Bayesian Hierarchical Models in Finance

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Table of Contents

# Solution

library(rstan)

## Warning: package 'rstan' was built under R version 3.3.2

## Loading required package: ggplot2

## Warning: package 'ggplot2' was built under R version 3.3.2

## Loading required package: StanHeaders

## Warning: package 'StanHeaders' was built under R version 3.3.2

## rstan (Version 2.14.2, packaged: 2017-03-19 00:42:29 UTC, GitRev: 5fa1e80eb817)

## For execution on a local, multicore CPU with excess RAM we recommend calling  
## rstan\_options(auto\_write = TRUE)  
## options(mc.cores = parallel::detectCores())

library(ggplot2)  
library(dplyr)

##   
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':  
##   
## filter, lag

## The following objects are masked from 'package:base':  
##   
## intersect, setdiff, setequal, union

library(readr)  
library(readxl)

I am going to apply bayesian hierarchical models for solving following example problems as solutions to hopefully pass the project tests.

* Simple multivariate regression
* Multivariate regression with groupings

DIRDATA <- './data'  
DIRFIG <- './fig'  
if (!dir.exists(DIRFIG)) {dir.create(DIRFIG)}  
if (!dir.exists(DIRDATA)) {dir.create(DIRDATA)}

## Perform simple multivariate regression on Istanbul Stock Exchange Dataset

# Fetch and reading stock data  
file\_url <- 'https://archive.ics.uci.edu/ml/machine-learning-databases/00247/data\_akbilgic.xlsx'  
file\_path <- file.path(DIRDATA, 'istanbul.xlsx')  
download.file(url = file\_url,   
 destfile = file\_path,  
 method = 'wget', quiet = T)  
istanbul <- read\_excel(file\_path,   
 skip = 1)  
colnames(istanbul)[2:3] <- c('ISE\_TL', 'ISE\_USD')  
knitr::kable(istanbul)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| date | ISE\_TL | ISE\_USD | SP | DAX | FTSE | NIKKEI | BOVESPA | EU | EM |
| 2009-01-05 | 0.0357537 | 0.0383762 | -0.0046793 | 0.0021934 | 0.0038944 | 0.0000000 | 0.0311902 | 0.0126980 | 0.0285245 |
| 2009-01-06 | 0.0254259 | 0.0318127 | 0.0077867 | 0.0084553 | 0.0128656 | 0.0041625 | 0.0189196 | 0.0113407 | 0.0087726 |
| 2009-01-07 | -0.0288617 | -0.0263530 | -0.0304691 | -0.0178331 | -0.0287346 | 0.0172929 | -0.0358986 | -0.0170728 | -0.0200154 |
| 2009-01-08 | -0.0622081 | -0.0847159 | 0.0033914 | -0.0117263 | -0.0004660 | -0.0400613 | 0.0282832 | -0.0055610 | -0.0194238 |
| 2009-01-09 | 0.0098599 | 0.0096581 | -0.0215332 | -0.0198728 | -0.0127097 | -0.0044735 | -0.0097639 | -0.0109886 | -0.0078022 |
| 2009-01-12 | -0.0291910 | -0.0423612 | -0.0228226 | -0.0135257 | -0.0050255 | -0.0490385 | -0.0538495 | -0.0124513 | -0.0226297 |
| 2009-01-13 | 0.0154453 | -0.0002722 | 0.0017566 | -0.0176736 | -0.0061415 | 0.0000000 | 0.0035720 | -0.0122202 | -0.0048271 |
| 2009-01-14 | -0.0411676 | -0.0355525 | -0.0340325 | -0.0473834 | -0.0509452 | 0.0029124 | -0.0403016 | -0.0452202 | -0.0086766 |
| 2009-01-15 | 0.0006619 | -0.0172678 | 0.0013283 | -0.0195506 | -0.0143347 | -0.0504476 | 0.0303136 | -0.0120704 | -0.0234287 |
| 2009-01-16 | 0.0220373 | 0.0322780 | 0.0075331 | 0.0067908 | 0.0062892 | 0.0254532 | 0.0048667 | 0.0085609 | 0.0109169 |
| 2009-01-19 | -0.0226925 | -0.0443488 | -0.0542620 | -0.0115499 | -0.0093513 | 0.0032389 | -0.0131510 | -0.0120452 | -0.0040290 |
| 2009-01-20 | -0.0137087 | -0.0296614 | 0.0000000 | -0.0178336 | -0.0041708 | -0.0234115 | -0.0408993 | -0.0150880 | -0.0241072 |
| 2009-01-21 | 0.0008647 | 0.0015294 | 0.0425720 | 0.0050112 | -0.0077289 | -0.0205613 | 0.0335321 | -0.0033386 | -0.0050922 |
| 2009-01-22 | -0.0038151 | 0.0050432 | -0.0152785 | -0.0098414 | -0.0018984 | 0.0188179 | -0.0169817 | -0.0065522 | -0.0032272 |
| 2009-01-23 | 0.0056613 | -0.0100080 | 0.0053632 | -0.0096401 | 0.0000740 | -0.0388085 | 0.0062610 | -0.0036201 | -0.0080773 |
| 2009-01-26 | 0.0468313 | 0.0617082 | 0.0055379 | 0.0347868 | 0.0378911 | -0.0081816 | 0.0098382 | 0.0327996 | 0.0103197 |
| 2009-01-27 | -0.0066350 | 0.0109487 | 0.0108663 | -0.0007977 | -0.0034748 | 0.0481481 | 0.0049218 | -0.0026418 | 0.0063445 |
| 2009-01-28 | 0.0345670 | 0.0358709 | 0.0330068 | 0.0441820 | 0.0237478 | 0.0055940 | 0.0387247 | 0.0299742 | 0.0221041 |
| 2009-01-29 | -0.0205282 | -0.0202718 | -0.0336811 | -0.0202559 | -0.0247735 | 0.0177232 | -0.0147502 | -0.0231086 | 0.0004087 |
| 2009-01-30 | -0.0087767 | -0.0234583 | -0.0230528 | -0.0204788 | -0.0097127 | -0.0316660 | -0.0085383 | -0.0072013 | 0.0022425 |
| 2009-02-02 | -0.0259191 | -0.0356075 | -0.0005329 | -0.0156367 | -0.0174543 | -0.0151339 | -0.0162893 | -0.0197393 | -0.0190914 |
| 2009-02-03 | 0.0152795 | 0.0224028 | 0.0157099 | 0.0240400 | 0.0210386 | -0.0061747 | 0.0275737 | 0.0178623 | 0.0127187 |
| 2009-02-04 | 0.0185778 | 0.0232308 | -0.0075177 | 0.0265765 | 0.0152747 | 0.0269083 | 0.0095649 | 0.0187700 | 0.0151656 |
| 2009-02-05 | -0.0141329 | -0.0145714 | 0.0162332 | 0.0039319 | 0.0000709 | -0.0111693 | 0.0241278 | -0.0041391 | 0.0020725 |
| 2009-02-06 | 0.0366070 | 0.0427589 | 0.0265407 | 0.0293059 | 0.0147876 | 0.0158456 | 0.0392825 | 0.0191267 | 0.0323381 |
| 2009-02-09 | 0.0113532 | 0.0214676 | 0.0014840 | 0.0047662 | 0.0036514 | -0.0134107 | -0.0154618 | 0.0056272 | 0.0078954 |
| 2009-02-10 | -0.0405420 | -0.0439069 | -0.0503686 | -0.0351701 | -0.0221822 | -0.0029017 | -0.0214396 | -0.0243878 | -0.0021391 |
| 2009-02-11 | -0.0221056 | -0.0338935 | 0.0079235 | 0.0054341 | 0.0050193 | -0.0307449 | -0.0087992 | 0.0010974 | -0.0079260 |
| 2009-02-12 | -0.0148884 | -0.0208250 | 0.0017376 | -0.0274206 | -0.0076098 | 0.0000000 | -0.0084822 | -0.0140922 | -0.0147727 |
| 2009-02-13 | 0.0070267 | 0.0097092 | -0.0100480 | 0.0013219 | -0.0030029 | 0.0095630 | 0.0285508 | 0.0030319 | 0.0177644 |
| 2009-02-16 | -0.0114950 | -0.0246291 | -0.0466294 | -0.0456140 | -0.0131663 | -0.0037644 | 0.0039993 | -0.0127217 | -0.0068504 |
| 2009-02-17 | -0.0411360 | -0.0506875 | 0.0000000 | 0.0000000 | -0.0246557 | -0.0135962 | -0.0488296 | -0.0309350 | -0.0383228 |
| 2009-02-18 | -0.0026315 | -0.0121011 | -0.0009508 | -0.0027643 | -0.0067903 | -0.0146340 | -0.0043511 | -0.0033031 | -0.0033423 |
| 2009-02-19 | 0.0246546 | 0.0329232 | -0.0120969 | 0.0024346 | 0.0028909 | 0.0030758 | 0.0014105 | 0.0025695 | 0.0067645 |
| 2009-02-20 | -0.0358406 | -0.0497757 | -0.0114786 | -0.0487468 | -0.0327060 | -0.0188692 | -0.0258794 | -0.0379240 | -0.0272944 |
| 2009-02-23 | 0.0173032 | 0.0295662 | -0.0353154 | -0.0196734 | -0.0099228 | -0.0054379 | -0.0125543 | -0.0121596 | 0.0096779 |
| 2009-02-24 | 0.0017254 | -0.0041517 | 0.0393201 | -0.0103931 | -0.0089474 | -0.0146950 | 0.0000000 | -0.0094470 | -0.0118811 |
| 2009-02-25 | 0.0049759 | 0.0101978 | -0.0107150 | -0.0127980 | 0.0085058 | 0.0261607 | 0.0000000 | -0.0009942 | 0.0060994 |
| 2009-02-26 | 0.0006718 | -0.0008120 | -0.0159057 | 0.0247572 | 0.0171552 | -0.0004410 | -0.0013610 | 0.0209026 | -0.0023312 |
| 2009-02-27 | -0.0058919 | -0.0095185 | -0.0238465 | -0.0253996 | -0.0220777 | 0.0147064 | 0.0000786 | -0.0182614 | -0.0061501 |
| 2009-03-02 | -0.0136890 | -0.0313240 | -0.0477419 | -0.0353951 | -0.0548160 | -0.0388329 | -0.0523649 | -0.0488168 | -0.0353649 |
| 2009-03-03 | 0.0021930 | 0.0041229 | -0.0064274 | -0.0052292 | -0.0318608 | -0.0069512 | 0.0064097 | -0.0202991 | 0.0012903 |
| 2009-03-04 | 0.0079132 | 0.0027227 | 0.0234754 | 0.0528292 | 0.0373891 | 0.0084349 | 0.0516744 | 0.0365485 | 0.0303115 |
| 2009-03-05 | -0.0385222 | -0.0433816 | -0.0434633 | -0.0515376 | -0.0323337 | 0.0193602 | -0.0272681 | -0.0374652 | -0.0086718 |
| 2009-03-06 | 0.0079588 | -0.0192349 | 0.0012153 | -0.0079002 | 0.0002266 | -0.0356575 | -0.0070898 | -0.0111720 | -0.0020976 |
| 2009-03-09 | -0.0071335 | -0.0164370 | -0.0100743 | 0.0069635 | 0.0033083 | -0.0122127 | -0.0098584 | -0.0001779 | -0.0055584 |
| 2009-03-10 | 0.0112340 | 0.0218827 | 0.0617187 | 0.0514561 | 0.0476280 | -0.0043915 | 0.0543981 | 0.0504593 | 0.0249100 |
| 2009-03-11 | -0.0014104 | 0.0244324 | 0.0024428 | 0.0069529 | -0.0057768 | 0.0445140 | 0.0002577 | 0.0039505 | 0.0128157 |
| 2009-03-12 | 0.0109744 | 0.0027419 | 0.0399211 | 0.0107036 | 0.0049420 | -0.0244098 | 0.0089024 | 0.0098012 | 0.0054195 |
| 2009-03-13 | 0.0032133 | 0.0340667 | 0.0077092 | -0.0006625 | 0.0111443 | 0.0502600 | -0.0035053 | 0.0061939 | 0.0186892 |
| 2009-03-16 | 0.0002142 | 0.0056095 | -0.0035222 | 0.0227413 | 0.0289609 | 0.0176612 | -0.0105126 | 0.0266777 | 0.0102539 |
| 2009-03-17 | -0.0071188 | -0.0136301 | 0.0316343 | -0.0141356 | -0.0017873 | 0.0313033 | 0.0231455 | -0.0056837 | 0.0026887 |
| 2009-03-18 | 0.0018918 | -0.0008814 | 0.0206434 | 0.0021418 | -0.0135996 | 0.0028942 | 0.0158441 | -0.0042048 | 0.0060125 |
| 2009-03-19 | 0.0198742 | 0.0308887 | -0.0130641 | 0.0117268 | 0.0031226 | -0.0032931 | 0.0077176 | 0.0070284 | 0.0098473 |
| 2009-03-20 | 0.0029187 | -0.0009517 | -0.0199674 | 0.0062326 | 0.0067887 | 0.0333626 | -0.0093632 | 0.0033750 | -0.0066544 |
| 2009-03-23 | 0.0359681 | 0.0513307 | 0.0683664 | 0.0261091 | 0.0281969 | 0.0000000 | 0.0572901 | 0.0283794 | 0.0441216 |
| 2009-03-24 | 0.0032984 | 0.0118940 | -0.0206264 | 0.0026280 | -0.0105033 | 0.0326625 | -0.0229528 | -0.0039239 | 0.0022960 |
| 2009-03-25 | 0.0211651 | 0.0148580 | 0.0095803 | 0.0085440 | -0.0028675 | -0.0009795 | 0.0077575 | 0.0071259 | 0.0083097 |
| 2009-03-26 | -0.0049684 | 0.0005461 | 0.0230526 | 0.0085068 | 0.0063638 | 0.0182685 | 0.0187236 | 0.0045644 | 0.0164176 |
| 2009-03-27 | 0.0112479 | 0.0064080 | -0.0205247 | -0.0131919 | -0.0067228 | -0.0010844 | -0.0161431 | -0.0131921 | -0.0067309 |
| 2009-03-30 | -0.0217802 | -0.0405766 | -0.0354394 | -0.0523312 | -0.0355045 | -0.0463688 | -0.0303802 | -0.0395754 | -0.0385645 |
| 2009-03-31 | 0.0244066 | 0.0362165 | 0.0130442 | 0.0236647 | 0.0424566 | -0.0154846 | 0.0066929 | 0.0339053 | 0.0078342 |
| 2009-04-01 | 0.0069134 | 0.0195870 | 0.0164210 | 0.0112735 | 0.0074857 | 0.0294503 | 0.0253325 | 0.0131310 | 0.0153395 |
| 2009-04-02 | 0.0314018 | 0.0525224 | 0.0283222 | 0.0589505 | 0.0419337 | 0.0431038 | 0.0410735 | 0.0462999 | 0.0385062 |
| 2009-04-03 | -0.0052474 | 0.0108959 | 0.0096847 | 0.0007004 | -0.0233741 | 0.0034414 | 0.0148652 | -0.0135659 | 0.0043115 |
| 2009-04-06 | 0.0007357 | 0.0186135 | -0.0083673 | -0.0080552 | -0.0090239 | 0.0122777 | -0.0050588 | -0.0066394 | 0.0041919 |
| 2009-04-07 | -0.0102976 | -0.0350282 | -0.0241437 | -0.0062982 | -0.0159014 | -0.0028354 | -0.0077735 | -0.0109735 | -0.0055659 |
| 2009-04-08 | 0.0472389 | 0.0460461 | 0.0117146 | 0.0081609 | -0.0012729 | -0.0272959 | 0.0081130 | 0.0045762 | -0.0075011 |
| 2009-04-09 | 0.0317777 | 0.0515575 | 0.0373471 | 0.0301072 | 0.0147173 | 0.0366723 | 0.0302516 | 0.0203502 | 0.0276959 |
| 2009-04-10 | 0.0101707 | 0.0146486 | 0.0025302 | 0.0000000 | 0.0013295 | 0.0053747 | 0.0098984 | 0.0000000 | 0.0053860 |
| 2009-04-13 | -0.0136613 | -0.0184581 | 0.0000000 | 0.0000000 | 0.0000000 | -0.0044364 | 0.0000000 | 0.0000000 | 0.0058796 |
| 2009-04-14 | -0.0101114 | -0.0092198 | -0.0202685 | 0.0145646 | 0.0000000 | -0.0092025 | -0.0125590 | 0.0104106 | 0.0074141 |
| 2009-04-15 | 0.0057888 | -0.0072719 | 0.0124709 | -0.0015856 | -0.0051776 | -0.0113412 | -0.0031977 | -0.0056921 | 0.0027113 |
| 2009-04-16 | 0.0414550 | 0.0371139 | 0.0154193 | 0.0130296 | 0.0210944 | 0.0014059 | 0.0164739 | 0.0196792 | 0.0024387 |
| 2009-04-17 | -0.0026180 | -0.0064409 | 0.0049571 | 0.0145120 | 0.0097720 | 0.0172479 | -0.0053811 | 0.0150008 | -0.0055259 |
| 2009-04-20 | -0.0309548 | -0.0435617 | -0.0437323 | -0.0415944 | -0.0252126 | 0.0019257 | -0.0298212 | -0.0331451 | -0.0083578 |
| 2009-04-21 | 0.0045482 | -0.0139764 | 0.0210294 | 0.0034112 | -0.0008523 | -0.0242038 | 0.0101881 | 0.0001071 | -0.0072766 |
| 2009-04-22 | 0.0096559 | 0.0179867 | -0.0077113 | 0.0204030 | 0.0107756 | 0.0018316 | 0.0000000 | 0.0142466 | -0.0009667 |
| 2009-04-24 | 0.0245170 | 0.0414637 | 0.0265313 | 0.0172412 | 0.0306130 | -0.0022150 | 0.0411142 | 0.0197327 | 0.0229151 |
| 2009-04-27 | -0.0041629 | -0.0077655 | -0.0101176 | 0.0042163 | 0.0026433 | 0.0021050 | -0.0205641 | 0.0011938 | -0.0187367 |
| 2009-04-28 | -0.0123680 | -0.0212445 | -0.0027443 | -0.0186320 | -0.0170878 | -0.0270131 | 0.0000218 | -0.0161920 | -0.0132240 |
| 2009-04-29 | 0.0519803 | 0.0730054 | 0.0213798 | 0.0208642 | 0.0224967 | 0.0386250 | 0.0302233 | 0.0212245 | 0.0258124 |
| 2009-04-30 | 0.0290227 | 0.0404980 | -0.0009505 | 0.0136987 | 0.0128303 | 0.0000000 | 0.0013331 | 0.0133644 | 0.0164448 |
| 2009-05-04 | 0.0162611 | 0.0156193 | 0.0386891 | 0.0275041 | 0.0217243 | 0.0612293 | 0.0637915 | 0.0156414 | 0.0478045 |
| 2009-05-05 | 0.0258823 | 0.0424922 | -0.0037989 | -0.0101318 | 0.0000000 | 0.0000000 | 0.0052436 | 0.0047224 | 0.0040358 |
| 2009-05-06 | 0.0210611 | 0.0155400 | 0.0172546 | 0.0056874 | 0.0136490 | 0.0000000 | 0.0162284 | 0.0127287 | 0.0117374 |
| 2009-05-07 | -0.0262730 | -0.0116927 | -0.0132903 | -0.0158210 | 0.0005003 | 0.0000000 | -0.0283801 | -0.0052341 | -0.0024674 |
| 2009-05-08 | -0.0011239 | -0.0059183 | 0.0237839 | 0.0225982 | 0.0143105 | 0.0050089 | 0.0263780 | 0.0168389 | 0.0103309 |
| 2009-05-11 | -0.0185414 | -0.0184132 | -0.0217472 | -0.0096087 | -0.0059792 | 0.0020281 | -0.0082054 | -0.0118346 | -0.0055794 |
| 2009-05-12 | 0.0257567 | 0.0204679 | -0.0009793 | -0.0026335 | -0.0022571 | -0.0163593 | -0.0128331 | -0.0041182 | -0.0022450 |
| 2009-05-13 | -0.0065090 | -0.0007033 | -0.0272632 | -0.0264060 | -0.0214925 | 0.0044938 | -0.0332741 | -0.0244430 | -0.0106736 |
| 2009-05-14 | 0.0080706 | -0.0083645 | 0.0102984 | 0.0022945 | 0.0071774 | -0.0267735 | 0.0156334 | 0.0043935 | -0.0113050 |
| 2009-05-15 | 0.0117034 | 0.0190548 | -0.0114757 | -0.0002047 | -0.0033292 | 0.0186609 | -0.0089180 | 0.0025040 | 0.0081605 |
| 2009-05-18 | 0.0054076 | 0.0082946 | 0.0299366 | 0.0238732 | 0.0223783 | -0.0247318 | 0.0489000 | 0.0213451 | 0.0273480 |
| 2009-05-20 | 0.0428407 | 0.0612849 | -0.0068830 | 0.0378130 | 0.0049131 | 0.0332887 | -0.0042451 | 0.0175558 | 0.0234053 |
| 2009-05-21 | -0.0119998 | -0.0120659 | -0.0168996 | -0.0278238 | -0.0278896 | -0.0086508 | -0.0228566 | -0.0208690 | -0.0170319 |
| 2009-05-22 | 0.0084305 | 0.0085595 | -0.0014983 | 0.0036825 | 0.0045461 | -0.0041471 | 0.0095575 | -0.0008097 | 0.0021301 |
| 2009-05-25 | 0.0111665 | 0.0028121 | 0.0259622 | -0.0000610 | 0.0105732 | 0.0130504 | 0.0048923 | 0.0016306 | 0.0008415 |
| 2009-05-26 | -0.0155726 | -0.0220491 | 0.0000000 | 0.0135603 | 0.0000000 | -0.0038793 | 0.0199701 | 0.0069303 | -0.0053315 |
| 2009-05-27 | 0.0088012 | 0.0060894 | -0.0191534 | 0.0030381 | 0.0010195 | 0.0136496 | -0.0009456 | 0.0035961 | 0.0163607 |
| 2009-05-28 | -0.0042092 | -0.0094697 | 0.0153012 | -0.0136689 | -0.0065200 | 0.0013361 | 0.0238295 | -0.0093201 | 0.0085829 |
| 2009-05-29 | -0.0005147 | 0.0174513 | 0.0134834 | 0.0016083 | 0.0069049 | 0.0074956 | 0.0029556 | 0.0027275 | 0.0077608 |
| 2009-06-01 | 0.0281313 | 0.0367760 | 0.0254900 | 0.0400197 | 0.0197898 | 0.0161720 | 0.0239230 | 0.0229885 | 0.0299783 |
| 2009-06-02 | -0.0077924 | -0.0104236 | 0.0019813 | 0.0002916 | -0.0065010 | 0.0027407 | -0.0089597 | 0.0004509 | -0.0066305 |
| 2009-06-03 | -0.0223624 | -0.0203928 | -0.0138345 | -0.0175578 | -0.0211285 | 0.0038424 | -0.0360686 | -0.0191999 | -0.0130267 |
| 2009-06-04 | -0.0191720 | -0.0265030 | 0.0114182 | 0.0020298 | 0.0007981 | -0.0074918 | 0.0260931 | 0.0011987 | -0.0012837 |
| 2009-06-05 | 0.0139471 | 0.0142071 | -0.0025179 | 0.0024118 | 0.0117162 | 0.0101920 | -0.0023033 | 0.0062554 | 0.0071952 |
| 2009-06-08 | -0.0320059 | -0.0432971 | -0.0010111 | -0.0143450 | -0.0075534 | 0.0099442 | 0.0054033 | -0.0100882 | -0.0105369 |
| 2009-06-09 | 0.0044784 | 0.0066707 | 0.0034971 | -0.0013716 | -0.0000908 | -0.0080204 | -0.0088588 | 0.0022475 | -0.0051489 |
| 2009-06-10 | 0.0170891 | 0.0267133 | -0.0034864 | 0.0106121 | 0.0072385 | 0.0206971 | 0.0047669 | 0.0095636 | 0.0196234 |
| 2009-06-11 | 0.0096798 | 0.0064144 | 0.0060933 | 0.0110412 | 0.0056413 | -0.0010174 | 0.0027485 | 0.0076079 | 0.0028886 |
| 2009-06-12 | 0.0026710 | 0.0086824 | 0.0013960 | -0.0074722 | -0.0044700 | 0.0153593 | 0.0000000 | -0.0033602 | -0.0021802 |
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| 2010-12-14 | 0.0019455 | 0.0046893 | 0.0009105 | -0.0002831 | 0.0051736 | 0.0022202 | -0.0055560 | 0.0029448 | 0.0029709 |
| 2010-12-15 | -0.0153100 | -0.0267033 | -0.0051356 | -0.0015708 | -0.0015289 | -0.0006778 | -0.0127808 | -0.0030665 | -0.0054337 |
| 2010-12-16 | -0.0164666 | -0.0196412 | 0.0061660 | 0.0011438 | -0.0001870 | 0.0001465 | -0.0083447 | 0.0005709 | -0.0052808 |
| 2010-12-17 | -0.0141507 | -0.0169853 | 0.0008364 | -0.0059899 | -0.0015826 | -0.0007237 | 0.0099789 | -0.0035726 | 0.0036264 |
| 2010-12-20 | -0.0003558 | -0.0173917 | 0.0025452 | 0.0051639 | 0.0033664 | -0.0085204 | -0.0106031 | 0.0037375 | -0.0035650 |
| 2010-12-21 | 0.0205439 | 0.0182172 | 0.0060120 | 0.0084262 | 0.0101661 | 0.0149729 | 0.0140393 | 0.0105567 | 0.0094689 |
| 2010-12-22 | 0.0095284 | 0.0121767 | 0.0033739 | -0.0014237 | 0.0053120 | -0.0023218 | 0.0037458 | 0.0011311 | 0.0013270 |
| 2010-12-23 | 0.0118301 | 0.0124789 | -0.0016457 | -0.0014484 | 0.0021036 | -0.0065249 | 0.0002190 | 0.0008880 | -0.0002079 |
| 2010-12-24 | 0.0007300 | 0.0042330 | 0.0006125 | -0.0123978 | 0.0021324 | 0.0000000 | -0.0100229 | 0.0001830 | -0.0024749 |
| 2010-12-27 | 0.0013458 | 0.0006340 | 0.0000000 | 0.0000000 | -0.0020824 | 0.0074436 | 0.0000000 | -0.0058607 | -0.0024167 |
| 2010-12-28 | 0.0012854 | 0.0004384 | 0.0007710 | 0.0001965 | 0.0000000 | -0.0061370 | 0.0035040 | 0.0002086 | -0.0001955 |
| 2010-12-29 | 0.0041715 | -0.0055818 | 0.0010086 | 0.0033463 | 0.0000000 | 0.0050307 | 0.0133001 | 0.0019233 | 0.0078615 |
| 2010-12-30 | 0.0015347 | 0.0084385 | -0.0015093 | -0.0116870 | -0.0042449 | -0.0112398 | 0.0051064 | -0.0091907 | 0.0033136 |
| 2010-12-31 | -0.0123118 | -0.0068611 | -0.0001908 | 0.0000000 | -0.0119790 | 0.0164041 | 0.0094352 | -0.0061579 | 0.0027894 |
| 2011-01-03 | 0.0240022 | 0.0175155 | 0.0112513 | 0.0108675 | 0.0191381 | 0.0000000 | 0.0000000 | 0.0096329 | 0.0081677 |
| 2011-01-04 | 0.0090402 | 0.0110476 | -0.0013139 | -0.0020609 | 0.0000000 | 0.0000000 | 0.0050756 | 0.0065765 | 0.0042388 |
| 2011-01-05 | 0.0088595 | 0.0117802 | 0.0049946 | -0.0051067 | 0.0049760 | -0.0016680 | 0.0109329 | -0.0005483 | -0.0011801 |
| 2011-01-06 | 0.0069824 | 0.0068502 | -0.0021251 | 0.0059722 | -0.0040453 | 0.0142505 | -0.0072281 | -0.0006202 | -0.0026460 |
| 2011-01-07 | -0.0078351 | -0.0187548 | -0.0018465 | -0.0048172 | -0.0058648 | 0.0010707 | -0.0074235 | -0.0054614 | -0.0068197 |
| 2011-01-10 | -0.0131088 | -0.0263247 | -0.0013773 | -0.0131520 | -0.0046899 | -0.0028843 | 0.0009987 | -0.0098457 | -0.0067087 |
| 2011-01-11 | -0.0030355 | 0.0017948 | 0.0037182 | 0.0122492 | 0.0096406 | 0.0000000 | 0.0042120 | 0.0126380 | 0.0047726 |
| 2011-01-12 | 0.0037605 | 0.0090641 | 0.0089673 | 0.0181599 | 0.0060839 | 0.0002017 | 0.0170359 | 0.0143967 | 0.0118722 |
| 2011-01-13 | 0.0095468 | 0.0162976 | -0.0017122 | 0.0008951 | -0.0044391 | 0.0072939 | -0.0128133 | -0.0003675 | -0.0021093 |
| 2011-01-14 | -0.0101990 | -0.0047002 | 0.0073574 | 0.0000834 | -0.0036255 | -0.0086037 | 0.0030919 | -0.0007612 | 0.0002376 |
| 2011-01-17 | -0.0155634 | -0.0153677 | 0.0013754 | 0.0003335 | -0.0027361 | 0.0003638 | -0.0046768 | -0.0021468 | -0.0045367 |
| 2011-01-18 | -0.0060494 | 0.0045795 | 0.0000000 | 0.0091960 | 0.0117423 | 0.0015336 | 0.0043949 | 0.0109948 | 0.0024059 |
| 2011-01-19 | 0.0005207 | -0.0032090 | -0.0101672 | -0.0085322 | -0.0132470 | 0.0036174 | -0.0122290 | -0.0106446 | 0.0010858 |
| 2011-01-20 | -0.0178350 | -0.0316517 | -0.0012958 | -0.0082924 | -0.0183718 | -0.0114117 | -0.0071050 | -0.0100879 | -0.0104420 |
| 2011-01-21 | 0.0097441 | -0.0005108 | 0.0024107 | 0.0054165 | 0.0048282 | -0.0157198 | -0.0061863 | 0.0083960 | -0.0068535 |
| 2011-01-24 | -0.0110671 | -0.0074263 | 0.0058193 | 0.0007572 | 0.0080404 | 0.0068469 | 0.0042437 | 0.0041580 | -0.0011448 |
| 2011-01-25 | -0.0007489 | 0.0046386 | 0.0002634 | -0.0012402 | -0.0044176 | 0.0114670 | -0.0103956 | -0.0040442 | -0.0008855 |
| 2011-01-26 | 0.0123261 | 0.0054044 | 0.0042121 | 0.0096347 | 0.0086651 | -0.0059924 | 0.0000000 | 0.0070969 | 0.0050185 |
| 2011-01-27 | -0.0140821 | -0.0149764 | 0.0022418 | 0.0039530 | -0.0006871 | 0.0073523 | -0.0096228 | 0.0019194 | -0.0011489 |
| 2011-01-28 | -0.0284982 | -0.0385990 | -0.0180137 | -0.0074034 | -0.0141310 | -0.0113558 | -0.0200825 | -0.0104778 | -0.0099119 |
| 2011-01-31 | 0.0010562 | -0.0088830 | 0.0076333 | -0.0035712 | -0.0031505 | -0.0118866 | -0.0018458 | -0.0026495 | -0.0057887 |
| 2011-02-01 | 0.0241158 | 0.0352568 | 0.0165558 | 0.0149760 | 0.0160569 | 0.0035666 | 0.0189260 | 0.0150886 | 0.0062239 |
| 2011-02-02 | 0.0074468 | 0.0142386 | -0.0027263 | -0.0000835 | 0.0070748 | 0.0176409 | -0.0172301 | 0.0016178 | 0.0036313 |
| 2011-02-03 | -0.0244781 | -0.0278502 | 0.0023515 | 0.0013925 | -0.0028039 | -0.0024894 | 0.0011540 | -0.0028835 | 0.0004761 |
| 2011-02-04 | 0.0245066 | 0.0139592 | 0.0028801 | 0.0031270 | 0.0023538 | 0.0106948 | -0.0226618 | 0.0027611 | -0.0031849 |
| 2011-02-07 | -0.0061961 | 0.0085529 | 0.0062207 | 0.0092981 | 0.0088975 | 0.0045913 | 0.0014239 | 0.0082167 | -0.0033457 |
| 2011-02-08 | 0.0053556 | 0.0068857 | 0.0041761 | 0.0054249 | 0.0066380 | 0.0041398 | 0.0062380 | 0.0039803 | -0.0044990 |
| 2011-02-09 | 0.0048230 | -0.0032549 | -0.0027897 | -0.0003196 | -0.0064232 | -0.0017079 | -0.0238955 | -0.0030241 | -0.0142486 |
| 2011-02-10 | -0.0176644 | -0.0249206 | 0.0007492 | 0.0026437 | -0.0053511 | -0.0011478 | 0.0055902 | -0.0037424 | -0.0147596 |
| 2011-02-11 | 0.0047823 | 0.0064182 | 0.0054922 | 0.0042035 | 0.0071010 | 0.0112409 | 0.0180771 | 0.0047272 | 0.0039309 |
| 2011-02-14 | -0.0024979 | 0.0004045 | 0.0023821 | 0.0034440 | -0.0004619 | 0.0000000 | 0.0121228 | 0.0001685 | 0.0134481 |
| 2011-02-15 | 0.0036064 | 0.0008927 | -0.0032402 | 0.0004609 | -0.0038025 | 0.0019681 | -0.0032656 | -0.0005499 | -0.0014304 |
| 2011-02-16 | 0.0085991 | 0.0133999 | 0.0062380 | 0.0019252 | 0.0079523 | 0.0057175 | 0.0183708 | 0.0069746 | 0.0030390 |
| 2011-02-17 | 0.0093103 | 0.0159772 | 0.0030709 | -0.0011862 | 0.0003450 | 0.0026196 | 0.0016857 | -0.0005805 | 0.0010386 |
| 2011-02-18 | 0.0001910 | -0.0016526 | 0.0019229 | 0.0028721 | -0.0007231 | 0.0005683 | 0.0056279 | 0.0005716 | 0.0069379 |
| 2011-02-21 | -0.0130690 | -0.0137060 | -0.0207422 | -0.0142389 | -0.0112749 | 0.0013576 | -0.0119417 | -0.0126153 | -0.0009577 |
| 2011-02-22 | -0.0072463 | -0.0194418 | 0.0000000 | -0.0004727 | -0.0029971 | -0.0179196 | -0.0122516 | -0.0054649 | -0.0142969 |

## Perform multivariate regression with groups on Insurance Company Benchmark dataset

file\_url <- 'https://archive.ics.uci.edu/ml/datasets/Insurance+Company+Benchmark+%28COIL+2000%29'  
# multivariate regression with training and prediction