "data.frame"

class(tbl_example[, 1])
## [1] "tbl_df"     "tbl"        "data.frame"

df_example$ab
## [1] 1 2 3

tbl_example$ab
## Warning: Unknown column 'ab'
## NULL
```

Source: UBS Quant

Data manipulation in the tidyverse

Cleaning and manipulating data to a format that is useful to work with is the least enjoyable yet most time consuming data science task. It is commonly believed that data scientists spend 50% to 80% of their time on data preparation[3]. Two packages make wrangling data less painful and more efficient: *tidyr* and *dplyr*. The former is essentially a successor of the reshape2 package, containing two main functions: **`spread`** and **`gather`** (equivalent to reshape2's **`melt`** and **`cast`**). Therefore, in this note we will mainly focus on data manipulation with dplyr.

The core verbs in dplyr

Compared to other data wrangling packages (e.g. data.table, discussed in our recent note) or base R, dplyr is quite verbose. The syntax is centered around five core verbs, each of which performs one simple task:

- **`select`** for subsetting variables (columns)
- **`mutate`** for creating new variables from existing ones
- **`filter`** for subsetting observations (rows)
- **`arrange`** for rearranging/ordering observations
- **`summarise`** for computing various summary statistics

Along with the **`group_by`** adverb, combining multiple simple pieces (verbs) with the pipe operator **`%>%`** is a powerful way of solving complex problems.

Shortcut for `%>%` in RStudio: `Ctrl + Shift + M`

To put the data manipulation into practice, we give a simple example using a dataset from previous Quantessentials report, which contains information about 40 large-cap companies. Suppose we have the following task:

> *Calculate the mean ROE by sector and 12-month momentum (positive or negative), making sure that there are at least 3 observations per group. Finally, arrange the data in descending order of ROE.*

The tidyverse, data.table and base R solutions are given in Figure 4.

Figure 4: Three solutions to the problem

```
# To reproduce the examples - please refer to the appendix for the data.
# Tidyverse ------------------------------------------------------------
data %>%
  mutate(Momentum = ifelse(Return12m > 0, "Positive", "Negative")) %>%
  group_by(Sector, Momentum) %>%
  filter(n() >= 3) %>%       # n() returns row count in each group
  summarise(ROE = mean(ROE, na.rm = TRUE)) %>%
  arrange(desc(ROE))

# data.table -----------------------------------------------------------
data_dt[, if (.N >= 3) .(ROE = mean(ROE, na.rm = T)),
  by = .(Sector, Momentum = ifelse(Return12m > 0, "Positive", "Negative"))][
  order(ROE, decreasing = TRUE)]

# Base R ---------------------------------------------------------------
data_df$Momentum <- ifelse(data$Return12m > 0, "Positive", "Negative")
data_df <- transform(data_df, freq = as.numeric(as.character(
  ave(Sector, Sector, Momentum, FUN = length))))
data_df_filtered <- subset(data_df, freq >= 3)
mean_roe <- aggregate(ROE ~ Sector + Momentum, data = data_df_filtered,
                      FUN = mean, na.rm = T)
mean_roe[order(mean_roe$ROE, decreasing = TRUE), ]
```

Source: UBS Quant

Clean and straightforward
Easy to follow even if you have never used dplyr (or R!)

Terse syntax
Might be harder to follow as most operations use "`[`" instead of explicit function calls

Quite messy
Many intermediate steps, different syntax required by each function

[3] https://www.nytimes.com/2014/08/18/technology/for-big-data-scientists-hurdle-to-insights-is-janitor-work.html?_r=0

More dplyr verbs and helper functions

What if you need to mutate or summarise multiple columns, satisfying certain criteria? Using various derivatives of the core verbs together with helper functions makes this possible, as the examples in Figure 5 show.

Figure 5: Core verbs derivatives and helper function

```
# To reproduce the examples - please refer to the appendix for the data.

# Rearrange columns, e.g. make Sector the first variable, followed by everything else
data %>% select(Sector, everything())

# Rename columns using "rename(new_name = old_name)"
data %>% rename(market_cap = MarketCap)

# Find unique values in a variable
data %>% distinct(Sector)

# Select variables that satisfy certain conditions
# More select helpers: http://dplyr.tidyverse.org/reference/select_helpers.html
data %>% select(contains("Return"), starts_with("P"))

# Conditional mapping with "_if" and "_at"; the latter supports select helpers
data %>% summarise_if(is.numeric, funs(mean(., na.rm = TRUE)))
data %>% summarise_at(vars(ends_with("Return")), funs(mean, sd))

# To use dplyr programmatically, add "_" at the end of each core verb
what_var <- "PE"
data %>% select_(what_var)

what_statistic <- "mean(PE)"
data %>% summarise_(what_statistic)

# Combine dplyr with other tidyverse packages!
data %>%
  group_by(Sector) %>%
  summarise_at(vars(contains("Return")), funs(mean)) %>%
  tidyr::gather(Variable, Return, -Sector) %>%
  ggplot(aes(x = Variable, y = Return)) +
  geom_bar(stat = "identity") + ylab("") +facet_wrap(~ Sector, ncol = 4)
```

Source: UBS Quant

Combining datasets

Combining data from multiple tables is another common task in data analysis. dplyr provides flexible tools for such a task, including simple binding, joins and set operations. How to perform some of these is illustrated in Figure 6.

Figure 6: Joining datasets

```
# Binding ---------------------------------------------------------------------
data1 <- data[1:3, 1:2]
data2 <- data[3:7, 1:3]

# Unlike rbind, bind_rows does not require columns to match
bind_rows(data1, data2)

# Specify "id" to create a column linking observations to its original data frame
bind_rows("one" = data1, "two" = data2, .id = "id")

# Joins -----------------------------------------------------------------------
recommendations <- tibble(Ticker = c(sample(data$Ticker, 4), "Made up ticker"),
                          Rating = sample(c("A", "B", "C"), 5, replace = TRUE))

# returns rows that are in both datasets
inner_join(data, recommendations, by = "Ticker")

# returns all the rows
full_join(data, recommendations, by = "Ticker")

# Retain rows that are in the first (left) table
left_join(data, recommendations, by = "Ticker")

# Retain rows that are in the second (right) table
right_join(data, recommendations, by = "Ticker")
```

Source: UBS Quant

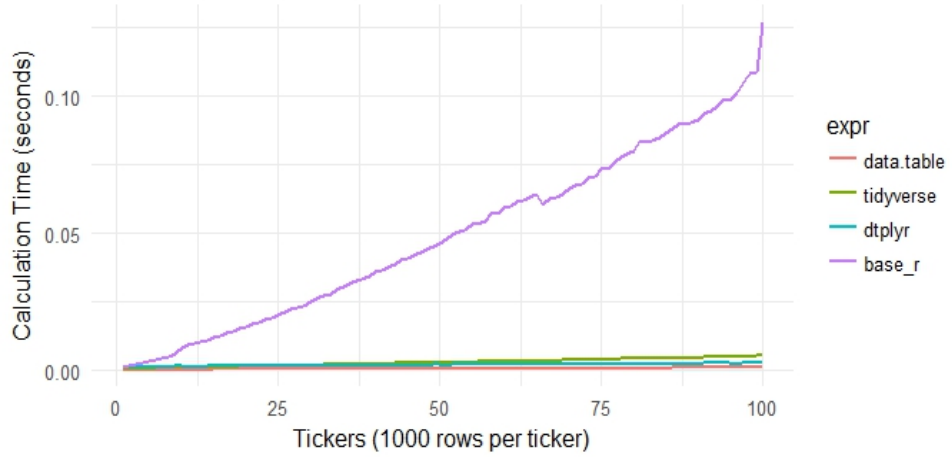
dplyr vs data.table

As our previous Quantessentials note shows, data.table is a very powerful package for data analysis. It does scale better for very large datasets (containing several millions of rows) and is the preferable package if performance and memory usage are the bottlenecks. Many R users, however, work with datasets of well under a million rows, in which case it is almost impossible to "feel" performance differences between the two alternatives (as operations tend to take milliseconds – see Figure 6 in the data table note and the simple benchmarking exercise in Figure 7).

Figure 7: Aggregating over groups

```
require(microbenchmark)
require(dtplyr)

fn <- function(n) {
  daily_dt <- data.table(
    Ticker = unique(stringi::stri_rand_strings(n, 6, pattern = "[A-Z]")),
    Date = as.Date("1999-12-31") + rep(1:1000, each = n),
    Blah = rep(1:1000, each = n) + runif(1000 * n))
  daily_tbl <- as_tibble(daily_dt)
  bm <- microbenchmark(
    data.table = daily_dt[, .(mean_Blah = mean(Blah)), by = Ticker],
    tidyverse = daily_tbl %>% group_by(Ticker) %>%
      summarise(mean_Blah = mean(Blah)),
    # use dplyr with data.table backend by passing a data.table object
    dtplyr = daily_dt %>% group_by(Ticker) %>%
      summarise(mean_Blah = mean(Blah)),
    base_r = aggregate(Blah ~ Ticker, mean, data = daily_tbl),
    times = 20, unit = "s")
  data.table(summary(bm))[, N:=n]
}
res <- rbindlist(lapply(seq(100), fn))
ggplot(res) +
  geom_line(aes(N, median, colour = expr), size = 1) +
  theme_minimal(base_size = 12) +
  xlab("Tickers (1000 rows per ticker)") +
  ylab("Calculation Time (seconds)")
```



Source: UBS Quant. We generate a random dataset, containing n groups (tickers) and calculate the mean of each group using data.table, dplyr with tibble backend, dplyr with data.table backend and base R.

If dplyr's performance with tibble/data.frame backend is not sufficient, it is easy to speed up certain operations using data.table as a backend[4], by simply passing a data.table object instead of a tibble (Figure 7). Finally, if data doesn't fit in memory, dplyr can also be used with databases[5].

Flexibility of dplyr allows you to use data.table or a database as a backend

Although there is some subjectivity to it, a main benefit of dplyr is its clean and consistent syntax. Because the tidyverse uses English verbs, it tends to be easier to learn and follow (and when you look at a piece of old code – still understand what it is meant to do). To allow the reader to compare the two, we reproduce the examples from the data.table report in the language of the tidyverse (see Figure 8 and Figure 9).

Figure 8: dplyr solutions to "Simple examples" from the data.table note

```
# Average dividend yield
data %>% summarise(mean_DivYield = mean(DivYield))

# Dividend yield for each sector
data %>%
  group_by(Sector) %>%
  summarise(mean_DivYield = mean(DivYield))

# Calculate sector P/E (aggregating over E/P)
data %>%
  group_by(Sector) %>%
  summarise(mean_PE = 1 / mean(1 / PE))

# Calculate a market-cap weighted P/E per sector
data %>%
  group_by(Sector) %>%
  summarise(sector_PE = 1 / weighted.mean(1 / PE, MarketCap))

# Add a new column with mutate
data <- data %>%
  group_by(Sector) %>%
  mutate(SectorPE = 1 / weighted.mean(1 / PE, MarketCap)) %>%
  ungroup()

# Impute missing data, e.g. fill in missing PBR's with the sector median
data <- data %>%
  group_by(Sector) %>%
  mutate(PBR = ifelse(is.na(PBR), median(PBR, na.rm = T), PBR)) %>%
  ungroup()

# Write multiple columns at once
data <- data %>%
  mutate(
    PayoutRatio = DivYield * PE,
    LogMarketCap = log(MarketCap) / log(10)
   )

# Subset columns with "select"
data %>%
  mutate(SectorRelPE = PE / SectorPE) %>%
  select(Ticker, PE, SectorRelPE)

# Write special symbols (spaces/slashes) in the column names if needed
data %>%
  mutate(`Sector Relative P/E` = PE / SectorPE) %>%
  select(Ticker, `P/E` = PE, `Sector Relative P/E`)

# Aggregating over multiple columns
data %>%
  mutate(Momentum = ifelse(Return12m > 0, "Positive", "Negative")) %>%
  group_by(Sector, Momentum) %>%
  summarise(ROE = mean(ROE, na.rm = TRUE))
```

Source: UBS Quant

[4] Via the package *dtplyr*
[5] dplyr currently supports sqlite, mysql and postgresql.
https://cran.r-project.org/web/packages/dplyr/vignettes/databases.html

Figure 9: dplyr solutions to "More advanced examples" from the data.table note

```
# The function n() returns the row count in each group
data %>%
  group_by(Sector) %>%
  summarise(N = n())

# Get the tickers with the highest ROE per sector using "slice"
data %>%
  group_by(Sector) %>%
  slice(which.max(ROE)) %>% # alternative: filter(ROE == max(ROE, na.rm = T))
  select(Ticker)

# Or return their entire row
data %>%
  group_by(Sector) %>%
  slice(which.max(ROE))

# All of these queries can be run after subsetting rows first
data %>%
  filter(Return12m < 0) %>%
  group_by(Sector) %>%
  slice(which.max(ROE))

# Sector average P/E, excluding each stock
data %>%
  filter(!is.na(PE)) %>%
  group_by(Sector) %>%
  mutate(SectorPEx = (n() - 1) / (sum(1 / PE) - 1 / PE)) %>%
  select(Ticker, PE, SectorPEx)

# Same as above, but with a market-cap weighted P/E
data %>%
  filter(!is.na(PE)) %>%
  group_by(Sector) %>%
  mutate(SectorPEx = (sum(MarketCap) - MarketCap) /
            (sum(MarketCap / PE) - MarketCap / PE)) %>%
  select(Ticker, PE, SectorPEx)

# Excluding each stock from the median sector P/E
## Helper function
get_pe <- function(PE) {
  sapply(seq_along(PE), function(i) median(PE[-i], na.rm = T))
}
data %>%
  filter(!is.na(PE)) %>%
  group_by(Sector) %>%
  mutate(SectorPEx = get_pe(PE)) %>%
  select(Ticker, PE, SectorPEx)

# Estimate the stock return component not explained by common risk factors
data <- data %>%
  mutate(ReturnResid = resid(
     lm(FwdReturn ~ log(MarketCap) + Beta + 1 / PBR,
        data = ., na.action = "na.exclude")))

# To refer to columns programmatically, use standard evaluation
value_cols <- c("PE", "PBR", "DivYield")
data %>% select_(.dots = value_cols)

# create new columns from the pre-specified
data %>% mutate_at(.cols = value_cols, funs("Vol" = . / Vol))

# Run a formula across these columns, e.g. to calculate the rank IC
data %>%
  summarise_at(value_cols, funs(cor(., data$FwdReturn, method = "spearman", use = "pairwise")))

# A better approach is to convert the table to a long format first
data %>%
  select_(.dots = value_cols, "FwdReturn") %>%
  tidyr::gather(measure, value, -FwdReturn) %>%
  group_by(measure) %>%
  summarise(rank_cor = cor(FwdReturn, value, method = "spearman", use = "pairwise"))
```

Source: UBS Quant

Appendix

Figure 10 contains the data required to run the examples in this report. It is identical to the one used in data.table, the best package in the world?

Figure 10: Data used in the report

```
data <- as_tibble(read.csv(
text = "Ticker,Sector,MarketCap,Beta,GrossMargin,PEG,PE,PBR,DivYield,ROE,ROIC,Vol,FwdReturn,Return1m,Return12m,NetDE
  AAPL UW,Information Technology,562022,1.38,38.80,2.12,11.84,4.38,2.00,39.06,27.47,21.97,2.36,11.49,-13.70,0.19
  MSFT UW,Information Technology,442557,1.23,62.66,NA,19.39,5.96,2.36,12.34,8.72,22.65,2.01,13.69,27.42,-0.79
  XOM UN,Energy,368876,0.82,21.54,NA,24.26,2.14,3.28,7.58,6.63,13.99,-1.18,-0.78,13.34,0.22
  JNJ UN,Health Care,344596,0.75,69.43,0.20,18.06,4.74,2.40,21.89,17.51,9.79,-4.07,5.27,29.44,-0.23
  AMZN UW,Consumer Discretionary,359676,1.34,33.48,0.00,91.71,24.27,0.00,9.10,4.35,27.04,1.36,6.31,43.07,0.10
  GE UN,Industrials,279053,1.02,34.08,0.03,19.02,3.14,2.95,8.33,2.72,17.84,0.32,4.38,23.61,1.22
  FB UW,Information Technology,355708,1.17,83.88,0.47,27.29,7.52,0.00,11.02,11.01,17.89,1.76,10.91,31.18,-0.44
  NESN VX,Consumer Staples,250209,0.78,49.62,NA,22.10,3.84,2.90,13.69,11.59,13.88,0.77,5.11,10.82,0.24
  T UN,Telecommunication Services,266320,0.46,38.60,NA,14.68,2.16,4.39,13.19,6.59,11.39,-5.57,2.46,30.59,0.98
  JPM UN,Financials,231060,1.25,NA,0.51,10.71,1.04,2.75,9.69,4.09,24.89,5.52,8.54,-3.00,2.27
  WFC UN,Financials,242176,1.07,NA,0.94,11.59,1.40,3.13,11.75,5.69,20.34,6.75,4.40,-13.69,1.82
  GOOG UW,Information Technology,527988,1.21,61.78,0.40,20.29,4.27,0.00,14.24,13.93,16.61,-0.23,9.69,18.78,-0.57
  PG UN,Consumer Staples,228360,0.60,50.23,NA,21.47,3.92,3.11,14.03,10.80,11.36,2.01,3.66,9.32,0.33
  PFE UN,Health Care,223762,0.61,72.03,0.09,14.45,3.55,3.09,11.65,8.10,12.78,-4.86,6.48,7.43,0.32
  VZ UN,Telecommunication Services,225851,0.60,47.56,2.26,13.93,12.12,4.05,128.45,14.94,12.93,-5.56,1.08,25.13,5.58
  CVX UN,Energy,193144,1.23,8.07,NA,30.39,1.28,4.18,0.85,0.70,16.28,-0.83,0.16,15.52,0.22
  NOVN VX,Health Care,197850,1.09,64.35,NA,16.84,2.78,3.36,9.13,7.54,18.76,-3.61,3.68,-15.70,0.32
  BRK/B UN,Financials,355729,0.88,24.96,1.22,18.60,1.38,0.00,9.80,7.20,15.94,4.31,2.95,0.84,0.17
  KO UN,Consumer Staples,188263,0.57,59.90,NA,22.08,7.59,3.07,27.08,13.62,13.52,-0.46,-1.20,11.11,0.99
  MRK UN,Health Care,162462,0.82,62.81,0.71,15.67,3.71,3.10,10.08,6.56,16.40,7.04,5.13,5.11,0.29
  ROG VX,Health Care,218243,1.04,69.34,0.02,15.97,10.05,3.27,43.70,23.02,20.07,-3.11,-0.28,-8.42,0.66
  HD UN,Consumer Discretionary,170865,1.06,32.27,0.91,20.51,27.17,1.78,93.09,28.78,15.99,-2.48,8.18,22.59,2.79
  INTC UW,Information Technology,164400,1.41,62.20,0.12,13.30,2.69,2.81,19.46,15.12,21.46,3.74,11.48,24.05,0.17
  BAC UN,Financials,148041,1.46,NA,NA,10.19,0.63,1.38,6.18,3.22,33.22,11.90,15.59,-16.82,1.12
  7203 JT,Consumer Discretionary,173183,0.94,20.05,5.23,10.57,1.07,3.56,13.60,8.60,33.75,5.84,17.77,-25.12,0.76
  CMCSA UW,Consumer Discretionary,162195,0.69,58.39,0.99,17.97,3.10,1.52,15.72,8.27,13.67,-2.96,8.05,10.63,0.95
  CSCO UW,Information Technology,153688,1.37,62.51,0.63,12.52,2.46,2.92,16.91,12.63,19.58,2.98,10.83,11.97,-0.56
  V UN,Information Technology,184419,0.93,78.23,0.91,24.14,5.81,0.67,23.85,18.68,21.15,3.83,5.36,6.71,-0.17
  PM UN,Consumer Staples,155536,0.72,64.38,0.03,21.19,NA,4.05,NA,50.88,16.76,-0.33,0.57,21.11,-2.11
  PEP UN,Consumer Staples,156954,0.62,54.91,NA,21.84,13.99,2.58,38.27,12.83,12.88,-1.30,5.86,15.84,2.04
  005930 KP,Information Technology,194464,0.99,37.45,0.54,9.58,1.28,1.36,11.65,11.54,21.70,5.26,7.80,24.56,-0.36
  700 HK,Information Technology,226081,0.96,58.39,0.62,31.22,11.53,0.25,28.87,19.78,23.56,8.20,10.85,29.39,-0.83
  DIS UN,Consumer Discretionary,163115,1.06,41.35,1.08,15.75,3.70,1.43,20.22,15.49,15.01,-1.55,0.57,-17.93,0.37
  HSBA LN,Financials,130240,1.19,NA,NA,11.19,0.73,6.91,6.44,3.34,19.57,15.59,10.66,-7.94,0.22
  IBM UN,Information Technology,153528,0.96,48.76,0.18,11.59,10.33,3.24,95.80,25.52,18.82,-0.23,10.75,4.66,2.06
  C UN,Financials,127286,1.62,NA,1.22,8.83,0.61,0.46,7.16,3.81,34.88,8.97,9.40,-23.90,1.24
  2330 TT,Information Technology,130621,0.97,45.46,0.80,13.34,3.49,3.48,24.33,20.89,20.60,2.03,12.42,36.80,-0.31
  ORCL UN,Information Technology,169536,1.10,74.74,0.30,14.61,3.72,1.46,18.82,10.76,19.97,0.44,5.65,6.50,-0.23
  MO UN,Consumer Staples,132286,0.46,62.41,0.31,21.00,48.25,3.27,205.76,35.00,11.90,-2.38,-1.18,26.19,3.29
  UNH UN,Health Care,136613,0.83,NA,0.34,16.68,3.88,1.40,17.93,10.94,13.06,-4.99,2.92,19.52,0.66",
stringsAsFactors = FALSE))
require(data.table)
data_dt <- data.table(data)
data_df <- as.data.frame(data)
```

Source: UBS Quant. The dataset contains 40 large-cap companies and factors associated with them as of 31/Jul/2016.

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Source: UBS. Rating allocations are as of 31 March 2017.
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2:Percentage of companies within the 12-month rating category for which investment banking (IB) services were provided within the past 12 months.
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