

# Supplementary Material of “Statistical Modeling of Financial Data with Skew-Symmetric Error Distributions”

September 14, 2023

## 1 Nikkei Industry Classification Codes

Major	Middle	Minor	Major	Middle	Minor
Manufacturing Industry	Foods	Feeds	1	01	001
Manufacturing Industry	Foods	Sugar Refining	1	01	002
Manufacturing Industry	Foods	Grain Mill Products	1	01	003
Manufacturing Industry	Foods	Vegetable Oils	1	01	004
Manufacturing Industry	Foods	Breweries & Distilleries	1	01	005
Manufacturing Industry	Foods	Bakery Products	1	01	006
Manufacturing Industry	Foods	Meat Products	1	01	007
Manufacturing Industry	Foods	Flavoring Extracts	1	01	008
Manufacturing Industry	Foods	Dairy Products	1	01	009
Manufacturing Industry	Foods	Foods, NEC	1	01	010
Manufacturing Industry	Textile Products	Chemistry & Synthetic Fibers	1	03	021
Manufacturing Industry	Textile Products	Cotton Spinning & Weaving	1	03	022
Manufacturing Industry	Textile Products	Silk Reeling	1	03	023
Manufacturing Industry	Textile Products	Wool Spinning & Weaving	1	03	024
Manufacturing Industry	Textile Products	Finished Textile Goods	1	03	025
Manufacturing Industry	Textile Products	Miscellaneous Textile Products	1	03	026
Manufacturing Industry	Pulp & Paper	Pulp and Paper (Major)	1	05	041
Manufacturing Industry	Pulp & Paper	Other Paper	1	05	042
Manufacturing Industry	Chemicals	Chemicals (Major)	1	07	061
Manufacturing Industry	Chemicals	Chemical Fertilizers	1	07	062
Manufacturing Industry	Chemicals	Alkali & Chlorine	1	07	063
Manufacturing Industry	Chemicals	Petro-Chemicals	1	07	064
Manufacturing Industry	Chemicals	Plastics	1	07	065
Manufacturing Industry	Chemicals	Oxygen	1	07	066
Manufacturing Industry	Chemicals	Oils, Fats & Soap	1	07	067
Manufacturing Industry	Chemicals	Cosmetics & Toilet Goods	1	07	068
Manufacturing Industry	Chemicals	Paint & Printing Inks	1	07	069
Manufacturing Industry	Chemicals	Agricultural Chemicals	1	07	070
Manufacturing Industry	Chemicals	Chemical Products, NEC	1	07	071
Manufacturing Industry	Drugs	Drugs (Major)	1	09	081
Manufacturing Industry	Drugs	Ethical Drugs	1	09	082
Manufacturing Industry	Drugs	Proprietary Drugs	1	09	083
Manufacturing Industry	Petroleum	Oil Refining & Sales	1	11	101
Manufacturing Industry	Petroleum	Oil & Coal Products	1	11	102
Manufacturing Industry	Rubber Products	Tires	1	13	121
Manufacturing Industry	Rubber Products	Rubber Products, NEC	1	13	122
Manufacturing Industry	Stone, Clay & Glass Products	Glass	1	15	141
Manufacturing Industry	Stone, Clay & Glass Products	Cement	1	15	142
Manufacturing Industry	Stone, Clay & Glass Products	Concrete Products	1	15	143
Manufacturing Industry	Stone, Clay & Glass Products	Pottery & Related Products	1	15	144
Manufacturing Industry	Stone, Clay & Glass Products	Bricks	1	15	145
Manufacturing Industry	Stone, Clay & Glass Products	Carbon, NEC	1	15	146
Manufacturing Industry	Iron & Steel	Iron & Steel (Major)	1	17	161
Manufacturing Industry	Iron & Steel	Ordinary Steel	1	17	162
Manufacturing Industry	Iron & Steel	Special Steel	1	17	163
Manufacturing Industry	Iron & Steel	Alloy Steel	1	17	164
Manufacturing Industry	Iron & Steel	Iron & Steel Foundries	1	17	165
Manufacturing Industry	Iron & Steel	Stainless Steel	1	17	166
Manufacturing Industry	Iron & Steel	Steel, NEC	1	17	167
Manufacturing Industry	Non ferrous Metal & Metal Products	Non-Ferrous Refining (Major)	1	19	181
Manufacturing Industry	Non ferrous Metal & Metal Products	Other Non-Ferrous Metal Refining	1	19	182
Manufacturing Industry	Non ferrous Metal & Metal Products	Aluminum	1	19	183
Manufacturing Industry	Non ferrous Metal & Metal Products	Wire & Cable	1	19	184
Manufacturing Industry	Non ferrous Metal & Metal Products	Fabricated Metal Products	1	19	185

Manufacturing Industry	Non ferrous Metal & Metal Products	Metal Products, NEC	1	19	186
Manufacturing Industry	Machinery	Machine Tools	1	21	201
Manufacturing Industry	Machinery	Press Machines	1	21	202
Manufacturing Industry	Machinery	Textile Machines	1	21	203
Manufacturing Industry	Machinery	Construction Machines	1	21	204
Manufacturing Industry	Machinery	Agricultural Machines	1	21	205
Manufacturing Industry	Machinery	Special Industrial Machines	1	21	206
Manufacturing Industry	Machinery	Sawing & Knitting Machines	1	21	207
Manufacturing Industry	Machinery	Bearings	1	21	208
Manufacturing Industry	Machinery	Office Machines	1	21	209
Manufacturing Industry	Machinery	Machinery, NEC	1	21	210
Manufacturing Industry	Electric & Electronic Equipment	General Electric	1	23	221
Manufacturing Industry	Electric & Electronic Equipment	Heavy Electric	1	23	222
Manufacturing Industry	Electric & Electronic Equipment	Household Appliances	1	23	223
Manufacturing Industry	Electric & Electronic Equipment	Communication Equipment	1	23	224
Manufacturing Industry	Electric & Electronic Equipment	Electronic Components	1	23	225
Manufacturing Industry	Electric & Electronic Equipment	Electric Industrial Controls	1	23	226
Manufacturing Industry	Electric & Electronic Equipment	Battery	1	23	227
Manufacturing Industry	Electric & Electronic Equipment	Electric Auto Parts	1	23	228
Manufacturing Industry	Electric & Electronic Equipment	Electric Equipment, NEC	1	23	229
Manufacturing Industry	Shipbuilding & Repairing	Shipbuilding & Repairing	1	25	241
Manufacturing Industry	Motor Vehicles & Auto Parts	Motor Vehicles	1	27	261
Manufacturing Industry	Motor Vehicles & Auto Parts	Auto Parts & Accessories	1	27	262
Manufacturing Industry	Motor Vehicles & Auto Parts	Auto Body, NEC	1	27	263
Manufacturing Industry	Transportation Equipment	Railroad Equipment	1	29	281
Manufacturing Industry	Transportation Equipment	Bicycles	1	29	282
Manufacturing Industry	Transportation Equipment	Transportation Equipment, NEC	1	29	283
Manufacturing Industry	Precision Equipment	Watches & Clocks	1	31	301
Manufacturing Industry	Precision Equipment	Optical Instrument	1	31	302
Manufacturing Industry	Precision Equipment	Measuring Devices, NEC	1	31	303
Manufacturing Industry	Other Manufacturing	Printing	1	33	321
Manufacturing Industry	Other Manufacturing	Musical Instrument	1	33	322
Manufacturing Industry	Other Manufacturing	Lumber & Wood Products	1	33	323
Manufacturing Industry	Other Manufacturing	Office Supplies	1	33	324
Manufacturing Industry	Other Manufacturing	Manufacturing, NEC	1	33	325
Non-Manufacturing Industry	Fish & Marine Products	Fish & Marine Products	2	35	341
Non-Manufacturing Industry	Mining	Coal Mining	2	37	361
Non-Manufacturing Industry	Mining	Mining Except Coal Mining	2	37	362
Non-Manufacturing Industry	Construction	General Construction (Major)	2	41	401
Non-Manufacturing Industry	Construction	Other General Construction	2	41	402
Non-Manufacturing Industry	Construction	Civil Engineering	2	41	403
Non-Manufacturing Industry	Construction	Electric Plant Construction	2	41	404
Non-Manufacturing Industry	Construction	Home & Pre-Fabs	2	41	406
Non-Manufacturing Industry	Construction	Special Constructions	2	41	406
Non-Manufacturing Industry	Wholesale Trade	General Trading Companies	2	43	421
Non-Manufacturing Industry	Wholesale Trade	Auto Wholesales & Dealers	2	43	422
Non-Manufacturing Industry	Wholesale Trade	Wholesale - Foods	2	43	423
Non-Manufacturing Industry	Wholesale Trade	Wholesale - Fabrics & Apparel	2	43	424
Non-Manufacturing Industry	Wholesale Trade	Wholesale - Machinery & Metals	2	43	425
Non-Manufacturing Industry	Wholesale Trade	Wholesale - Chemicals	2	43	426
Non-Manufacturing Industry	Wholesale Trade	Wholesale - Lumber & Building Materials	2	43	427
Non-Manufacturing Industry	Wholesale Trade	Wholesale - Electric Goods	2	43	428
Non-Manufacturing Industry	Wholesale Trade	Miscellaneous Wholesales	2	43	429
Non-Manufacturing Industry	Retail Trade	Department Stores	2	45	441
Non-Manufacturing Industry	Retail Trade	Supermarket Chains	2	45	442
Non-Manufacturing Industry	Retail Trade	Installment Stores	2	45	443
Non-Manufacturing Industry	Retail Trade	Retail Stores, NEC	2	45	444
Non-Manufacturing Industry	Banks	Long-Term Credit Banks	2	47	461
Non-Manufacturing Industry	Banks	City Banks	2	47	462
Non-Manufacturing Industry	Banks	Regional Banks	2	47	463
Non-Manufacturing Industry	Banks	Trust Banks	2	47	464
Non-Manufacturing Industry	Banks	Mutual Loan & Saving Banks	2	47	465
Non-Manufacturing Industry	Banks	Securities Finance	2	47	466
Non-Manufacturing Industry	Securities houses	Securities houses	2	49	481
Non-Manufacturing Industry	Insurance	Insurance	2	51	501
Non-Manufacturing Industry	Credit & Leasing	Credit & Leasing	2	52	511
Non-Manufacturing Industry	Real Estate	Real Estate - Rental	2	53	521
Non-Manufacturing Industry	Real Estate	Real Estate - Sales	2	53	522
Non-Manufacturing Industry	Railroad Transportation	Railroad (Major)	2	55	541
Non-Manufacturing Industry	Railroad Transportation	Railroad (Minor)	2	55	542
Non-Manufacturing Industry	Railroad Transportation	Bus Transits	2	55	543
Non-Manufacturing Industry	Trucking	Trucking	2	57	561
Non-Manufacturing Industry	Sea Transportation	Shipping - Nucleus	2	59	581
Non-Manufacturing Industry	Sea Transportation	Shipping - Domestic	2	59	582
Non-Manufacturing Industry	Sea Transportation	Shipping - Foreign, NEC	2	59	583
Non-Manufacturing Industry	Air Transportation	Air Transportation	2	61	601
Non-Manufacturing Industry	Warehousing & Harbor Transportation	Warehousing	2	63	621
Non-Manufacturing Industry	Warehousing & Harbor Transportation	Harbor Transportation	2	63	622
Non-Manufacturing Industry	Communication Services	Communication Services	2	65	641
Non-Manufacturing Industry	Utilities - Electric	Utilities - Electric	2	67	661
Non-Manufacturing Industry	Utilities - Gas	Utilities - Gas	2	69	681
Non-Manufacturing Industry	Services	Motion Picture Production	2	71	701
Non-Manufacturing Industry	Services	Amusement Services	2	71	702
Non-Manufacturing Industry	Services	Hotels	2	71	703
Non-Manufacturing Industry	Services	Miscellaneous Services	2	71	704

## 2 Structure of Directories and Files

The structure of directories and files used to make this paper is given in Figure 1.

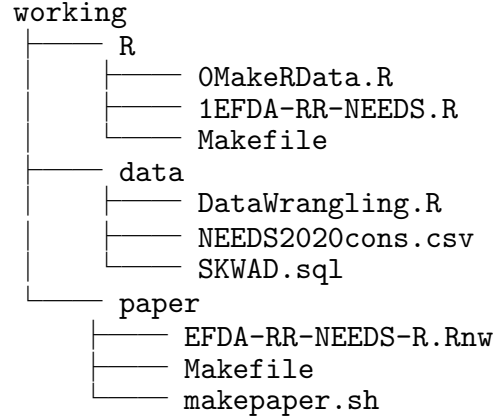


Figure 1: Structure of directories and files for study

## 3 Data Extraction and Wrangling

In this section, we describe the data extraction and wrangling used in this paper.

### 3.1 Data Extraction

The data in this paper are extracted from the data extraction system SKWAD (see Jimichi, 2022<sup>1</sup>) by using the SQL query file SKWAD.sql.

Script 1: SQL query file: SKWAD.sql

```
1 SELECT
2 f.firmname AS name,
3 b.a05 AS nikkei_firm_code,
4 b.a02 AS ym,
5 b.a35 AS sector,
6 b.a08 AS term,
7 b.a27 AS ac,
8 d.b001 AS sales,
9 h.b021 AS employees,
10 b.b001 AS assets_total
11 FROM (SELECT a02, a05, a08, a27, a29, a35, b001 FROM
12        yb01) AS b
13 JOIN (SELECT a02, a05, a08, a27, a29, a35, b001 FROM
14        yd01) AS d
15 ON d.a02 = b.a02 AND d.a05 = b.a05 AND d.a27 = b.a27
```

<sup>1</sup><http://hdl.handle.net/10236/00030225>

```

14 JOIN (SELECT a02, a05, a08, a27, a29, a35, b021 FROM
      yh01) AS h
15 ON h.a02 = b.a02 AND h.a05 = b.a05 AND h.a27 = b.a27
16 JOIN (SELECT nikkei_corp_code, firmname FROM firmlist)
      AS f
17 ON f.nikkei_corp_code = b.a05
18 WHERE d.a29 = '11'
19 ORDER BY b.a05, d.a02;

```

This file is stored in the `data` directory in Figure 1.

### 3.2 Data Wrangling

Data wrangling (cf. Wickham and Grolemund, 2016) is performed by executing the following R script file `DataWrangling.R` (Script 2).

Script 2: R script file for data wrangling: `DataWrangling.R`

```

1 # -----
2 # Data Wrangling
3 # -----
4 # Load Data
5 rawdata <- vroom::vroom("./NEEDS2020cons.csv")
6 # Data Manipulation
7 library(dplyr)
8 library(zoo)
9 x <- rawdata %>%
10   filter(substr(ym, 5, 6) == "03", term == 12) %>%
11   mutate(employees = na_if(employees, "-999999999999999"),
12          assets_total = na_if(assets_total, "-999999999999999"),
13          sales = na_if(sales, "-999999999999999")) %>%
14   mutate(
15     name = paste0(gsub("_", "", name), nikkei_firm_code),
16     sales = as.numeric(sales),
17     employees = as.numeric(employees),
18     assets = as.numeric(assets_total),
19     sector1 = as.factor(substr(sector, 1, 1)),
20     sector2 = as.factor(substr(sector, 2, 3)),
21     sector3 = as.factor(substr(sector, 4, 6)),
22     ymd = as.Date(as.yearmon(as.character(ym), "%Y%m")))
23     %>%
24     filter(ymd >= "1984-03-01") %>%
25     select(name, ymd, sector1, sector2, sector3, ac, sales
26            , employees, assets)

```

## 4 Reproducible Research with Dynamic Documents

In recent years, one of the methods to achieve *reproducible research* in the sense of ensuring the reproducibility of research, is the so-called *dynamic documents* in which a data analysis language code is embedded in a document and automatically executed by some method to dynamically generate the analysis results and then automatically read them to create a document. Dynamic documents have been proposed, in which a document is created by embedding data analysis

language code into a document and automatically executing it in some way (cf. Xie, 2015, Gandrud, 2022).

Although some tools for dynamic documents, such as Quarto (<https://quarto.org>), have been actively developed in recent years, in this study, we use Sweave developed by Leisch (2002) for document creation and GNU make (cf. Mecklenburg, 2005) for overall control including data analysis.

We introduce the environment and specifications for dynamic documents to create this paper. The source file of this paper is Sweave file `EFDA-RR-NEEDS-R.Rnw` located in the `paper` directory (see Figure 1), and to generate this paper dynamically, we use Makefile (Script 3) in the directory `paper` (see also Figure 1).

Script 3: Makefile File for Dynamic Documents

```

1 all:
2     date > start-all.txt
3     (cd ../R; make RData)
4     (/bin/bash makepaper.sh)
5     date > end-all.txt
6 paper:
7     /bin/bash makepaper.sh
8 clean:
9     rm paper-*.png
10    rm -r paper.tex *.log *.dvi *.aux *.out *.toc

```

The correspondence between the roles of the target `all` given in the Makefile file (Script 3) and the directory structure (Figure 1) is given in Figure 2.

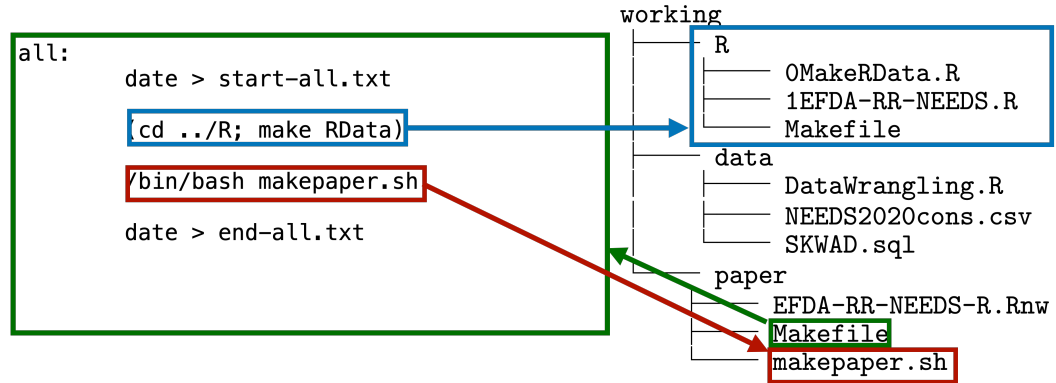


Figure 2: Correspondence between target `all` of Makefile file (Script 3) and directory structure (Figure 1)

The targets are defined in the first, sixth, and eighth lines of the Makefile file (Script 3). By executing the first target, `all`, with the command `make`, all the processes necessary for this paper, such as data analysis, Sweave processing, and compilation, are executed dynamically.

Dynamic documents are executed by executing the following command from the command line, using the **paper** directory in Figure 1 as current:

Execution of target **all** by the command **make**

```
% make all
```

Note that ‘%’ is a shell prompt.

The correspondence of all processes by execution of the **make** command of the target **Makefile** file (Script 3) of **all** is given in Figure 3.

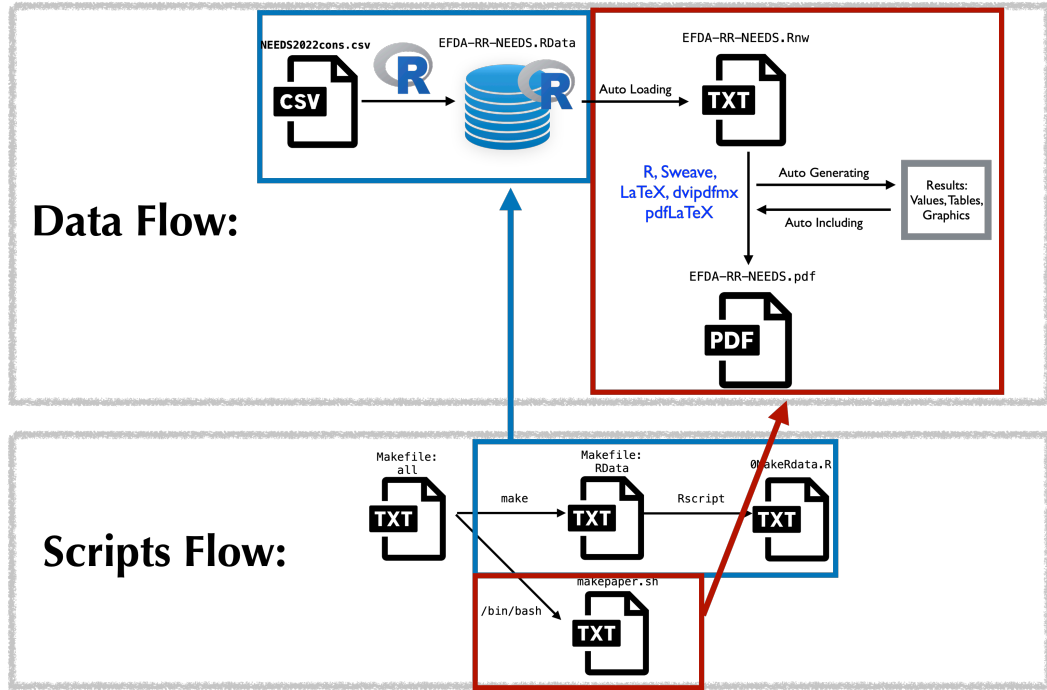


Figure 3: Flow of data files, document files, and script files and their correspondence with the execution of target **all**

Regarding the reproducibility research mentioned at the beginning of this section, the *reproducibility spectrum* by Peng (2011) is interesting as a criterion to express the degree of achievement (see Fig. 1 in Peng, 2011). According to the spectrum, the following grades are proposed to express the degree of achievement of reproducibility:

- (G1) publication only (not reproducible)
- (G2) code
- (G3) code and data

(G4) linked and executable code and data

(G5) full replication (gold standard)

In light of this spectrum, this study seems to belong to the “gold standard” zone because the reproducibility is ensured by automatically executing all the processes by **make**. Therefore, it can be said that the reproducibility of all the processes in Figure 4 is guaranteed at a high level.

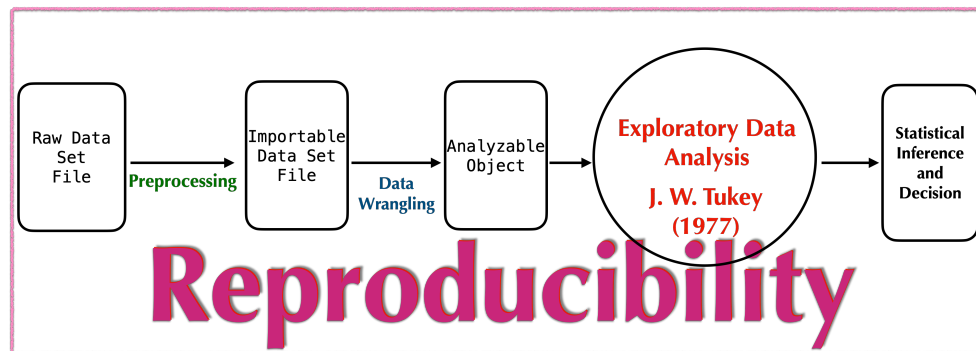


Figure 4: Total process of data analysis

## 5 Computing Environments

Our computing environments are as follows:

### Hardware

- MacBook Pro 2021:  
Processor: M1 Max  
Main Memory: 64 GB  
OS: macOS Ventura (12.7)
- Mac Studio 2022:  
Processor: M1 Ultra  
Main Memory: 128 GB  
OS: macOS Ventura (12.7)

### Software

- R (R. Ihaka, R. Gentleman, R Core Team, <https://www.r-project.org/>)

- R Packages
  - `{car}` (J. Fox, <https://socialsciences.mcmaster.ca/jfox/Books/Companion/index.html>)
  - `{dplyr}` (H. Wickham, <http://dplyr.tidyverse.org/>)
  - `{GGally::}ggpairs` (B. Schloerke, <http://ggobi.github.io/ggally/>)
  - `{ggplots2}` (H. Wickham, <https://ggplot2.tidyverse.org>)
  - `{magrittr}` (S. M. Bache, H. Wickham, and L. Henry, <https://magrittr.tidyverse.org>)
  - `{plotly}` (C. Sievert, <https://plotly.com/r/>)
  - `{purrr}` (L. Henry and H. Wickham, <https://purrr.tidyverse.org>)
  - `{rgl}` (D. Murdoch, <https://dmurdoch.github.io/rgl/>)
  - `{sn}` (A. Azzalini, <http://azzalini.stat.unipd.it/SN/>)
  - `{vroom}` (J. Hester, <https://vroom.r-lib.org>)
  - `{xtable}` (D. B. Dahl, <https://cran.r-project.org/web/packages/xtable/index.html>)
- RStudio (Posit, <https://posit.co>)
- Sweave (F. Leisch, <https://stat.ethz.ch/R-manual/R-devel/library/utils/doc/Sweave.pdf>)
- `sessionInfo`
  - R version 4.3.1 (2023-06-16), aarch64-apple-darwin20
  - Locale:
    - ja\_JP.UTF-8/ja\_JP.UTF-8/ja\_JP.UTF-8/C/ja\_JP.UTF-8/ja\_JP.UTF-8
  - Time zone: Asia/Tokyo
  - TZcode source: internal
  - Running under: macOS Ventura 13.5.1
  - Matrix products: default
  - BLAS:
    - /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/lib/libRblas.0.dylib
  - LAPACK:
    - /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/lib/libRlapack.dylib
    - ; LAPACK version 3.11.0
  - Base packages: base, datasets, graphics, grDevices, methods, stats, stats4, utils
  - Other packages: car 3.1-2, carData 3.0-5, dplyr 1.1.2, forcats 1.0.0, ggplot2 3.4.2, lubridate 1.9.2, purrr 1.0.1, readr 2.1.4, sn 2.1.1, stringr 1.5.0, tibble 3.2.1, tidyr 1.3.0, tidyverse 2.0.0, xtable 1.8-4



– Loaded via a namespace (and not attached): abind 1.4-5, cli 3.6.1, colorspace 2.1-0, compiler 4.3.1, fansi 1.0.4, generics 0.1.3, glue 1.6.2, grid 4.3.1, gtable 0.3.3, hms 1.1.3, lifecycle 1.0.3, magrittr 2.0.3, mnormt 2.1.1, munsell 0.5.0, numDeriv 2016.8-1.1, pillar 1.9.0, pkgconfig 2.0.3, R6 2.5.1, rlang 1.1.1, scales 1.2.1, stringi 1.7.12, tidyselect 1.2.0, timechange 0.2.0, tools 4.3.1, tzdb 0.4.0, utf8 1.2.3, vctrs 0.6.3, withr 2.5.0