データ解析

Ｒによる多変量解析入門

(1) Ｒ入門

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R

- データ操作，統計計算，グラフィックスのための統合ソフトウエア環境
- 行列操作に優れている，データ解析の一貫したツール群，簡単で効率的なプログラム言語
- Rはフリーソフトでソースも公開（`http://cran.r-project.org`）
- Rの開発は１９９０年代後半からネット上で行われている
- Rの前身であるはＳはＣ言語やUNIXと同じAT&T(現Lucent Technologies）のベル研究所で１９８４年ころ開発（ちなみにＣ言語およびUNIXの開発は１９７１年ころ)

講義内容

「データ解析」では統計処理ソフトウエアであるＲを用いた多変量解析の実践的な講義を行う．Ｒの使用法について簡単に紹介した後，実際にＲを使ったデータ解析を行う．単にソフトの使用法を学ぶのではなく，その背後にある数学を自分のものにすることが目標である．回帰分析や主成分分析のためのＲ関数を自分自身で書き，それを使ってデータ解析を行うのである．この経験は将来未知の問題で新しい手法を開発する場面で役に立つだろう．

講義予定

Ｒ入門　（１）
端末室での演習１　（２）
Ｒによる線形代数　（３）
回帰分析　（４，５）
主成分分析　（６，７）
端末室での演習２　（８）
クラスター分析　（９）
正準相関分析　（１０）
判別分析　（１１）
モデル選択　（１２）
ブートストラップ法　（１３）
端末室での演習３　（１４）

講義について

- ホームページ
  http://www.is.titech.ac.jp/~shimo/class/
- 担当：下平
- ティーチングアシスタント：　坂口，多賀
- 評価方法：　出席とレポート
- 質問受け付け：　まずティーチングアシスタントに質問内容のメールを出すこと．面談が必要な場合はあらかじめメールにてアポイントを取ること．もしくは講義か演習時に直接質問する．

eduでのＲの利用の準備

- 最新版のＲが`~shimo/program/R`にインストールされている．利用するにはまず自分の`.cshrc`ファイルに以下のように書き加える．

```
setenv SHIMO ~shimo/program
setenv PATH ${SHIMO}/R/bin:${PATH}
```

- 以上の設定を有効にするため，`source ~/.cshrc`を実行する．(次回にログインするときはこの必要ない)

- 作業用ディレクトリを作る．例えば

```
shimo@edu[~] mkdir -p class/gakubu200209
shimo@edu[~] chmod og-rx class/gakubu200209
```

eduでのＲの利用

- 作業用ディレクトリに移動しＲを起動

```
shimo@edu[~] cd class/gakubu200209
shimo@edu[gakubu200209] R
```

- たとえば $\sin(x)$の曲線を描く

```
> x <- seq(0,10,0.1)
> plot(x,sin(x),type="l")
```

- Ｒの終了は q() コマンド

```
> q()
Save workspace image? [y/n/c]: y
```

- 作業用ディレクトリにファイル .RDataが自動的に作られる．

emacsでの統合環境 ESS

- .emacsファイルに以下を書き加えてからemacsを再起動．

```
;;; ess
(setq load-path (cons
   (expand-file-name  "~shimo/program/ess/lisp") load-path ))
(autoload 'R "ess-site" "" t)
(add-hook 'ess-post-run-hook (function (lambda ()
   (set-buffer-process-coding-system 'euc-japan 'euc-japan))))
```

- emacs内で`M-x R`によってＲを起動する．
- セッションは`C-x C-w`によって`xxxx.Rt`のような名前でセーブする．
- プログラムのファイルは`yyyy.R`のような名前で作成しＲコマンド`source ("yyyy.R")`でロード．
- Ｒのヘルプは`C-c C-v`で別ウィンドウが開く

講義で用いるデータセット

総務庁統計局統計センターが公開している社会・人口統計体系
`http://www.stat.go.jp/data/ssds/index.htm`

`edu:~shimo/class/gakubu200209/data/X2000.R`
というファイルで X2000 というリスト型の変数を定義している．

X2000$x	[データ本体]	サイズ 47×1173 の行列
X2000$item	[項目名]	サイズ 1173 の文字型ベクトル
X2000$jitem		(日本語)
X2000$pref	[県名]	サイズ 47 の文字型ベクトル
X2000$jpref		(日本語)

項目例

1	A05201	自然増加率
2	A06102	一般世帯の平均人員
3	A06202	核家族世帯割合
4	F01503	共働き世帯割合
5	A06205	単独世帯割合
6	A06301	65歳以上の親族のいる世帯割合
7	A06302	高齢夫婦のみの世帯の割合
8	A06304	高齢単身世帯の割合
9	A06601	婚姻率（人口千人当たり）
10	A06602	離婚率（人口千人当たり）

データ行列の一部

	A05201	A06102	A06202	F01503	···
Hokkaido	0.04	2.42	60.54	26.54	···
Aomori	-0.02	2.86	54.20	34.38	···
Iwate	-0.07	2.92	50.87	38.82	···
Miyagi	0.18	2.80	51.96	31.88	···
Akita	-0.25	3.00	50.48	39.55	···
Yamagata	-0.12	3.25	45.79	47.09	···
Fukushima	0.06	3.05	52.12	39.53	···
Ibaraki	0.16	2.99	58.28	35.84	···
Tochigi	0.13	2.97	56.47	37.59	···
Gumma	0.12	2.88	60.07	36.35	···
Saitama	0.36	2.78	65.46	30.89	···
Chiba	0.27	2.70	62.55	29.57	···
Tokyo	0.11	2.21	52.15	22.09	···
Kanagawa	0.36	2.53	62.04	25.04	···
⋮	⋮	⋮	⋮	⋮	
Okinawa	0.67	2.91	64.54	25.70	···

サンプルセッション

西７号館端末室(edu)で演習する．セッションファイルと同じことを自分でやってみる．詳しい意味は分からなくても良い．データ解析とＲについて慣れることが目的．

- サンプルセッション１
  Ｒによるデータ解析１（主成分分析，クラスタリング，重回帰分析)
  ファイル： ~shimo/class/gakubu200209/note20020919a.Rt
- サンプルセッション２
  Ｒによるデータ解析２（ランダムにデータ項目を選ぶ)
  ファイル： ~shimo/class/gakubu200209/note20020919b.Rt
- サンプルセッション３
  Ｒ言語入門
  ファイル： ~shimo/class/gakubu200209/note20020919c.Rt

サンプルセッション1

```
Last login: Fri Sep 20 2002 15:54:22 +0900 from grandma
Sun Microsystems Inc.   SunOS 5.8       Generic Patch   October 2001
No mail.
Sun Microsystems Inc.   SunOS 5.8       Generic Patch   October 2001
shimo@edu[~] cd class/gakubu200209
shimo@edu[gakubu200209] R

R : Copyright 2002, The R Development Core Team
Version 1.5.1 Patched (2002-09-08)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type ‘license()’ or ‘licence()’ for distribution details.

R is a collaborative project with many contributors.
Type ‘contributors()’ for more information.
```

```
Type ‘demo()’ for some demos, ‘help()’ for on-line help, or
‘help.start()’ for a HTML browser interface to help.
Type ‘q()’ to quit R.

[Previously saved workspace restored]

> source("~shimo/class/gakubu200209/data/X2000.R")
> names(X2000)
 [1] "x"     "pref"  "code"  "item"  "cate"  "clab"  "jpref" "jitem" "junit"
[10] "jcate" "rm"
> dim(X2000$x)
[1]   47 1173
> X2000$pref
 [1] "Hokkaido"  "Aomori"    "Iwate"     "Miyagi"    "Akita"     "Yamagata"
 [7] "Fukushima" "Ibaraki"   "Tochigi"   "Gumma"     "Saitama"   "Chiba"
[13] "Tokyo"     "Kanagawa"  "Niigata"   "Toyama"    "Ishikawa"  "Fukui"
[19] "Yamanashi" "Nagano"    "Gifu"      "Shizuoka"  "Aichi"     "Mie"
[25] "Shiga"     "Kyoto"     "Osaka"     "Hyogo"     "Nara"      "Wakayama"
[31] "Tottori"   "Shimane"   "Okayama"   "Hiroshima" "Yamaguchi" "Tokushima"
```

```
[37] "Kagawa"    "Ehime"     "Kochi"     "Fukuoka"   "Saga"      "Nagasaki"
[43] "Kumamoto"  "Ooita"     "Miyazaki"  "Kagoshima" "Okinawa"
> X2000$jpref
  Hokkaido     Aomori      Iwate     Miyagi      Akita   Yamagata  Fukushima
"北 海 道" "青 森 県" "岩 手 県" "宮 城 県" "秋 田 県" "山 形 県" "福 島 県"
   Ibaraki    Tochigi      Gumma    Saitama      Chiba      Tokyo   Kanagawa
"茨 城 県" "栃 木 県" "群 馬 県" "埼 玉 県" "千 葉 県" "東 京 都" "神奈川県"
   Niigata     Toyama   Ishikawa      Fukui  Yamanashi     Nagano       Gifu
"新 潟 県" "富 山 県" "石 川 県" "福 井 県" "山 梨 県" "長 野 県" "岐 阜 県"
  Shizuoka      Aichi        Mie      Shiga      Kyoto      Osaka      Hyogo
"静 岡 県" "愛 知 県" "三 重 県" "滋 賀 県" "京 都 府" "大 阪 府" "兵 庫 県"
      Nara   Wakayama    Tottori    Shimane    Okayama  Hiroshima  Yamaguchi
"奈 良 県" "和歌山県" "鳥 取 県" "島 根 県" "岡 山 県" "広 島 県" "山 口 県"
 Tokushima     Kagawa      Ehime      Kochi    Fukuoka       Saga   Nagasaki
"徳 島 県" "香 川 県" "愛 媛 県" "高 知 県" "福 岡 県" "佐 賀 県" "長 崎 県"
  Kumamoto      Ooita   Miyazaki  Kagoshima    Okinawa
"熊 本 県" "大 分 県" "宮 崎 県" "鹿児島県" "沖 縄 県"
> ### get some items
> a <- c("A05201","A06102","A06202","F01503","A06205","A06301","A06302","A063
```

```
> X2000$item[a]
                                                     A05201
                              "Rate of natural increase  "
                                                     A06102
                         "Members per private household  "
                                                     A06202
                     "Ratio of family nuclei households  "
                                                     F01503
                       "Ratio of dual-income households  "
                                                     A06205
                        "Ratio of one-person households  "
                                                     A06301
"Ratio of households with members65 years old and over "
                                                     A06302
                       "Ratio of aged-couple households  "
                                                     A06304
                "Ratio of aged-single person households  "
                                                     A06601
                 "Rate of marriages (per 1,000 persons)  "
```

```
                                                  A06602
                 "Rate of divorces (per 1,000 persons)  "
> X2000$jitem[a]
                                  A05201                                        A06102
                 "自　然　増　加　率　"          "一 般 世 帯 の 平 均 人 員　"
                                  A06202                                        F01503
          "核　家　族　世　帯　割　合　"        "共　働　き　世　帯　割　合　"
                                  A06205                                        A06301
              "単　独　世　帯　割　合　"      "65歳以上の親族のいる世帯割合　"
                                  A06302                                        A06304
            "高齢夫婦のみの世帯の割合　"        "高 齢 単 身 世 帯 の 割 合　"
                                  A06601                                        A06602
"婚　　姻　　率　（人口千人当たり）" "離　　婚　　率　（人口千人当たり）"
> na <- paste(seq(along=a),a,X2000$item[a])
> na
 [1] "1 A05201 Rate of natural increase  "
 [2] "2 A06102 Members per private household  "
 [3] "3 A06202 Ratio of family nuclei households  "
 [4] "4 F01503 Ratio of dual-income households  "
```

```
 [5] "5 A06205 Ratio of one-person households  "
 [6] "6 A06301 Ratio of households with members65 years old and over "
 [7] "7 A06302 Ratio of aged-couple households  "
 [8] "8 A06304 Ratio of aged-single person households  "
 [9] "9 A06601 Rate of marriages (per 1,000 persons)  "
[10] "10 A06602 Rate of divorces (per 1,000 persons)  "
> jna <- paste(seq(along=a),a,X2000$jitem[a])
> jna
 [1] "1 A05201 自　然　増　加　率　"
 [2] "2 A06102 一 般 世 帯 の 平 均 人 員　"
 [3] "3 A06202 核　家　族　世　帯　割　合　"
 [4] "4 F01503 共　働　き　世　帯　割　合　"
 [5] "5 A06205 単　独　世　帯　割　合　"
 [6] "6 A06301 65歳以上の親族のいる世帯割合　"
 [7] "7 A06302 高齢夫婦のみの世帯の割合　"
 [8] "8 A06304 高 齢 単 身 世 帯 の 割 合　"
 [9] "9 A06601 婚　　姻　　率　（人口千人当たり）"
[10] "10 A06602 離　　婚　　率　（人口千人当たり）"
> x <- X2000$x[,a]
```

```
> x
          A05201 A06102 A06202 F01503 A06205 A06301 A06302 A06304 A06601 A066
Hokkaido    0.04   2.42  60.54  26.54  29.95  30.50   9.90   7.39   5.77   2.
Aomori     -0.02   2.86  54.20  34.38  24.08  38.99   7.45   6.61   5.24   1.
Iwate      -0.07   2.92  50.87  38.82  24.47  42.42   7.87   6.05   5.14   1.
Miyagi      0.18   2.80  51.96  31.88  28.59  33.04   6.42   4.54   5.79   1.
Akita      -0.25   3.00  50.48  39.55  21.24  47.77   9.15   6.71   4.69   1.
Yamagata   -0.12   3.25  45.79  47.09  19.98  49.75   7.50   5.27   5.40   1.
Fukushima   0.06   3.05  52.12  39.53  22.60  41.70   7.58   5.65   5.44   1.
Ibaraki     0.16   2.99  58.28  35.84  21.42  33.95   6.35   4.31   5.78   1.
Tochigi     0.13   2.97  56.47  37.59  22.42  34.95   6.28   4.69   5.87   1.
Gumma       0.12   2.88  60.07  36.35  21.78  35.61   7.95   5.49   5.73   1.
Saitama     0.36   2.78  65.46  30.89  23.15  25.10   5.89   3.94   6.19   2.
Chiba       0.27   2.70  62.55  29.57  25.45  26.75   6.36   4.51   6.30   2.
Tokyo       0.11   2.21  52.15  22.09  40.85  25.44   6.69   7.23   6.87   2.
Kanagawa    0.36   2.53  62.04  25.04  29.54  24.74   6.81   5.04   6.89   2.
Niigata    -0.03   3.07  51.07  43.22  21.69  43.77   7.82   5.27   5.03   1.
Toyama     -0.01   3.09  52.30  46.09  19.93  43.47   7.89   5.59   5.51   1.
Ishikawa    0.12   2.83  53.17  40.23  25.98  36.29   7.64   5.81   5.86   1.
```

Fukui	0.13	3.14	50.72	46.69	20.94	43.41	7.67	5.73	5.48	1.
Yamanashi	0.08	2.84	57.42	36.04	24.17	38.14	8.61	6.19	5.70	1.
Nagano	0.06	2.89	55.17	41.54	23.13	41.74	9.41	6.03	5.70	1.
Gifu	0.15	3.07	56.74	39.64	19.74	38.46	7.79	5.09	5.59	1.
Shizuoka	0.18	2.91	56.87	38.15	22.91	35.33	6.89	4.83	5.94	1.
Aichi	0.40	2.75	59.79	32.91	26.23	28.08	6.66	4.89	6.59	1.
Mie	0.11	2.88	59.40	36.87	21.73	37.49	9.17	6.65	5.72	1.
Shiga	0.35	3.02	57.50	36.76	22.22	33.67	6.65	4.48	6.24	1.
Kyoto	0.12	2.55	57.65	27.97	30.86	31.42	8.10	7.49	5.96	1.
Osaka	0.30	2.51	61.90	23.78	29.78	27.21	7.30	7.38	6.68	2.
Hyogo	0.22	2.69	63.21	26.94	24.95	32.23	8.54	7.43	6.23	2.
Nara	0.18	2.93	64.94	27.21	19.13	33.77	8.31	5.91	5.56	1.
Wakayama	-0.06	2.77	61.98	30.71	21.97	41.08	10.63	9.54	5.35	1.
Tottori	-0.08	3.00	51.83	43.23	22.69	44.73	8.44	7.33	5.24	1.
Shimane	-0.24	2.90	50.97	42.89	24.02	48.06	10.46	8.24	4.67	1.
Okayama	0.07	2.77	57.42	35.14	24.98	37.73	9.70	7.27	5.60	1.
Hiroshima	0.12	2.57	59.94	32.03	28.02	32.87	9.36	7.73	5.90	1.
Yamaguchi	-0.15	2.56	59.83	32.46	26.75	39.33	11.35	9.65	5.15	1.
Tokushima	-0.11	2.78	55.68	35.88	24.40	40.95	9.61	8.08	5.07	1.

```
Kagawa      0.03   2.75  58.53  36.35  23.81  38.88   9.95   7.59   5.63   1.
Ehime      -0.08   2.59  60.33  31.24  26.30  38.15  11.03   9.06   5.12   1.
Kochi      -0.25   2.47  57.67  33.12  29.85  40.21  10.98  11.16   5.00   2.
Fukuoka     0.14   2.57  57.86  26.51  30.24  31.10   7.88   7.48   5.94   2.
Saga        0.07   3.08  55.06  39.49  20.96  42.83   8.27   6.99   5.19   1.
Nagasaki    0.02   2.71  59.92  31.00  25.30  39.10   9.84   9.18   5.12   1.
Kumamoto    0.02   2.81  56.19  34.98  25.04  40.22   9.52   7.96   5.15   1.
Ooita      -0.06   2.64  58.01  32.47  26.42  39.43  10.79   8.93   5.08   1.
Miyazaki    0.07   2.61  62.18  35.51  25.74  36.93  11.13   9.11   5.32   2.
Kagoshima  -0.13   2.43  62.44  29.85  30.12  38.01  12.66  12.39   5.09   1.
Okinawa     0.67   2.91  64.54  25.70  24.26  27.92   5.39   6.22   6.47   2.
> dim(x)
[1] 47 10
> # load "mybiplot", "mylsfit", "mypca", "myplot", "mysvd", "psinit"
> source("~shimo/class/gakubu200209/myfunc20020919.R")
>
```

主成分分析

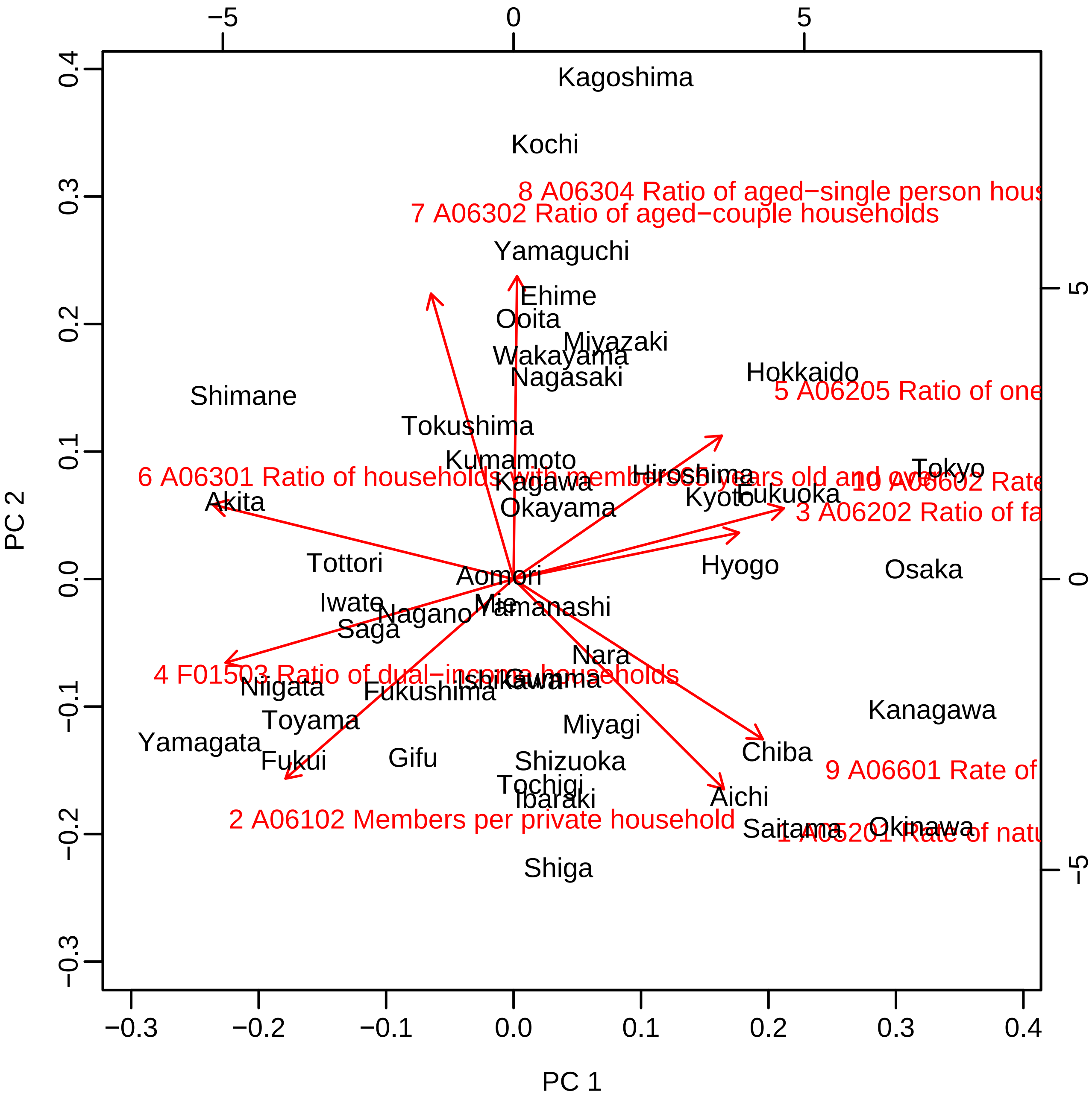
主成分分析 ＝ PCA (principal component analysis)

- 多変量解析の定番
- データの変動をできるだけ少数個の変換された変量で説明
- 主成分＝変換された変量
- バイプロットによって結果を視覚的に示す

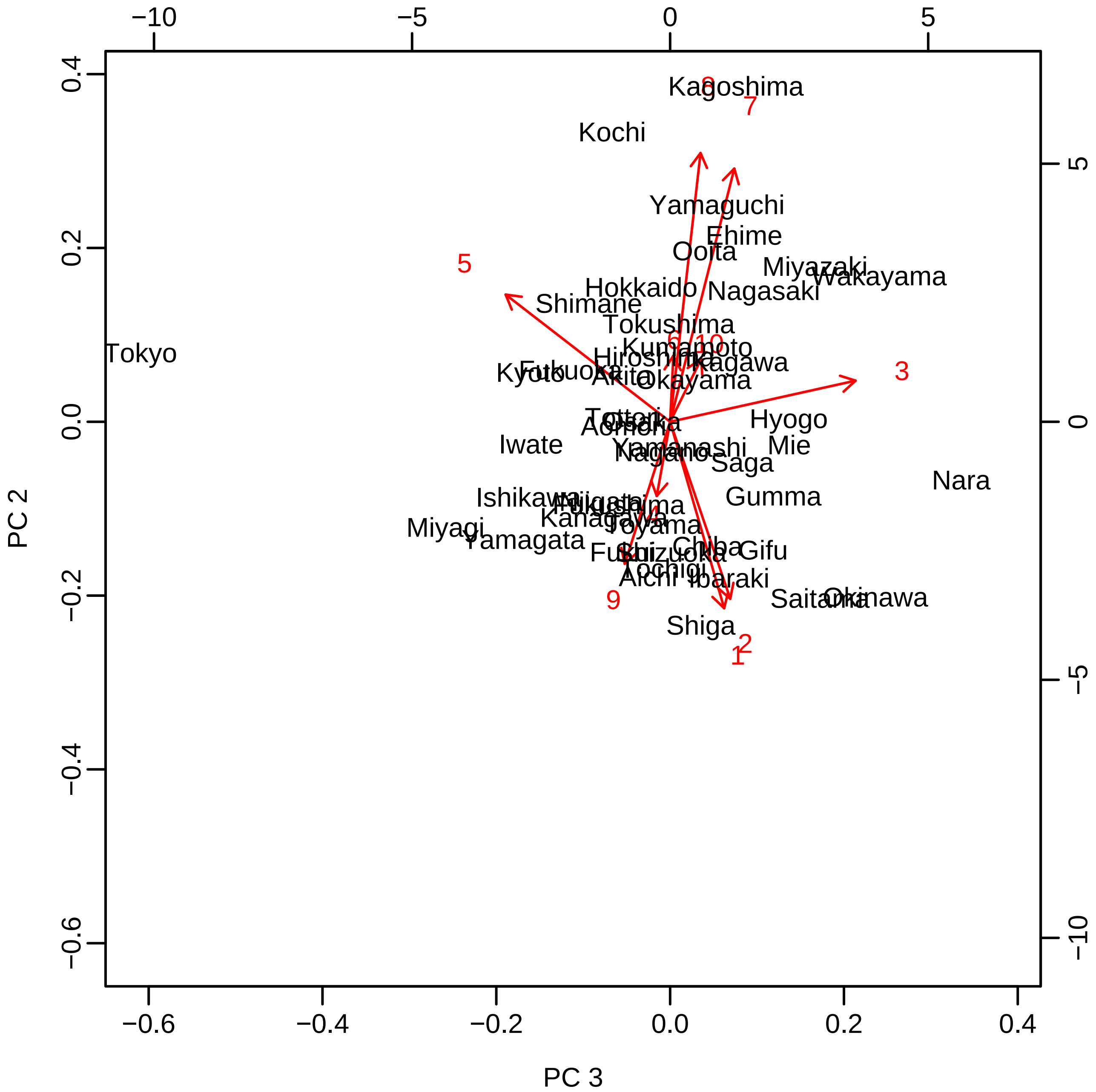
PCAの関数

```
mypca <- function(dat) {
  s <- mysvd(dat)
  x <- s$u %*% diag(s$d)
  y <- s$v %*% diag(s$d)
  list(x=x,y=y,d=s$d,u=s$u,v=s$v)
}

> p <- mypca(scale(x))
> mybiplot(p$u,p$y)
> mybiplot(p$u,p$y,choi=3:2)
```



PC 1
PC 2
Kagoshima
Kochi
8 A06304 Ratio of aged−single person hous
7 A06302 Ratio of aged−couple households
Yamaguchi
Ehime
Ooita
Miyazaki
Wakayama
Nagasaki
Hokkaido
5 A06205 Ratio of one
Shimane
Tokushima
Kumamoto
6 A06301 Ratio of households with members 65 years old and over
Hiroshima
Kagawa
Tokyo
10 A06602 Rate
Kyoto
Fukuoka
Akita
Okayama
3 A06202 Ratio of fa
Tottori
Hyogo
Osaka
Aomori
Iwate
Mie
Yamanashi
Nagano
Saga
Nara
4 F01503 Ratio of dual−income households
Niigata
Fukushima
Ishikawa
Gunma
Kanagawa
Toyama
Miyagi
Yamagata
Fukui
Gifu
Shizuoka
Chiba
9 A06601 Rate of
Tochigi
Ibaraki
Aichi
2 A06102 Members per private household
Saitama
1 A06201 Rate of natu
Okinawa
Shiga

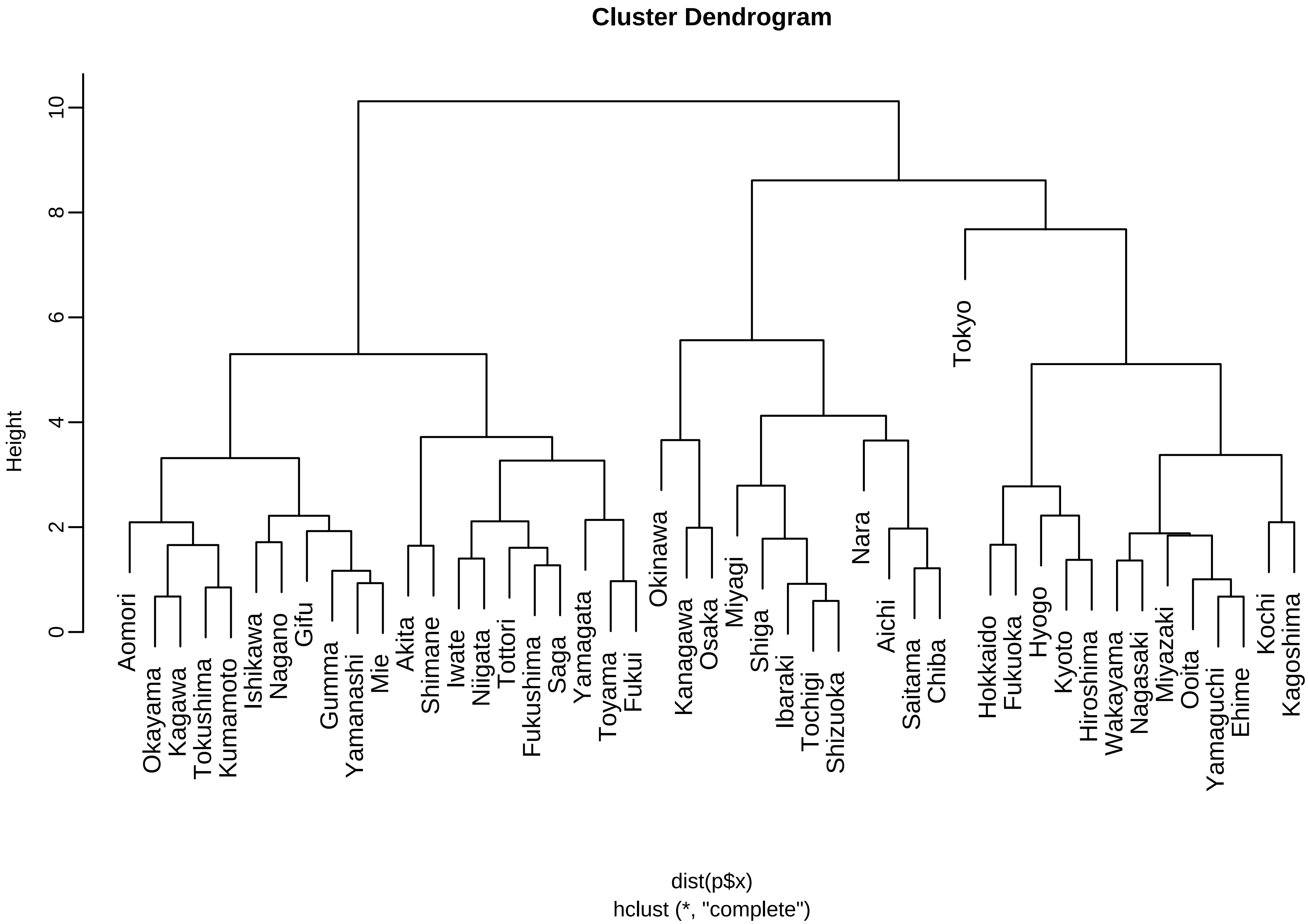

−10
−5
0
5
0.4
0.2
0.0
−0.2
−0.4
−0.6
Kagoshima
Kochi
Yamaguchi
Ehime
Ooita
Miyazaki
Wakayama
Hokkaido
Nagasaki
Shimane
Tokushima
Kumamoto
Hiroshima
Kagawa
Tokyo
Kyoto
Fukuoka
Akita
Okayama
Tottori
Osaka
Aomori
Hyogo
Iwate
Yamanashi
Mie
Nagano
Saga
Nara
Ishikawa
Niigata
Fukushima
Gumma
Kanagawa
Toyama
Miyagi
Yamagata
Chiba
Gifu
Fukui
Shizuoka
Tochigi
Aichi
Ibaraki
Saitama
Okinawa
Shiga
1
2
3
5
6
7
8
9
10
5
0
−5
−10
−0.6
−0.4
−0.2
0.0
0.2
0.4
PC 2
PC 3

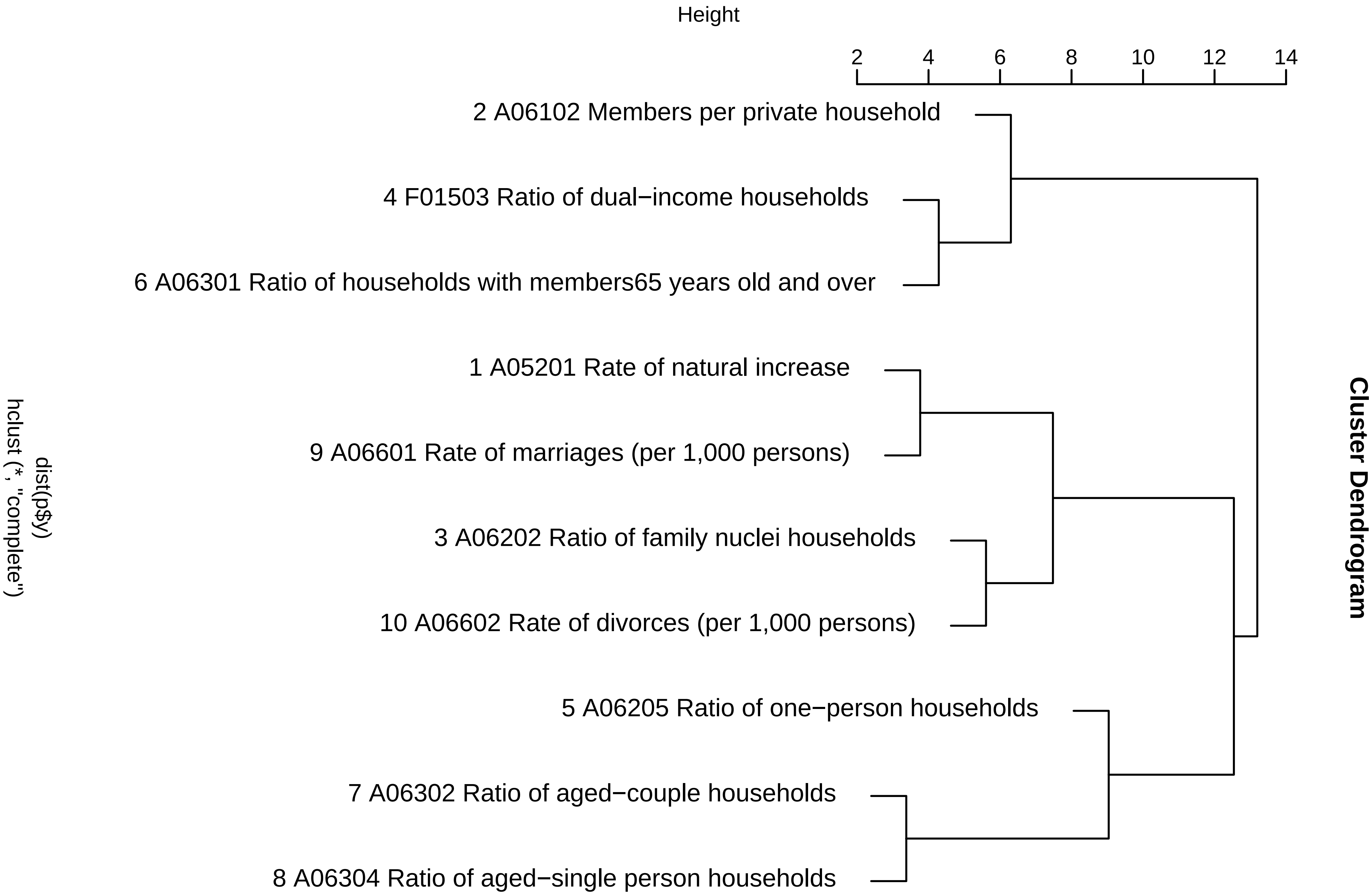
クラスター分析

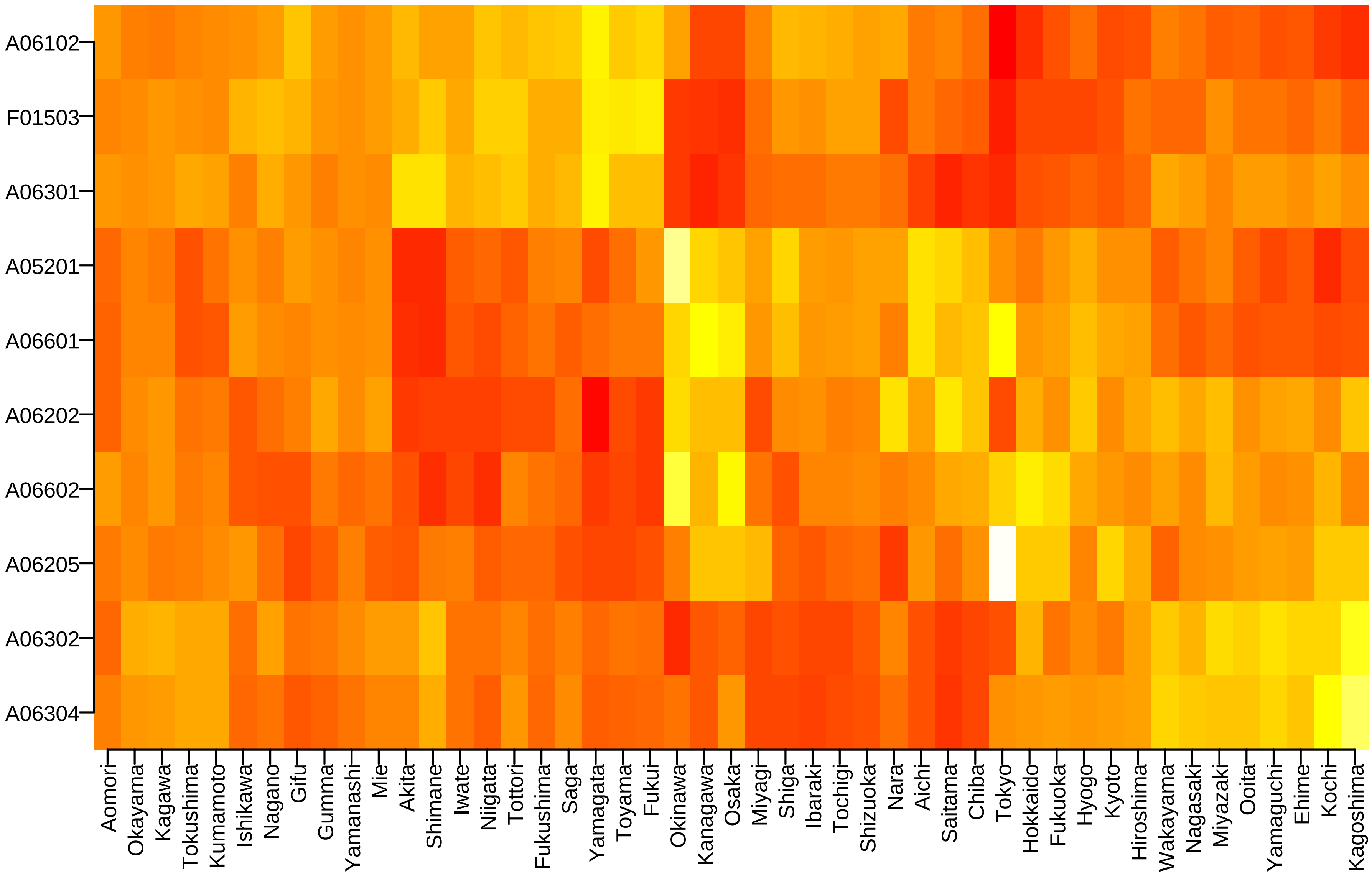
- 対象の自動分類,「教師なし」の分類
- 特徴ベクトルなどから対象間の「距離」を定義
- 距離に従って，似たもの同士の群（クラスター）に分類
- 階層的クラスタリング，樹状図

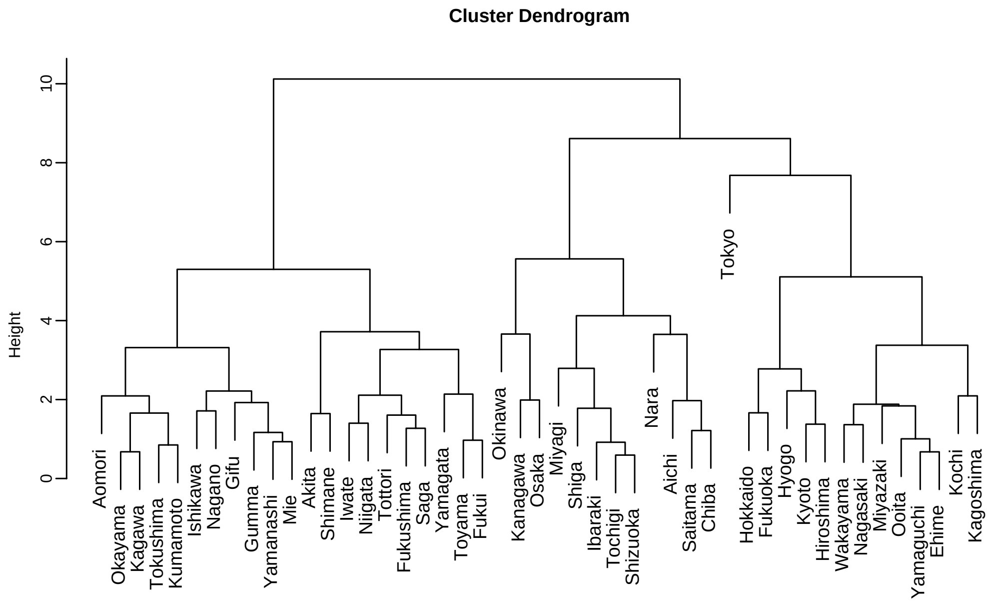
Ｒでのクラスター分析

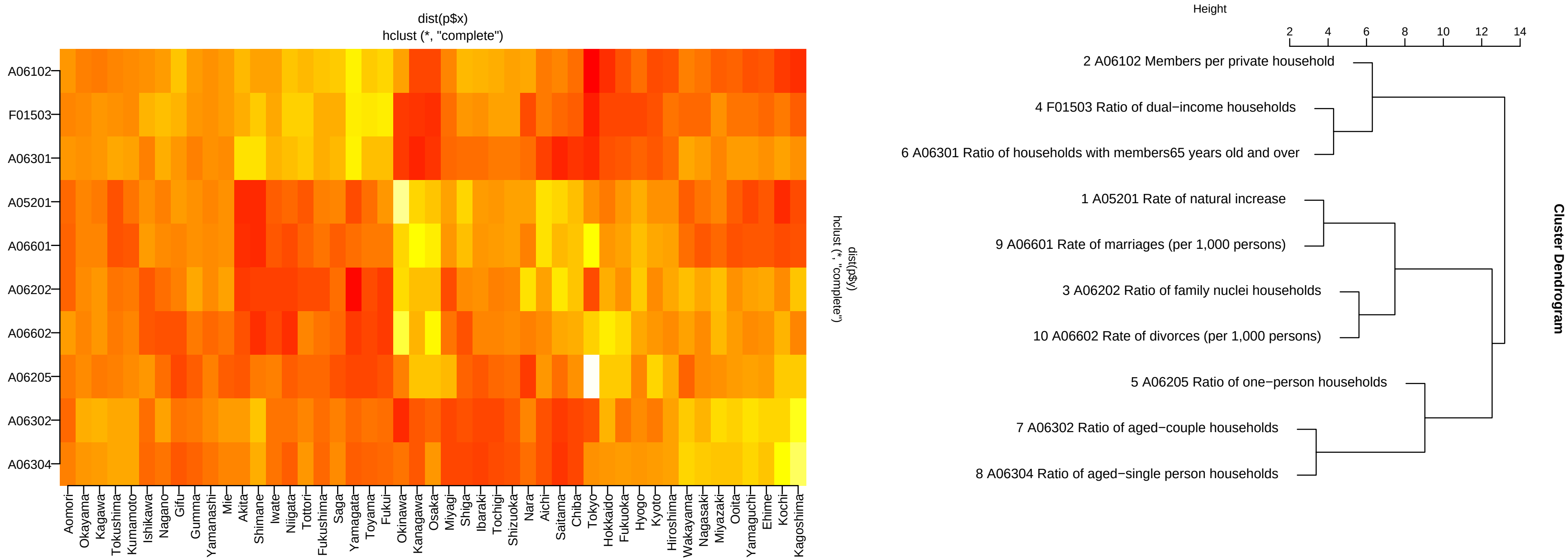
```
> library(mva)  # load multivariante analysis library
> hx <- hclust(dist(p$x))
> hy <- hclust(dist(p$y))
> # show clustering
> plot(hx,cex=1.2)
> plot(hy,labels=na,cex=0.9)
> # show matrix
> image(seq(along=hx$order),seq(along=hy$order),
+ scale(x)[hx$order,rev(hy$order)],
+ col=heat.colors(60),axes=F,xlab="",ylab="")
> axis(1,seq(along=hx$order),rownames(p$x)[hx$order],las=2)
> axis(2,seq(along=hy$order),rownames(p$y)[rev(hy$order)],las=2)
```


Cluster Dendrogram
Height
0
2
4
6
8
10
Aomori
Okayama
Kagawa
Tokushima
Kumamoto
Ishikawa
Nagano
Gifu
Gumma
Yamanashi
Mie
Akita
Shimane
Iwate
Niigata
Tottori
Fukushima
Saga
Yamagata
Toyama
Fukui
Okinawa
Kanagawa
Osaka
Miyagi
Shiga
Ibaraki
Tochigi
Shizuoka
Nara
Aichi
Saitama
Chiba
Tokyo
Hokkaido
Fukuoka
Hyogo
Kyoto
Hiroshima
Wakayama
Nagasaki
Miyazaki
Ooita
Yamaguchi
Ehime
Kochi
Kagoshima
dist(p$x)
hclust (*, "complete")


Cluster Dendrogram
Height
2
4
6
8
10
12
14
2 A06102 Members per private household
4 F01503 Ratio of dual−income households
6 A06301 Ratio of households with members65 years old and over
1 A05201 Rate of natural increase
9 A06601 Rate of marriages (per 1,000 persons)
3 A06202 Ratio of family nuclei households
10 A06602 Rate of divorces (per 1,000 persons)
5 A06205 Ratio of one−person households
7 A06302 Ratio of aged−couple households
8 A06304 Ratio of aged−single person households
dist(p$y)
hclust (*, "complete")


A06102
F01503
A06301
A05201
A06601
A06202
A06602
A06205
A06302
A06304
Aomori
Okayama
Kagawa
Tokushima
Kumamoto
Ishikawa
Nagano
Gifu
Gumma
Yamanashi
Mie
Akita
Shimane
Iwate
Niigata
Tottori
Fukushima
Saga
Yamagata
Toyama
Fukui
Okinawa
Kanagawa
Osaka
Miyagi
Shiga
Ibaraki
Tochigi
Shizuoka
Nara
Aichi
Saitama
Chiba
Tokyo
Hokkaido
Fukuoka
Hyogo
Kyoto
Hiroshima
Wakayama
Nagasaki
Miyazaki
Ooita
Yamaguchi
Ehime
Kochi
Kagoshima


Cluster Dendrogram
Height
0
2
4
6
8
10
Aomori
Okayama
Kagawa
Tokushima
Kumamoto
Ishikawa
Nagano
Gifu
Gumma
Yamanashi
Mie
Akita
Shimane
Iwate
Niigata
Tottori
Fukushima
Saga
Yamagata
Toyama
Fukui
Okinawa
Kanagawa
Osaka
Miyagi
Shiga
Ibaraki
Tochigi
Shizuoka
Nara
Aichi
Saitama
Chiba
Tokyo
Hokkaido
Fukuoka
Hyogo
Kyoto
Hiroshima
Wakayama
Nagasaki
Miyazaki
Ooita
Yamaguchi
Ehime
Kochi
Kagoshima


dist(p$x)
hclust (*, "complete")
A06102
F01503
A06301
A05201
A06601
A06202
A06602
A06205
A06302
A06304
dist(p$y)
hclust (*, "complete")
Height
2
4
6
8
10
12
14
2 A06102 Members per private household
4 F01503 Ratio of dual−income households
6 A06301 Ratio of households with members65 years old and over
1 A05201 Rate of natural increase
9 A06601 Rate of marriages (per 1,000 persons)
3 A06202 Ratio of family nuclei households
10 A06602 Rate of divorces (per 1,000 persons)
5 A06205 Ratio of one−person households
7 A06302 Ratio of aged−couple households
8 A06304 Ratio of aged−single person households
Cluster Dendrogram

回帰分析

- データ解析で最も利用頻度の高い分析法
- 重回帰 ＝ multiple regression
- 従属変数yと独立変数$x_1, x_2, \ldots, x_m$の関係を推定

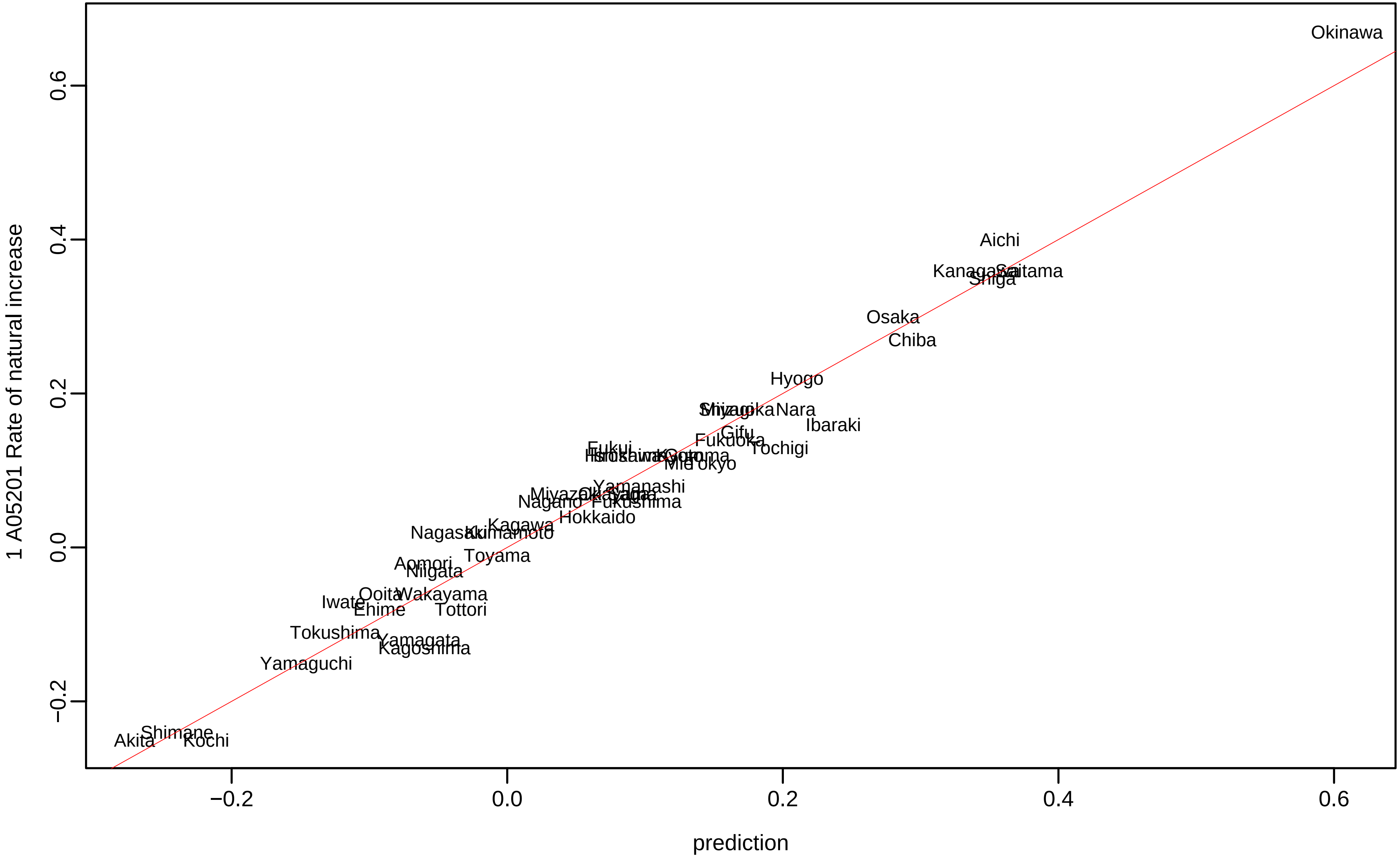
$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m + \epsilon$$

- 係数β_iがyとx_iの関係を表す

重回帰分析の関数

```
mylsfit <- function(x,y) {
  ...
  sx <- mysvd(x)
  coef <- sx$v %*% (1/sx$d * (t(sx$u) %*% y))
  ...
  ypred <- x %*% coef
  resid <- y - ypred
  ...
  list(coefficients=coef,residuals=resid,pred=ypred,...)
}

> f <- mylsfit(x[,-1],x[,1])
> myplot(f$pred,x[,1],xlab="prediction",ylab=na[1],cex=0.8)
> abline(0,1,col=2,lwd=0.5)
```



Okinawa
Aichi
Kanagawa
Saitama
Shiga
Osaka
Chiba
Hyogo
Shizuoka
Miyagi
Nara
Ibaraki
Gifu
Fukuoka
Tochigi
Fukui
Hiroshima
Ishikawa
Kyoto
Gunma
Mie
Tokyo
Yamanashi
Miyazaki
Okayama
Saga
Nagano
Fukushima
Hokkaido
Kagawa
Nagasaki
Kumamoto
Toyama
Aomori
Niigata
Ooita
Wakayama
Iwate
Ehime
Tottori
Tokushima
Yamagata
Kagoshima
Yamaguchi
Shimane
Akita
Kochi
1 A05201 Rate of natural increase
prediction
−0.2
0.0
0.2
0.4
0.6

```
> round(f$tsummary,3)
, ,  = Y

          Estimate Std.Err t-value Pr(>|t|)
Intercept   -7.887   1.334  -5.913    0.000
A06102       1.691   0.192   8.808    0.000
A06202       0.024   0.010   2.553    0.015
F01503       0.003   0.003   0.978    0.334
A06205       0.056   0.013   4.359    0.000
A06301      -0.022   0.009  -2.335    0.025
A06302       0.051   0.017   2.992    0.005
A06304      -0.010   0.016  -0.599    0.553
A06601       0.107   0.027   3.984    0.000
A06602       0.108   0.043   2.521    0.016
```

サンプルセッション２

```
> ### randomly selecting items
> a0 <- X2000$code[grep("^.$",X2000$clab)]  # indices
> a0
  [1] "A01101"   "A01601"   "A0160101" "A0160102" "A0160103" "A01201"
  [7] "A01202"   "A01302"   "A01401"   "A01402"   "A02101"   "A02102"
 [13] "A02103"   "A02104"   "A03101"   "A03102"   "A03103"   "A03401"
 [19] "A03402"   "A03403"   "A03404"   "A0410301" "A0410302" "A0410401"
 [25] "A0410402" "A0410501" "A0410502" "A0410601" "A0410602" "A0410701"
 [31] "A0410702" "A0410801" "A0410802" "A0430701" "A0430702" "A0440501"
 [37] "A0440502" "A0440601" "A0440602" "A05101"   "A05201"   "A05202"
 [43] "A05203"   "A05204"   "A0520401" "A0520402" "A05205"   "A05218"
 [49] "A0521901" "A0521902" "A05301"   "A05302"   "A05303"   "A05304"
 [55] "A05305"   "A0610101" "A06102"   "A06202"   "F01503"   "A06205"
 [61] "A06301"   "A06302"   "A06304"   "A06601"   "A06602"   "B01101"
 [67] "B01202"   "B01205"   "B01204"   "B01301"   "B01401"   "B0140101"
 [73] "B0140102" "B0140103" "B02101"   "B02102"   "B02103"   "B02201"
 [79] "B02401"   "B02402"   "B02301"   "B02303"   "B02304"   "C01301"
```

```
 [85] "C01101"   "C01105"   "C01106"   "C01107"   "C02102"   "C02103"  
 [91] "C02201"   "C02205"   "C03201"   "C03205"   "C03303"   "C0330303"
 [97] "C03304"   "C0330408" "C0410101" "C04105"   "C04106"   "C0410701"
[103] "C04401"   "C04404"   "C04505"   "C04507"   "C04601"   "C0460101"
[109] "C04602"   "L04201"   "L04203"   "L04101"   "L04102"   "L04104"  
[115] "L04105"   "L04106"   "L04107"   "L04108"   "L04109"   "L04110"  
[121] "L04111"   "L04112"   "L04113"   "L04302"   "L04304"   "D0110101"
[127] "D01102"   "D0120101" "D0130201" "D01401"   "D0140201" "D0140301"
[133] "D0210101" "D0210201" "D0210301" "D0220103" "D02202"   "D02204"  
[139] "D02206"   "D02207"   "D0310301" "D0310401" "D0310501" "D0310601"
[145] "D0310701" "D0310801" "D0310901" "D0311001" "D0311101" "D0311201"
[151] "D03113"   "D03114"   "D0311501" "D0312301" "D0320101" "D0320201"
[157] "D0320301" "D0330103" "D0330203" "D0330303" "D0330403" "D0330503"
[163] "D0330603" "D0330703" "D0331103" "D03312"   "D03313"   "D0331403"
[169] "D0332003" "D0332103" "D0331503" "D0331603" "D0331703" "D0331803"
[175] "D0331903" "E0110101" "E0110102" "E0110103" "E0110104" "E0110105"
[181] "E0110201" "E0110202" "E0110203" "E01303"   "E01304"   "E01305"  
[187] "E0210101" "E0210102" "E0210103" "E02601"   "E02602"   "E02603"  
[193] "E02701"   "E02702"   "E02703"   "E0410201" "E0410202" "E0510301"
```

```
[199] "E0510302" "E0510303" "E0510304" "E0510305" "E05203"   "E05204"
[205] "E05205"   "E0610101" "E0610102" "E0610201" "E0610202" "E0620401"
[211] "E0620402" "E0620403" "E08101"   "E08102"   "E08201"   "E08202"
[217] "E0910101" "E0910102" "E0910402" "E09211"   "E09212"   "I0821101"
[223] "I0821102" "E09213"   "E09214"   "E09401"   "E09402"   "E0940302"
[229] "E09501"   "E09502"   "E09503"   "E09504"   "F0110101" "F0110102"
[235] "F01201"   "F01202"   "F01203"   "F01301"   "F0130101" "F0130102"
[241] "F02301"   "F02501"   "F0260101" "F02701"   "F02702"   "F03101"
[247] "F03102"   "F03103"   "F03104"   "F0320101" "F03303"   "F03302"
[253] "F03301"   "F03304"   "F03401"   "F03403"   "F03402"   "F0350101"
[259] "F0350201" "F03601"   "F03602"   "F04101"   "F04102"   "F04103"
[265] "F04104"   "F05101"   "F0610101" "F0610102" "F0620101" "F0620102"
[271] "F06204"   "F0620301" "F0620302" "F0620303" "F0620304" "G01101"
[277] "G01104"   "G01107"   "G01109"   "G01115"   "G01202"   "G01311"
[283] "G01313"   "G01314"   "G01315"   "G01316"   "G01317"   "G03201"
[289] "G03203"   "G0320501" "G03207"   "G04101"   "G04211"   "G04306"
[295] "G04307"   "G05102"   "G0430501" "H01301"   "H01302"   "H0130202"
[301] "H01204"   "H01601"   "H01603"   "H01401"   "H01402"   "H01403"
[307] "H02104"   "H0210301" "H0210302" "H0210701" "H0210703" "H02101"
```

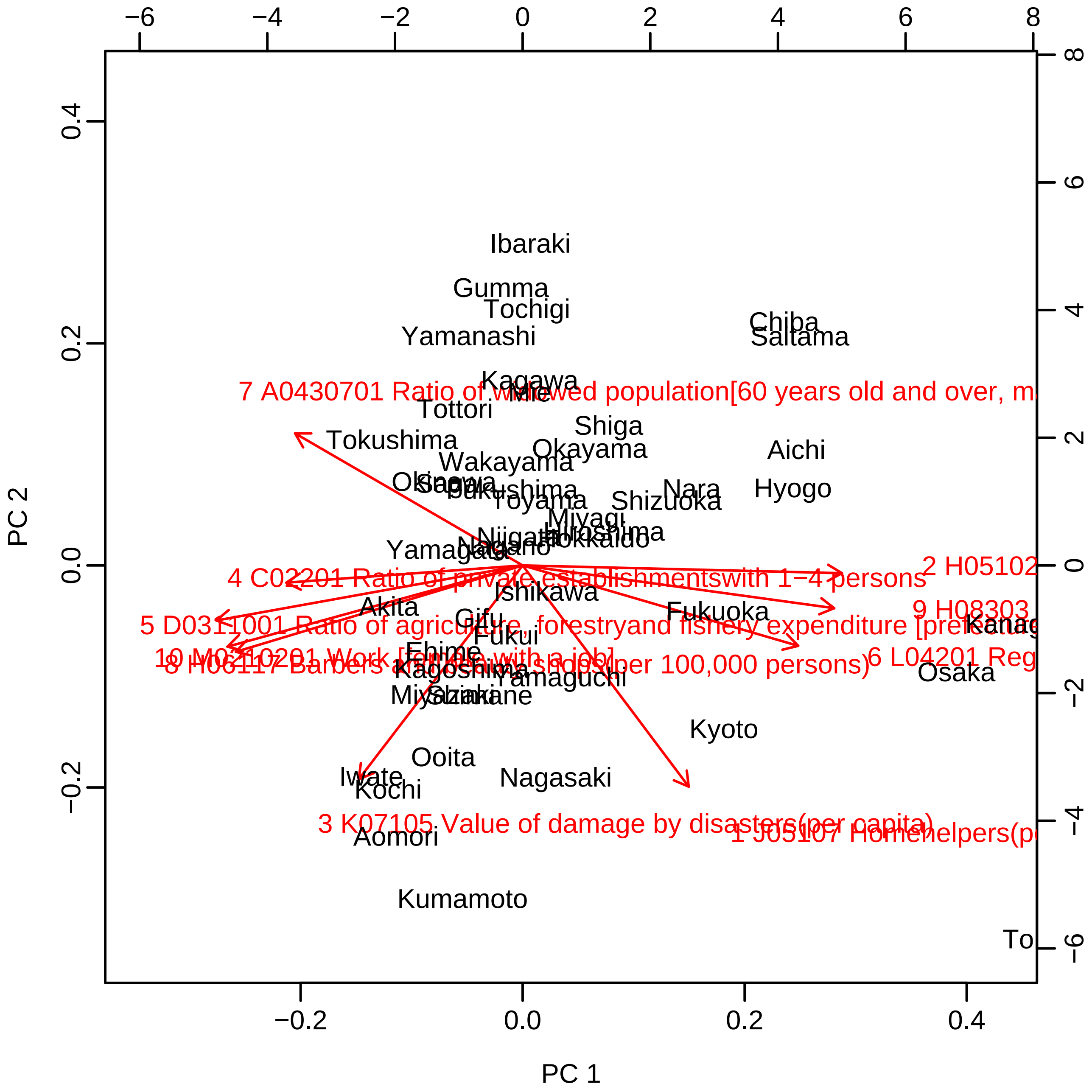
```
[313] "H0210101" "H0210102" "H0220301" "H0220302" "H0210201" "H0210202"
[319] "H02302"   "H02303"   "H02601"   "H04101"   "H04102"   "H04301"
[325] "H05102"   "H05201"   "H05304"   "H05306"   "H0540101" "H05503"
[331] "H05504"   "H05601"   "H06101"   "H06103"   "H06105"   "H06107"
[337] "H06109"   "H06111"   "H06113"   "H0611302" "H06125"   "H06117"
[343] "H06119"   "H06121"   "H06302"   "H06309"   "H06305"   "H06306"
[349] "H06307"   "H06401"   "H06402"   "H06406"   "H06408"   "H06412"
[355] "H06501"   "H0650101" "H0650102" "H03101"   "H07201"   "H0720202"
[361] "H0720201" "H0720204" "H0720203" "H0720205" "H0720206" "H08101"
[367] "H08301"   "H08302"   "H08303"   "H08304"   "I04105"   "I04104"
[373] "I04102"   "I04103"   "I0420102" "I0420103" "I0420202" "I0420203"
[379] "I05101"   "I0520101" "I0520102" "I0520201" "I0520202" "I0520501"
[385] "I0520502" "I06101"   "I06102"   "I06103"   "I06104"   "I06105"
[391] "I06106"   "I06201"   "I07101"   "I07102"   "I07103"   "I07104"
[397] "I07105"   "I07201"   "I0210101" "I0210102" "I0210103" "I0210104"
[403] "I0210105" "I0210106" "I0210201" "I0210202" "I0210203" "I0210204"
[409] "I0210205" "I0210206" "I0910103" "I0910105" "I0910106" "I0910107"
[415] "I0910203" "I0910205" "I0920101" "I0920201" "I0920301" "I0930201"
[421] "I0930301" "I09401"   "I09402"   "I0950102" "I0950103" "I0950104"
```

```
[427] "I10101"   "I10102"   "I10103"   "I10104"   "I10105"   "I10201"
[433] "I10202"   "I10203"   "I10204"   "I10205"   "I11101"   "I11102"
[439] "I11201"   "I12201"   "I13102"   "I13207"   "I13201"   "I13402"
[445] "I14101"   "I14102"   "I14201"   "I14202"   "J01101"   "J01107"
[451] "J0110803" "J0110804" "J0110902" "J01200"   "J02101"   "J02201"
[457] "J02204"   "J02202"   "J02203"   "J02301"   "J02401"   "J02501"
[463] "J03101"   "J03201"   "J03202"   "J03203"   "J03301"   "J03401"
[469] "J03501"   "J04101"   "J04102"   "J04201"   "J04202"   "J04203"
[475] "J04204"   "J04301"   "J04302"   "J04401"   "J04402"   "J05101"
[481] "J05102"   "J05103"   "J05107"   "J05201"   "J05202"   "J05203"
[487] "J05206"   "J05204"   "J05207"   "J0610101" "J0610102" "I15101"
[493] "I15102"   "I15103"   "I15202"   "I1520301" "I1520302" "I1520401"
[499] "I1520402" "F07101"   "F07102"   "F08101"   "F08102"   "F08201"
[505] "F08202"   "K01102"   "K01104"   "K01105"   "K01107"   "K01301"
[511] "K01302"   "K01401"   "K01402"   "K02101"   "K02103"   "K02203"
[517] "K02205"   "K02301"   "K02303"   "K02306"   "K03102"   "K03104"
[523] "K03112"   "K04102"   "K04101"   "K04105"   "K04106"   "K04107"
[529] "K04201"   "K04202"   "K04301"   "K05102"   "K05103"   "K06101"
[535] "K06104"   "K06201"   "K06204"   "K06401"   "K06402"   "K06403"
```

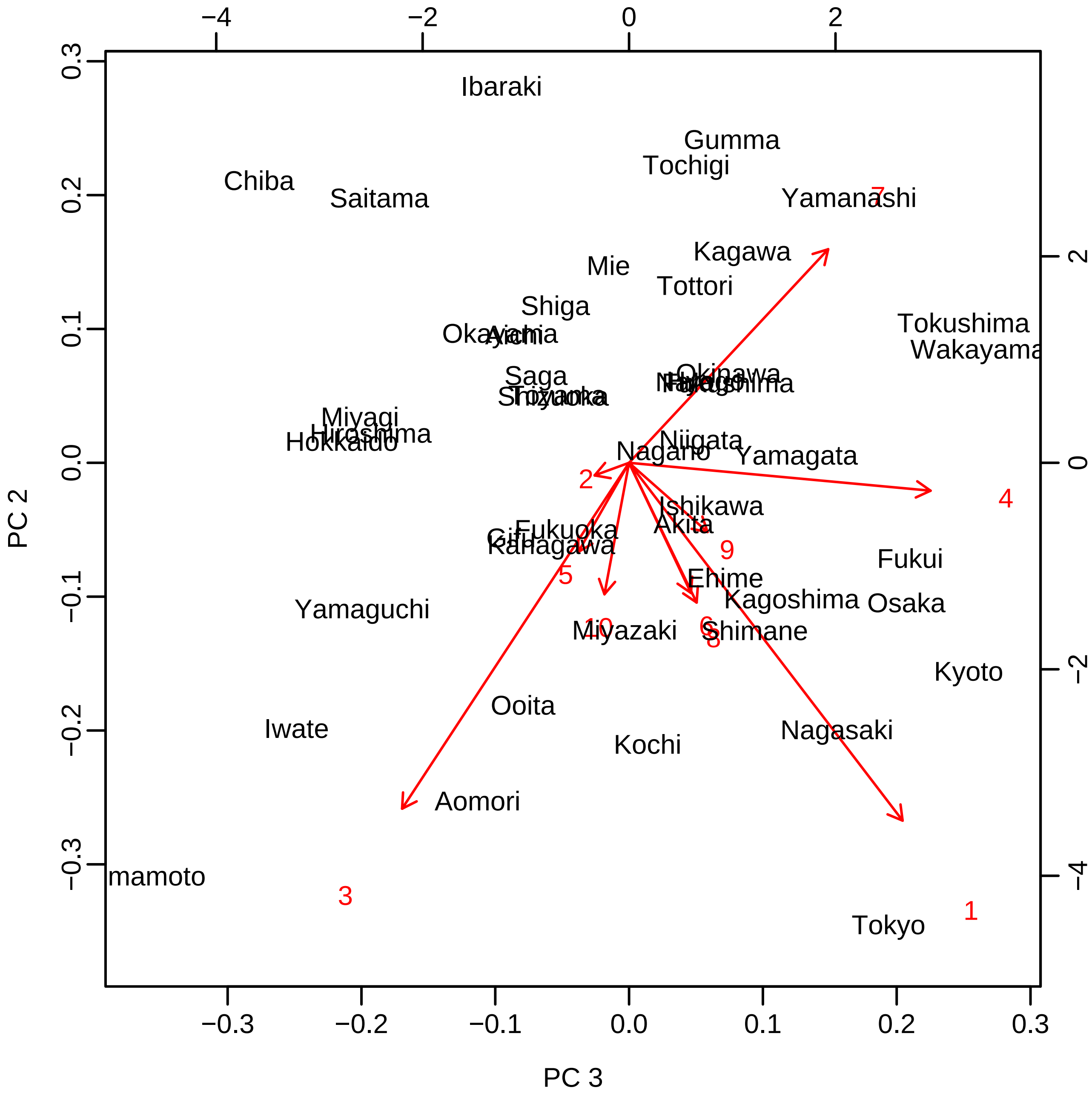
```
[541] "K06405"   "K06301"   "K06304"   "K06501"   "K06503"   "K07105"
[547] "K08101"   "K09201"   "K10101"   "K10105"   "K10107"   "K10201"
[553] "K10203"   "K10301"   "K10304"   "K10305"   "K10401"   "K10403"
[559] "K10501"   "K10502"   "K10503"   "L01201"   "L01204"   "L02602"
[565] "L02201"   "L02401"   "L02402"   "L02403"   "L02404"   "L02405"
[571] "L02406"   "L02407"   "L02408"   "L02409"   "L02410"   "L02734"
[577] "L02735"   "L02736"   "L01100"   "L0110101" "L0110102" "L02601"
[583] "L02101"   "L02301"   "L03201"   "L03212"   "L03213"   "L03214"
[589] "L03401"   "L03412"   "L03602"   "L03603"   "L03604"   "L03606"
[595] "L03607"   "M01101"   "M01102"   "M0120106" "M0120206" "M0120107"
[601] "M0120207" "M0130106" "M0130206" "M0130107" "M0130207" "M0210101"
[607] "M0210201" "M0310101" "M0310201" "M0310102" "M0310202" "M0330101"
[613] "M0330201" "M0330102" "M0330202"
> a <- sample(a0,10)  # randomly select 10 items
> a
 [1] "I07104"   "K06401"   "E0610202" "F07102"   "E09502"   "D03113"
 [7] "L01100"   "J02301"   "D0331803" "I0950103"
> a <- sample(a0,10)  # randomly select 10 items again
> a
```

```
 [1] "J05107"   "H05102"   "K07105"   "C02201"   "D0311001" "L04201"
 [7] "A0430701" "H06117"   "H08303"   "M0210201"
> na <- paste(seq(along=a),a,X2000$item[a])
> na
 [1] "1 J05107 Homehelpers(per 100,000 persons) "
 [2] "2 H05102 Ratio of households coveredby city gas supply system "
 [3] "3 K07105 Value of damage by disasters(per capita) "
 [4] "4 C02201 Ratio of private establishmentswith 1-4 persons "
 [5] "5 D0311001 Ratio of agriculture, forestryand fishery expenditure [prefe
 [6] "6 L04201 Regional difference index of consumerprices [general : ku-area
 [7] "7 A0430701 Ratio of widowed population[60 years old and over, male] "
 [8] "8 H06117 Barbers and beauty shops(per 100,000 persons) "
 [9] "9 H08303 Neighborhood parksper inhabitable area 100k "
[10] "10 M0210201 Work [female with a job]  "
> jna <- paste(seq(along=a),a,X2000$jitem[a])
> jna
 [1] "1 J05107 訪問介護員（ホームヘルパー）数（人口10万人当たり） "
 [2] "2 H05102 都市ガス供給区域内世帯比率  "
 [3] "3 K07105 災　害　被　害　額（人口１人当たり） "
```

```
 [4] "4 C02201 従業者１～４人の事業所割合［民　営］ "
 [5] "5 D0311001 農 林 水 産 業 費 割 合［県財政］ "
 [6] "6 L04201 消費者物価地域差指数［総合：東京都区部＝100］ "
 [7] "7 A0430701 死　別　者　割　合［60歳以上・男］ "
 [8] "8 H06117 理 容 ・ 美 容 所 数（人口10万人当たり） "
 [9] "9 H08303 近　隣　公　園　数（可住地面積100k　当たり） "
[10] "10 M0210201 仕 事 の 平 均 時 間［有業者・女］ "
> x <- X2000$x[,a]
> dim(x)
[1] 47 10
>
```



PC 1
PC 2
Ibaraki
Gumma
Tochigi
Yamanashi
Chiba
Saitama
Kagawa
Tottori
Tokushima
Shiga
Okayama
Aichi
Wakayama
Hyogo
Nara
Shizuoka
Toyama
Miyagi
Hokkaido
Yamagata
Ishikawa
Akita
Fukuoka
Gifu
Fukui
Ehime
Kagoshima
Yamaguchi
Osaka
Kyoto
Ooita
Iwate
Kochi
Nagasaki
Aomori
Kumamoto
7 A0430701 Ratio of widowed population[60 years old and over, m
4 C02201 Ratio of private establishmentswith 1−4 persons
2 H05102
9 H08303
5 D0311001 Ratio of agriculture, forestryand fishery expenditure [prefecture
6 L04201 Reg
3 K07105 Value of damage by disasters(per capita)
1 J05107 Homehelpers(p


PC 2
PC 3
Ibaraki
Gumma
Tochigi
Chiba
Saitama
Yamanashi
Kagawa
Mie
Tottori
Shiga
Tokushima
Wakayama
Okayama
Aichi
Okinawa
Saga
Toyama
Shizuoka
Miyagi
Hiroshima
Hokkaido
Niigata
Nagano
Yamagata
Ishikawa
Akita
Gifu
Fukuoka
Kanagawa
Fukui
Ehime
Kagoshima
Osaka
Yamaguchi
Miyazaki
Shimane
Kyoto
Ooita
Iwate
Kochi
Nagasaki
Aomori
mamoto
Tokyo
1
2
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8
9
10


Cluster Dendrogram
Height
0
2
4
6
8
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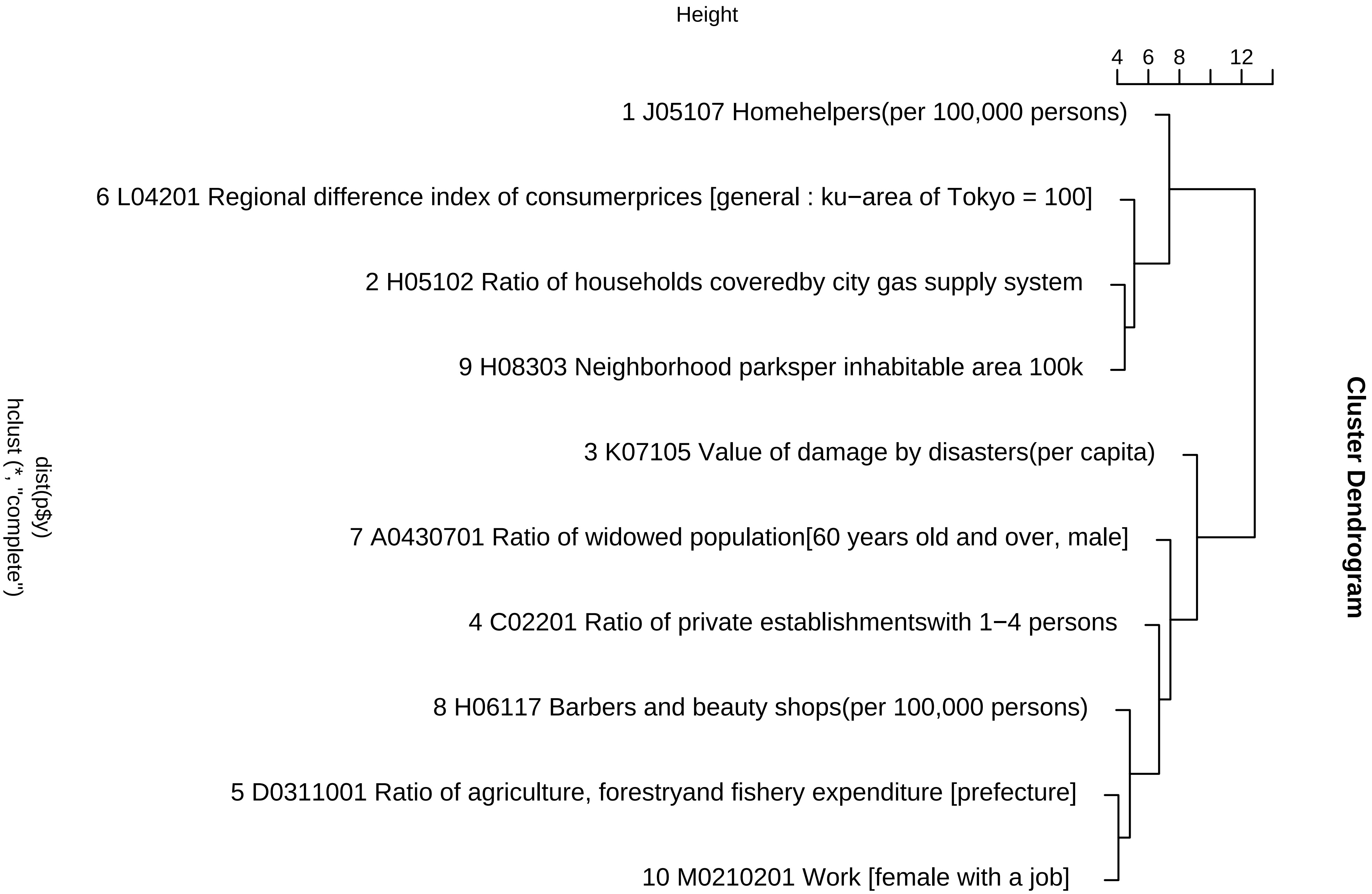
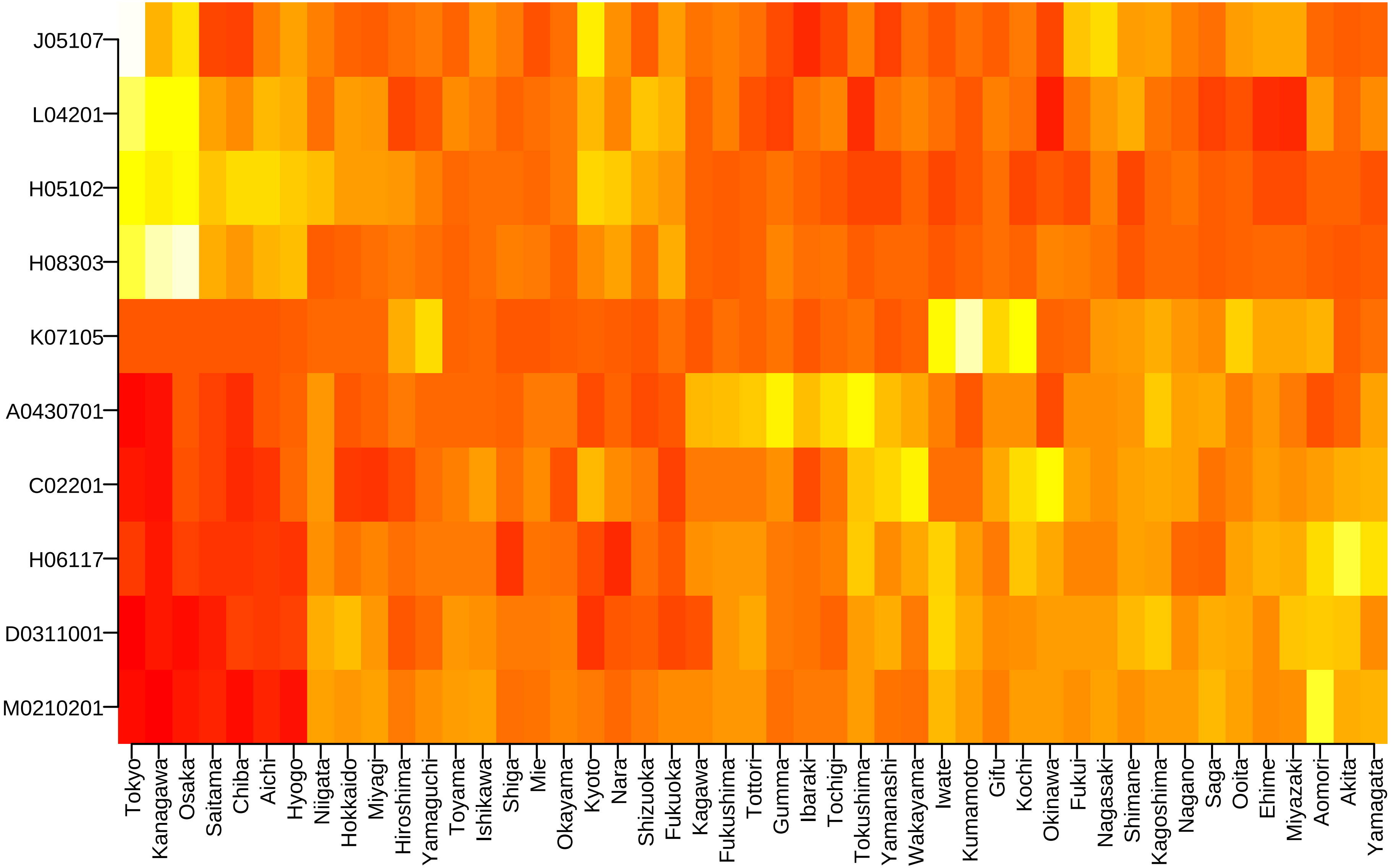
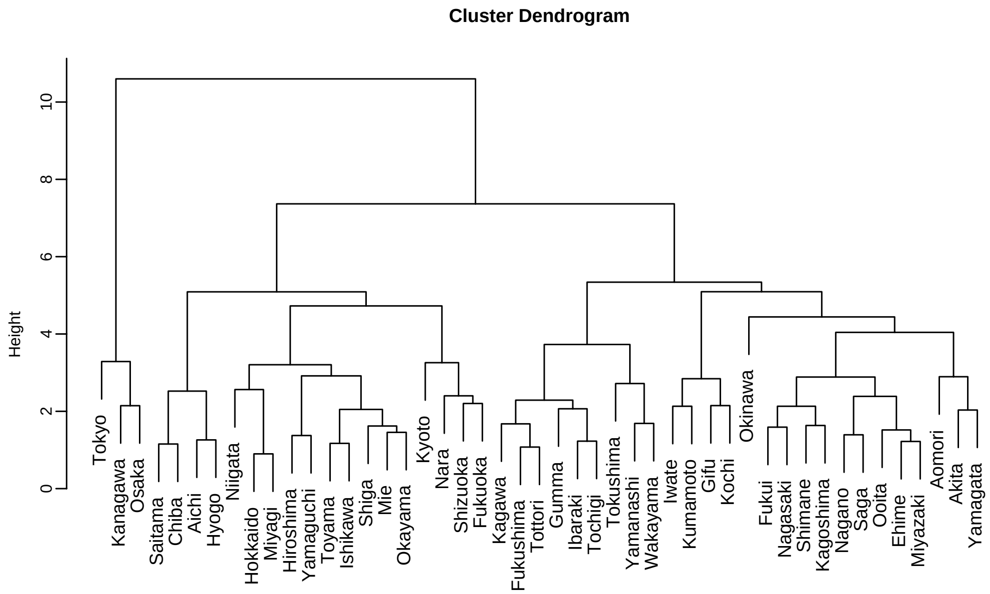
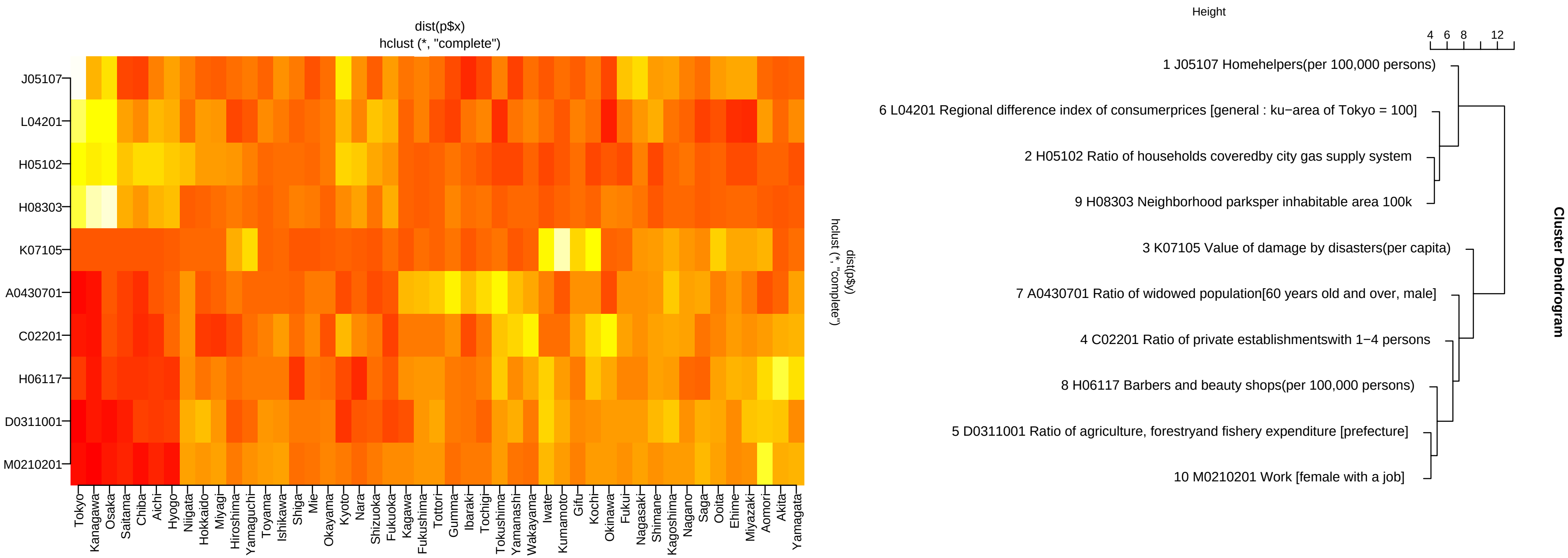
Tokyo
Kanagawa
Osaka
Saitama
Chiba
Aichi
Hyogo
Niigata
Hokkaido
Miyagi
Hiroshima
Yamaguchi
Toyama
Ishikawa
Shiga
Mie
Okayama
Kyoto
Nara
Shizuoka
Fukuoka
Kagawa
Fukushima
Tottori
Gumma
Ibaraki
Tochigi
Tokushima
Yamanashi
Wakayama
Iwate
Kumamoto
Gifu
Kochi
Okinawa
Fukui
Nagasaki
Shimane
Kagoshima
Nagano
Saga
Ooita
Ehime
Miyazaki
Aomori
Akita
Yamagata
dist(p$x)
hclust (*, "complete")


Cluster Dendrogram
Height
4
6
8
12
1 J05107 Homehelpers(per 100,000 persons)
6 L04201 Regional difference index of consumerprices [general : ku−area of Tokyo = 100]
2 H05102 Ratio of households coveredby city gas supply system
9 H08303 Neighborhood parksper inhabitable area 100k
3 K07105 Value of damage by disasters(per capita)
7 A0430701 Ratio of widowed population[60 years old and over, male]
4 C02201 Ratio of private establishmentswith 1−4 persons
8 H06117 Barbers and beauty shops(per 100,000 persons)
5 D0311001 Ratio of agriculture, forestryand fishery expenditure [prefecture]
10 M0210201 Work [female with a job]
dist(p$y)
hclust (*, "complete")


J05107
L04201
H05102
H08303
K07105
A0430701
C02201
H06117
D0311001
M0210201
Tokyo
Kanagawa
Osaka
Saitama
Chiba
Aichi
Hyogo
Niigata
Hokkaido
Miyagi
Hiroshima
Yamaguchi
Toyama
Ishikawa
Shiga
Mie
Okayama
Kyoto
Nara
Shizuoka
Fukuoka
Kagawa
Fukushima
Tottori
Gumma
Ibaraki
Tochigi
Tokushima
Yamanashi
Wakayama
Iwate
Kumamoto
Gifu
Kochi
Okinawa
Fukui
Nagasaki
Shimane
Kagoshima
Nagano
Saga
Ooita
Ehime
Miyazaki
Aomori
Akita
Yamagata


Cluster Dendrogram
Height
0
2
4
6
8
10
Tokyo
Kanagawa
Osaka
Saitama
Chiba
Aichi
Hyogo
Niigata
Hokkaido
Miyagi
Hiroshima
Yamaguchi
Toyama
Ishikawa
Shiga
Mie
Okayama
Kyoto
Nara
Shizuoka
Fukuoka
Kagawa
Fukushima
Tottori
Gumma
Ibaraki
Tochigi
Tokushima
Yamanashi
Wakayama
Iwate
Kumamoto
Gifu
Kochi
Okinawa
Fukui
Nagasaki
Shimane
Kagoshima
Nagano
Saga
Ooita
Ehime
Miyazaki
Aomori
Akita
Yamagata


dist(p$x)
hclust (*, "complete")
J05107
L04201
H05102
H08303
K07105
A0430701
C02201
H06117
D0311001
M0210201
Tokyo
Kanagawa
Osaka
Saitama
Chiba
Aichi
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Miyagi
Hiroshima
Yamaguchi
Toyama
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Shizuoka
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Tokushima
Yamanashi
Wakayama
Iwate
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Gifu
Kochi
Okinawa
Fukui
Nagasaki
Shimane
Kagoshima
Nagano
Saga
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dist(p$y)
hclust (*, "complete")
Height
4
6
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1 J05107 Homehelpers(per 100,000 persons)
6 L04201 Regional difference index of consumerprices [general : ku−area of Tokyo = 100]
2 H05102 Ratio of households coveredby city gas supply system
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7 A0430701 Ratio of widowed population[60 years old and over, male]
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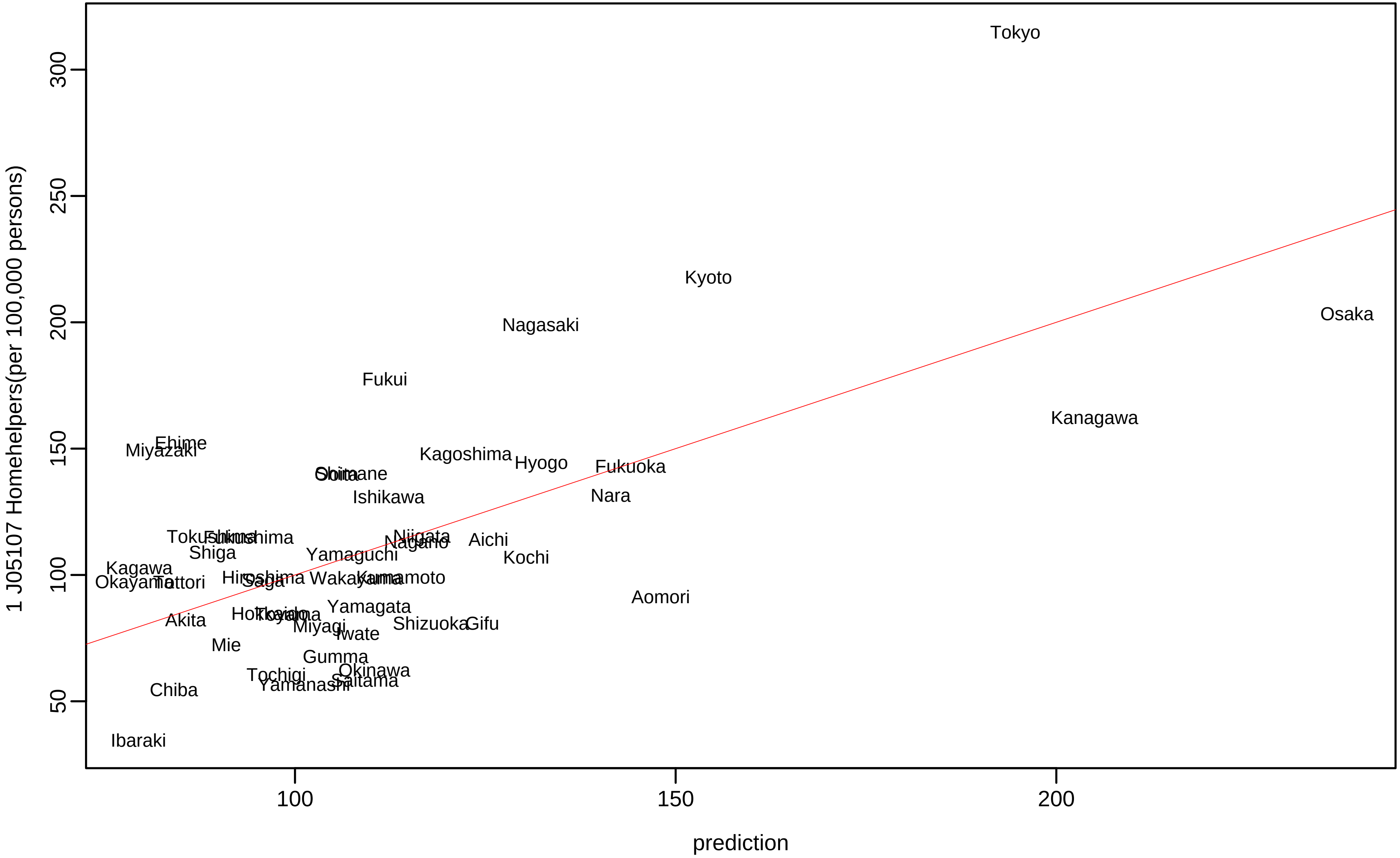
8 H06117 Barbers and beauty shops(per 100,000 persons)
5 D0311001 Ratio of agriculture, forestryand fishery expenditure [prefecture]
10 M0210201 Work [female with a job]
Cluster Dendrogram



1 J05107 Homehelpers(per 100,000 persons)
50
100
150
200
250
300
prediction
Tokyo
Kyoto
Osaka
Nagasaki
Fukui
Kanagawa
Ehime
Miyazaki
Kagoshima
Hyogo
Fukuoka
Shimane
Oita
Ishikawa
Nara
Tokushima
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Niigata
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Aichi
Yamaguchi
Kochi
Kagawa
Okayama
Tottori
Hiroshima
Saga
Wakayama
Kumamoto
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Yamagata
Hokkaido
Toyama
Akita
Miyagi
Iwate
Shizuoka
Gifu
Mie
Gumma
Okinawa
Tochigi
Yamanashi
Saitama
Chiba
Ibaraki

```
> round(f$tsummary,3)
, ,  = Y

           Estimate Std.Err t-value Pr(>|t|)
Intercept -1092.573 522.218  -2.092    0.043
H05102        0.458   0.600   0.764    0.450
K07105        0.001   0.000   1.259    0.216
C02201        4.757   3.484   1.365    0.180
D0311001      0.411   2.963   0.139    0.891
L04201        5.493   4.361   1.259    0.216
A0430701      6.486  13.400   0.484    0.631
H06117       -0.048   0.170  -0.283    0.778
H08303        7.267   2.901   2.505    0.017
M0210201     53.139  40.318   1.318    0.196
```

サンプルセッション３

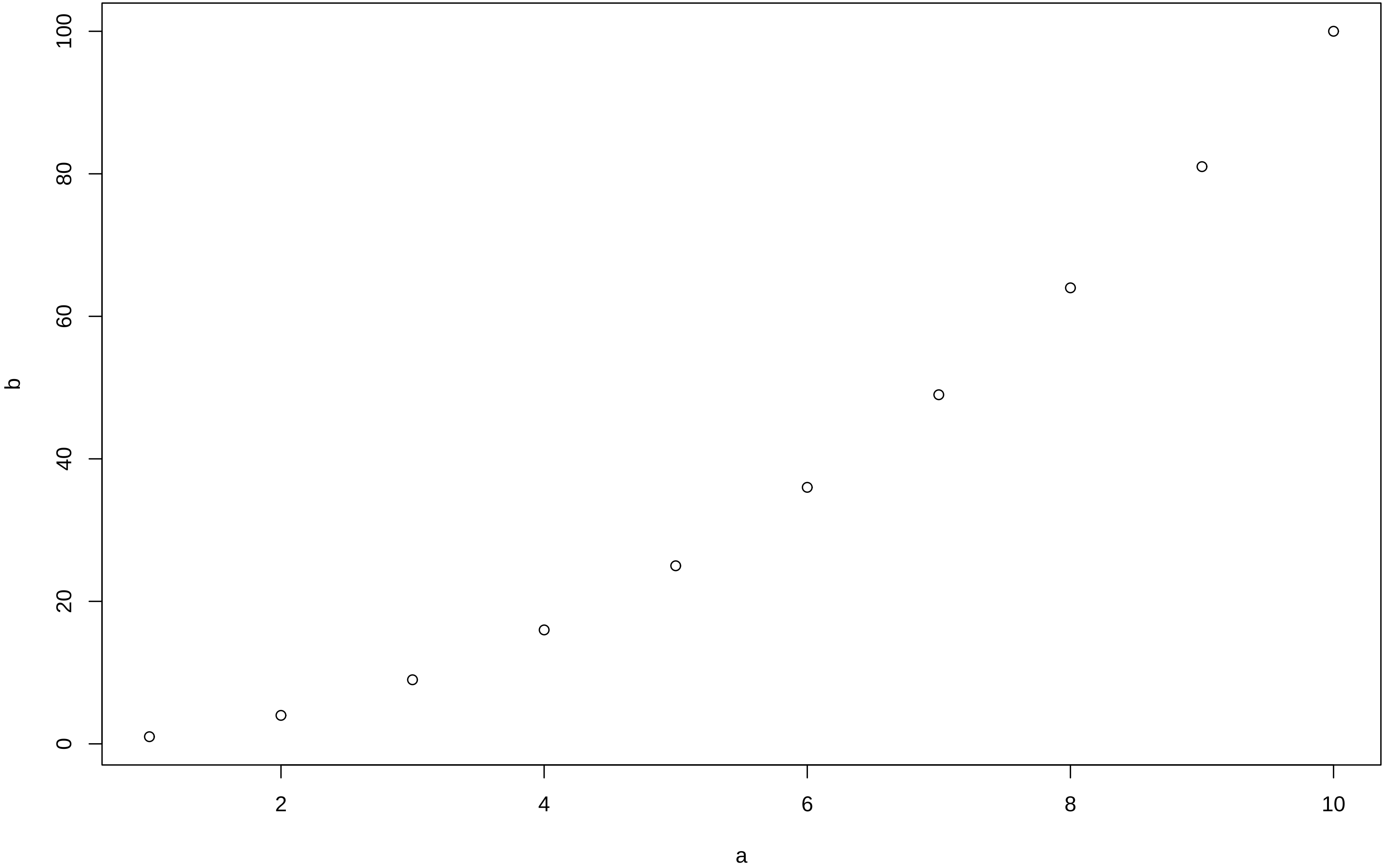
```
> ### values
> ##  character, numeric, and NA types
> "hello"
[1] "hello"
> 123/456
[1] 0.2697368
> sqrt(3/4)
[1] 0.8660254
> sin(pi/3)
[1] 0.8660254
> 1==2
[1] FALSE
> 1==1
[1] TRUE
> 1/0   # infinity
[1] Inf
> sqrt(-1)  # not a number
```

```
[1] NaN
Warning message:
NaNs produced in: sqrt(-1)
> sin(NA)  # not available
[1] NA
> ## vector
> c(1,3,2,4)
[1] 1 3 2 4
> 10:20
 [1] 10 11 12 13 14 15 16 17 18 19 20
> 30:20
 [1] 30 29 28 27 26 25 24 23 22 21 20
> seq(0,10,0.1)  # sequence from 0 to 10 increasing by 0.1
  [1]  0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0  1.1  1.2  1.3
 [16]  1.5  1.6  1.7  1.8  1.9  2.0  2.1  2.2  2.3  2.4  2.5  2.6  2.7  2.8
 [31]  3.0  3.1  3.2  3.3  3.4  3.5  3.6  3.7  3.8  3.9  4.0  4.1  4.2  4.3
 [46]  4.5  4.6  4.7  4.8  4.9  5.0  5.1  5.2  5.3  5.4  5.5  5.6  5.7  5.8
 [61]  6.0  6.1  6.2  6.3  6.4  6.5  6.6  6.7  6.8  6.9  7.0  7.1  7.2  7.3
 [76]  7.5  7.6  7.7  7.8  7.9  8.0  8.1  8.2  8.3  8.4  8.5  8.6  8.7  8.8
```

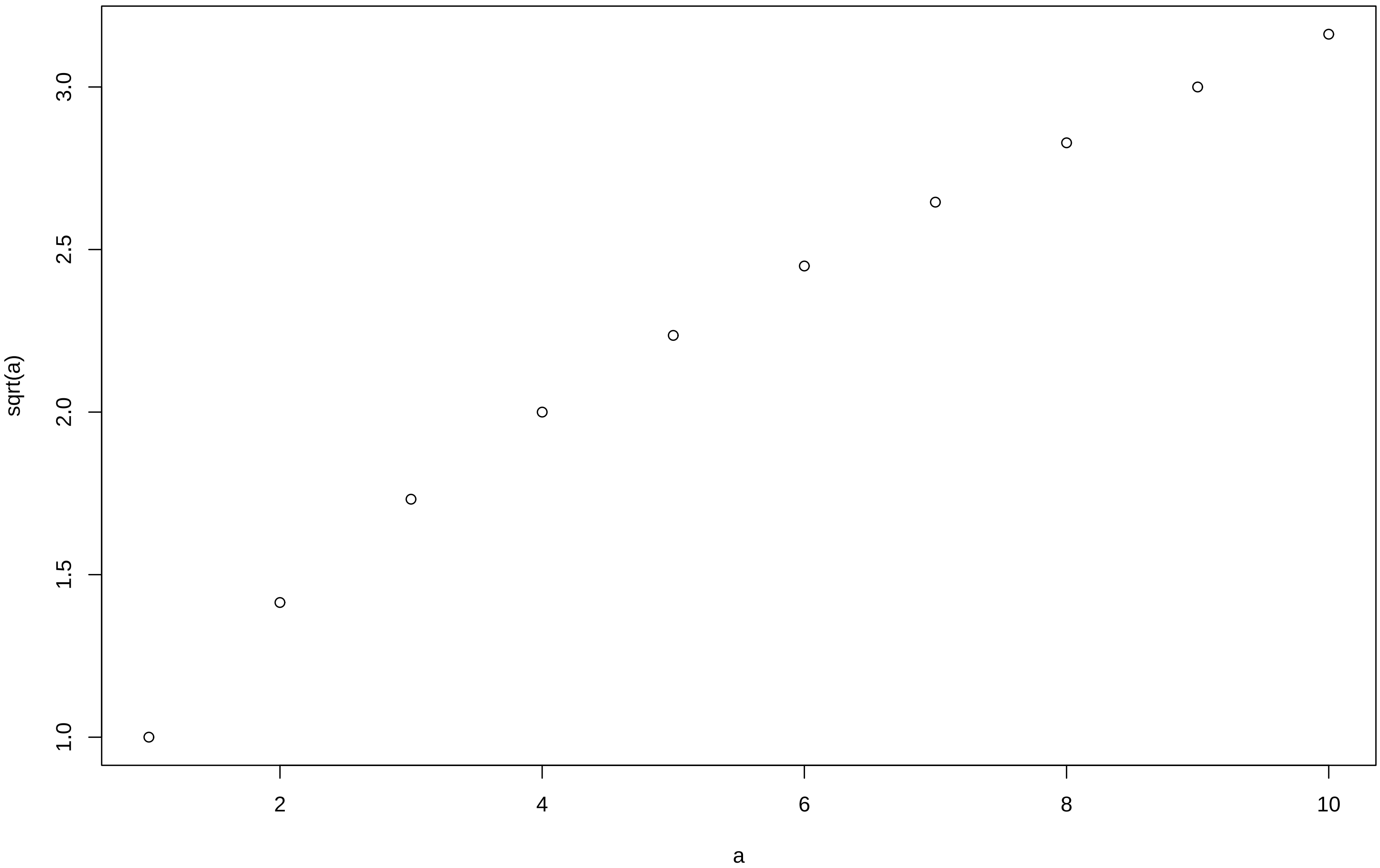
```
 [91]  9.0  9.1  9.2  9.3  9.4  9.5  9.6  9.7  9.8  9.9 10.0
> a <- 10:20
> length(a)  # length of vector
[1] 11
> seq(along=a)
 [1]  1  2  3  4  5  6  7  8  9 10 11
> seq(from=1,to=length(a))
 [1]  1  2  3  4  5  6  7  8  9 10 11
> 1:length(a)
 [1]  1  2  3  4  5  6  7  8  9 10 11
> help(seq)  # show the help message for the function "seq"
> rep(3,10) # replicate elements
 [1] 3 3 3 3 3 3 3 3 3 3
> rep(c(3,4),c(10,20))
 [1] 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
> rep(abc,1:4)
 [1] "abc"   "def"   "def"   "ghi"   "ghi"   "ghi"   "hello" "hello" "hello"
[10] "hello"
> help(rep)
```

```
> ### variables
> ## simple assignment
> a <- 1
> a
[1] 1
> a <- 1:10
> a
 [1]  1  2  3  4  5  6  7  8  9 10
> a^2
 [1]   1   4   9  16  25  36  49  64  81 100
> b <- a*a
> b
 [1]   1   4   9  16  25  36  49  64  81 100
```

```
> plot(a,b)
```

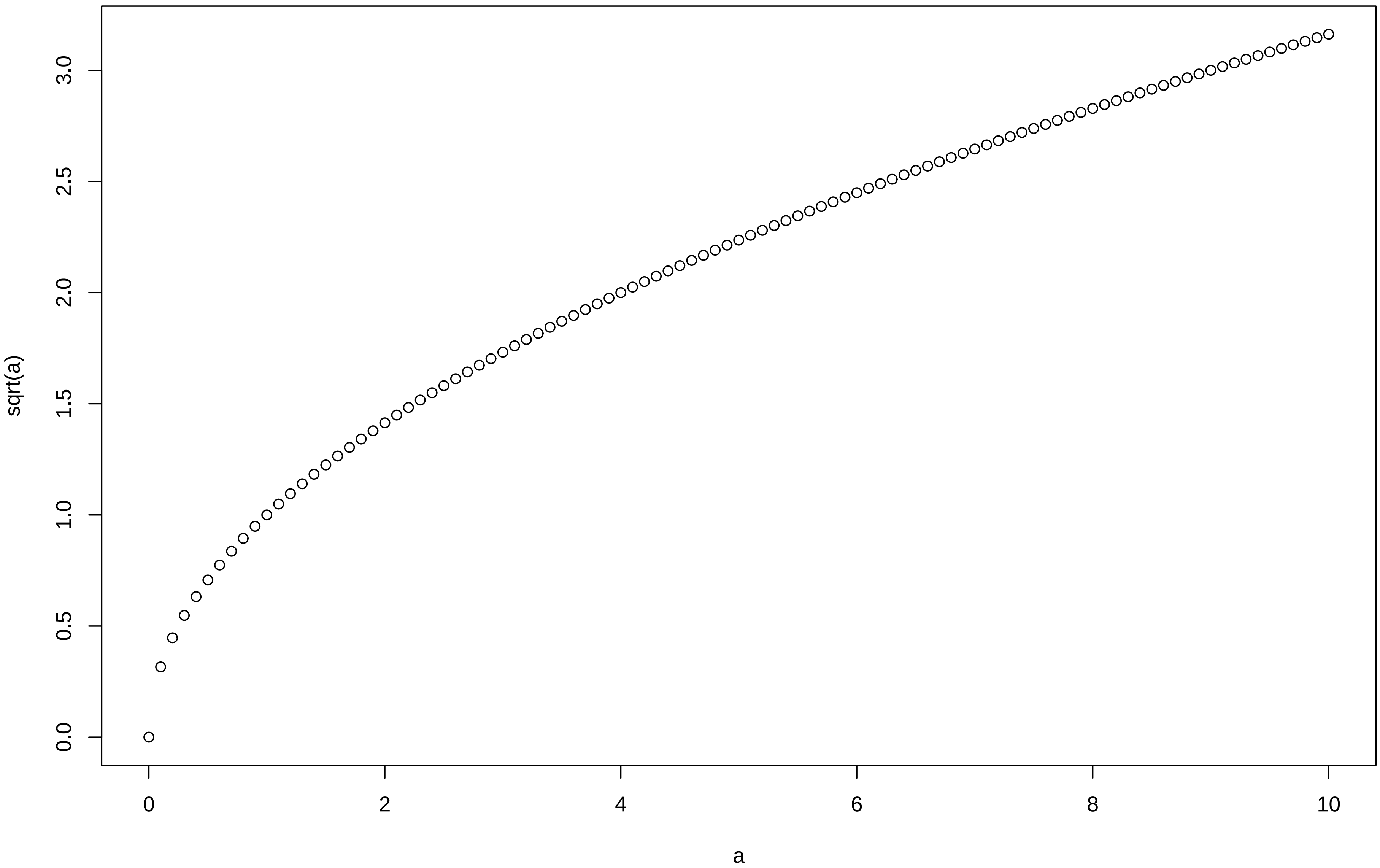


```
> plot(a,sqrt(a))
```

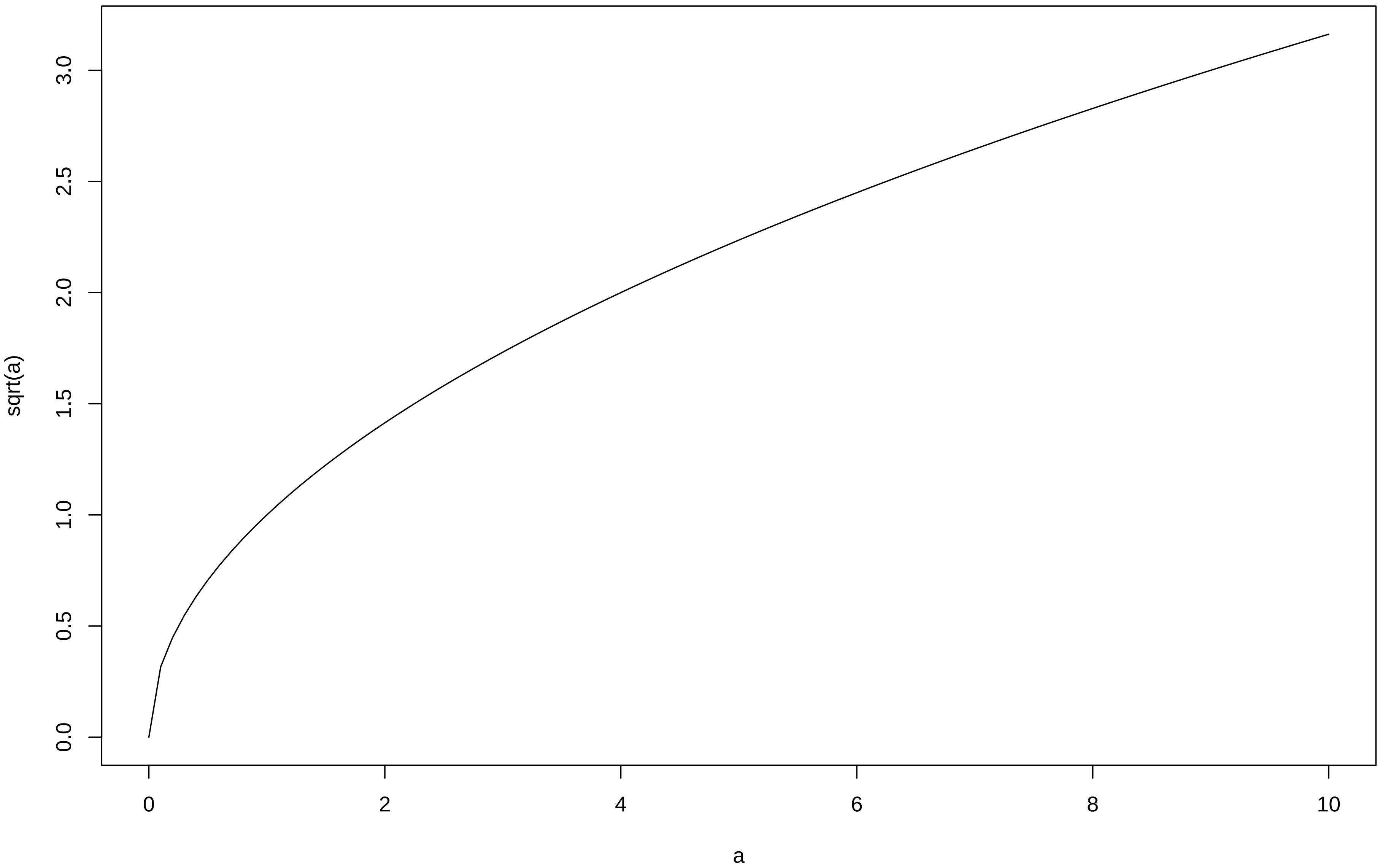


```
> a <- seq(0,10,0.1)
> plot(a,sqrt(a))
> plot(a,sqrt(a),type="l")
```

```
> plot(a,sqrt(a))
```



```
> plot(a,sqrt(a),type="l")
```



```
> abc <- c("abc","def","ghi","hello")
> abc
[1] "abc"   "def"   "ghi"   "hello"
> ## output postscript file
> options(papersize="a4")
> a <- 1:10
> b <- a*a
> postscript("ex01pt1.eps")
> plot(a,b)
> dev.off()
X11
  2
> postscript("ex01pt2.eps")
> plot(a,sqrt(a))
> dev.off()
X11
  2
> a <- seq(0,10,0.1)
> plot(a,sqrt(a))
```

```
> postscript("ex01pt3.eps")
> plot(a,sqrt(a))
> dev.off()
X11
  2
> postscript("ex01pt4.eps")
> plot(a,sqrt(a),type="l")
> dev.off()
X11
  2
> ## extract elements
> abc
[1] "abc"   "def"   "ghi"   "hello"
> abc[4]
[1] "hello"
> abc[1:3]
[1] "abc" "def" "ghi"
> abc[-1]
[1] "def"   "ghi"   "hello"
```

```
> abc[5]
[1] NA
> a <- 101:110
> a
 [1] 101 102 103 104 105 106 107 108 109 110
> a[1]
[1] 101
> a[10]
[1] 110
> a[11]
[1] NA
> a[-1]
[1] 102 103 104 105 106 107 108 109 110
> a[-(1:5)]
[1] 106 107 108 109 110
> a %% 2  # modulo by 2
 [1] 1 0 1 0 1 0 1 0 1 0
> a %% 2 == 0  # even numbers
 [1] FALSE  TRUE FALSE  TRUE FALSE  TRUE FALSE  TRUE FALSE  TRUE
```

```
> a[ a%%2==0 ]
[1] 102 104 106 108 110
> a[ a%%2==1 ]
[1] 101 103 105 107 109
> a >= 105
 [1] FALSE FALSE FALSE FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
> a[ a>=105 ]
[1] 105 106 107 108 109 110
> ## matrix
> a <- matrix(1:6,3,2)  # matrix of size 3 x 2 with elements 1:6
> a
     [,1] [,2]
[1,]    1    4
[2,]    2    5
[3,]    3    6
> dim(a)  # dimensions
[1] 3 2
> t(a)  # matrix transpose
     [,1] [,2] [,3]
```

```
[1,]    1    2    3
[2,]    4    5    6
> t(a) %*% a  # multiplication
     [,1] [,2]
[1,]   14   32
[2,]   32   77
> a %*% t(a)
     [,1] [,2] [,3]
[1,]   17   22   27
[2,]   22   29   36
[3,]   27   36   45
> a <- matrix(1:4,2,2)  # matrix of size 2 x 2 with elements 1:4
> a
     [,1] [,2]
[1,]    1    3
[2,]    2    4
> b <- solve(a)  # inverse matrix
> b
     [,1] [,2]
```

```
[1,]   -2  1.5
[2,]    1 -0.5
> a %*% b  # should be identity matrix
             [,1]          [,2]
[1,] 1.000000e+00 -5.551115e-17
[2,] 4.440892e-16  1.000000e-00
> round(a%*%b, 6)  # show results with 6 digits
     [,1] [,2]
[1,]    1    0
[2,]    0    1
> b %*% a
     [,1]         [,2]
[1,]    1 4.440892e-16
[2,]    0 1.000000e-00
> a * a  # element-wize multiplication
     [,1] [,2]
[1,]    1    9
[2,]    4   16
> a %*% a  # matrix multiplication
```

```
     [,1] [,2]
[1,]    7   15
[2,]   10   22
> sin(a)  # element-wise sin()
          [,1]       [,2]
[1,] 0.8414710  0.1411200
[2,] 0.9092974 -0.7568025
> a %% 2 == 0
      [,1]  [,2]
[1,] FALSE FALSE
[2,]  TRUE  TRUE
> a[a %% 2 == 0]  # result becomes a vector
[1] 2 4
> ## more on matrix
> a <- matrix(1:20,4)  # matrix of size 4 x 5
> a
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    9   13   17
[2,]    2    6   10   14   18
```

```
[3,]    3    7   11   15   19
[4,]    4    8   12   16   20
> a[3,]  # the third row
[1]  3  7 11 15 19
> a[,3]  # the third column
[1]  9 10 11 12
> a[2:3,]  # the second and third rows
     [,1] [,2] [,3] [,4] [,5]
[1,]    2    6   10   14   18
[2,]    3    7   11   15   19
> a[,2:3]  # the second and third columns
     [,1] [,2]
[1,]    5    9
[2,]    6   10
[3,]    7   11
[4,]    8   12
> a[3,,drop=F]  # the third row as matrix
     [,1] [,2] [,3] [,4] [,5]
[1,]    3    7   11   15   19
```

```
> a[,3,drop=F]  # the third column as matrix
     [,1]
[1,]    9
[2,]   10
[3,]   11
[4,]   12
> ### names and dimnames
> ## vector
> a <- 10:15
> a
[1] 10 11 12 13 14 15
> names(a) <- c("ten","eleven","twelve","thirteen","fourteen","fifteen")
> a
     ten    eleven    twelve thirteen fourteen  fifteen
      10        11        12       13       14       15
> names(a)
[1] "ten"       "eleven"    "twelve"    "thirteen" "fourteen" "fifteen"
> a[2]
eleven
```

```
    11
> a["eleven"]
eleven
    11
> a[2:3]
eleven twelve
    11     12
> a[c("eleven","twelve")]
eleven twelve
    11     12
> b <- names(a)
> b[a>=13]
[1] "thirteen" "fourteen" "fifteen"
> b[a%%2==0]
[1] "ten"      "twelve"   "fourteen"
> ## matrix
> a <- matrix(1:6,3)  # matrix of size 3 x 2
> a
     [,1] [,2]
```

```
[1,]    1    4
[2,]    2    5
[3,]    3    6
> rownames(a) <- c("one","two","three")
> a
      [,1] [,2]
one      1    4
two      2    5
three    3    6
> colnames(a) <- c("ichi","ni")
> a
      ichi ni
one      1  4
two      2  5
three    3  6
> rownames(a)
[1] "one"   "two"   "three"
> colnames(a)
[1] "ichi" "ni"
```

```
> dimnames(a)
[[1]]
[1] "one"   "two"   "three"

[[2]]
[1] "ichi" "ni"

> a[,"ni"]
  one   two three
    4     5     6
> a["two",]
ichi   ni
   2    5
> ### list
> a <- list(1:10,abc)
> a
[[1]]
 [1]  1  2  3  4  5  6  7  8  9 10
```

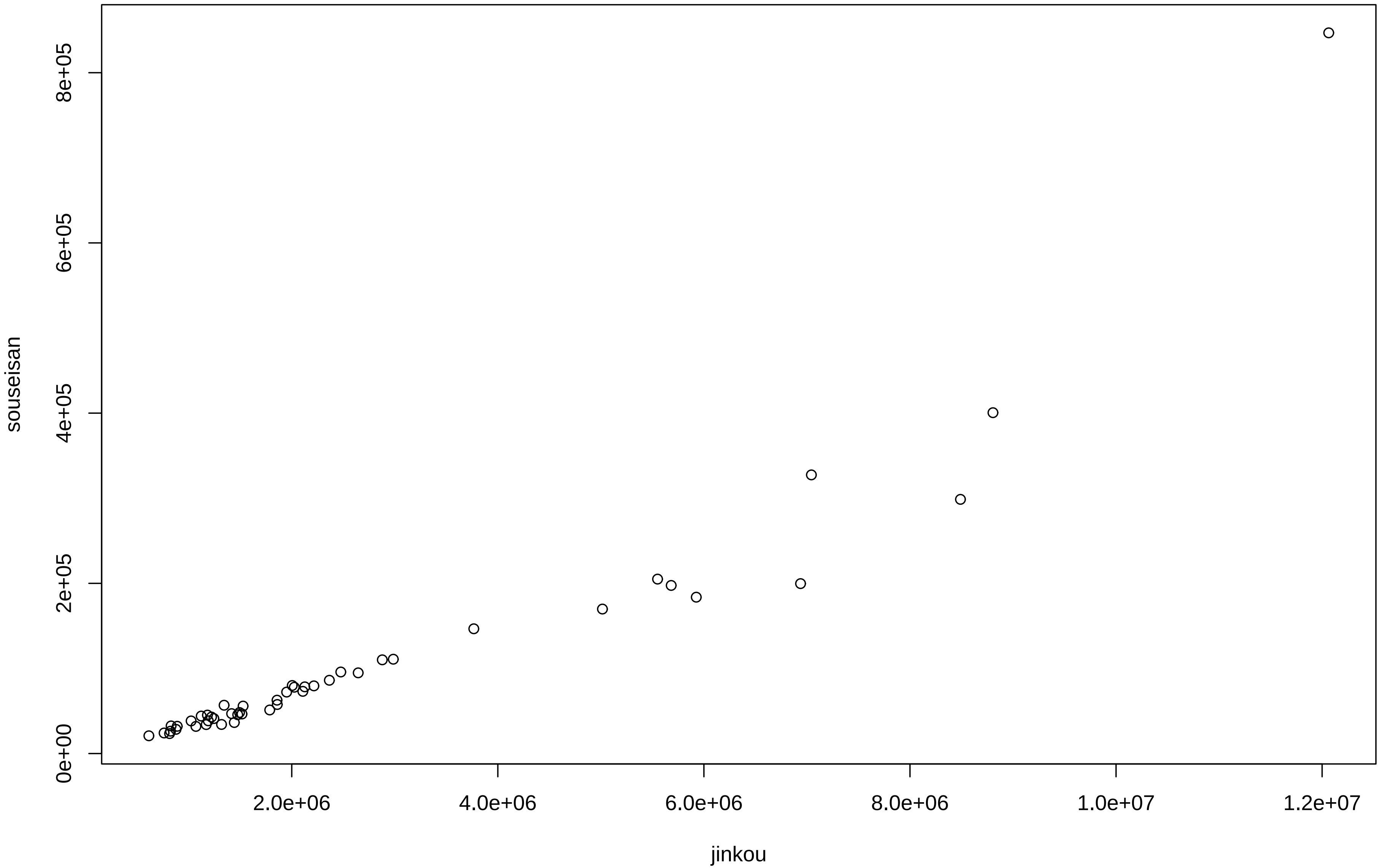
```
[[2]]
[1] "abc"   "def"   "ghi"   "hello"

> a[[1]]
 [1]  1  2  3  4  5  6  7  8  9 10
> a[[2]]
[1] "abc"   "def"   "ghi"   "hello"
> a <- list(suji=1:10,moji=abc)
> a
$suji
 [1]  1  2  3  4  5  6  7  8  9 10

$moji
[1] "abc"   "def"   "ghi"   "hello"

> a$suji
 [1]  1  2  3  4  5  6  7  8  9 10
> a$moji
[1] "abc"   "def"   "ghi"   "hello"
```

```
> ### simple analysis
> ## load a sample dataset
> source("~shimo/class/gakubu200209/data20020919c.R")
> x
             jinkou souseisan
Hokkaido    5683062    197473
Aomori      1475728     45620
Iwate       1416180     46949
Miyagi      2365320     86155
Akita       1189279     38414
Yamagata    1244147     41119
Fukushima   2126935     78345
Ibaraki     2985676    110819
Tochigi     2004817     79962
Gumma       2024852     77960
Saitama     6938006    199636
Chiba       5926285    183721
Tokyo      12064101    846809
Kanagawa    8489974    298661
```

Niigata	2475733	95874
Toyama	1120851	44087
Ishikawa	1180977	45230
Fukui	828944	32426
Yamanashi	888172	31981
Nagano	2215168	79508
Gifu	2107700	73078
Shizuoka	3767393	146616
Aichi	7043300	327476
Mie	1857339	62717
Shiga	1342832	56815
Kyoto	2644391	94863
Osaka	8805081	400519
Hyogo	5550574	204939
Nara	1442795	36523
Wakayama	1069912	31854
Tottori	613289	20817
Shimane	761503	24100
Okayama	1950828	72200

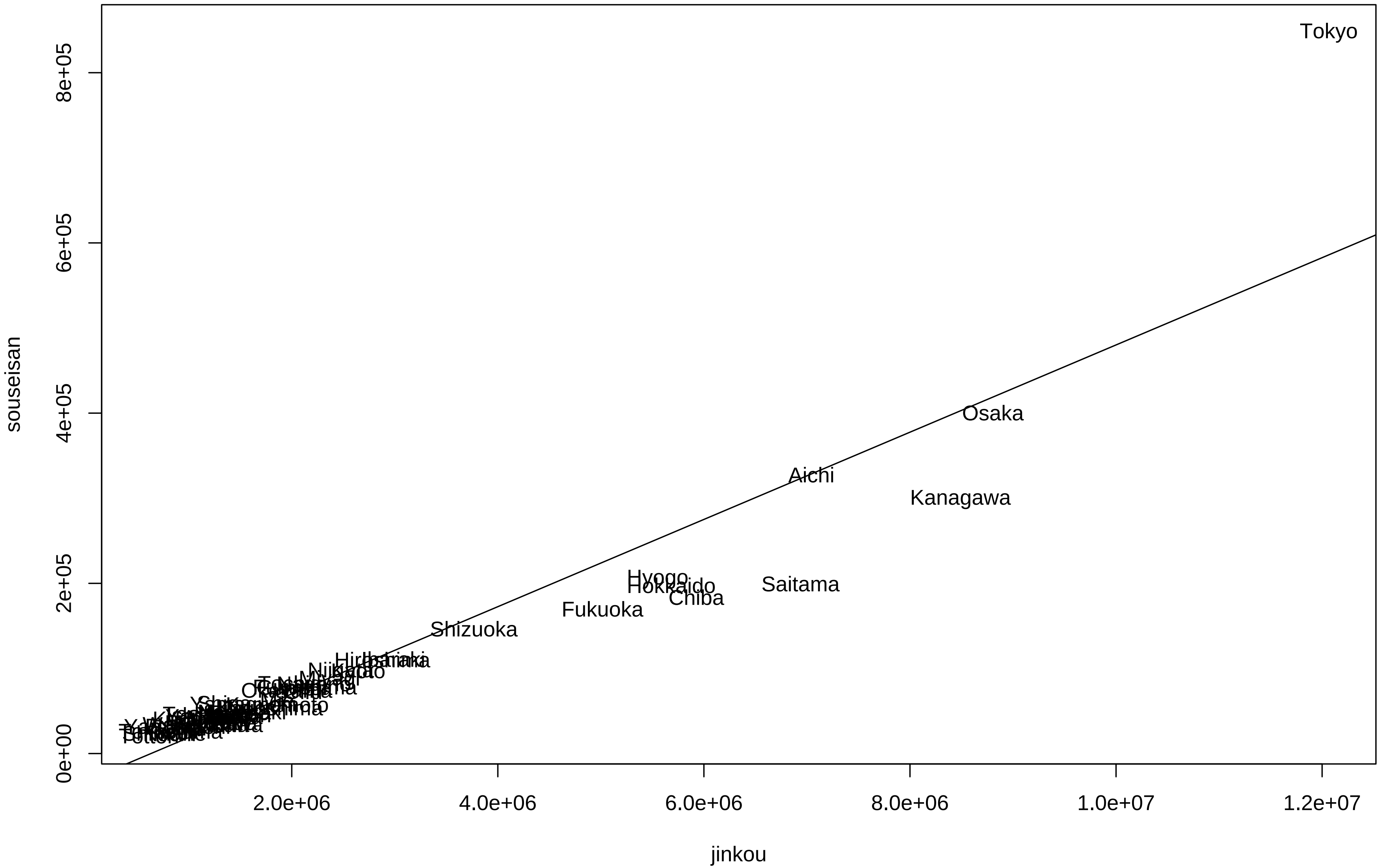
```
Hiroshima  2878915    110162
Yamaguchi  1527964     55796
Tokushima   824108     26357
Kagawa     1022890     38295
Ehime      1493092     48146
Kochi       813949     23417
Fukuoka    5015699    169834
Saga        876654     28484
Nagasaki   1516523     46426
Kumamoto   1859344     57580
Ooita      1221140     42965
Miyazaki   1170007     34026
Kagoshima  1786194     51166
Okinawa    1318220     34249
> x["Tokyo",]
   jinkou souseisan
 12064101    846809
> x[,"jinkou"]
 Hokkaido    Aomori     Iwate    Miyagi     Akita  Yamagata Fukushima   Ibara
```

```
  5683062   1475728   1416180   2365320   1189279   1244147   2126935   2985
  Tochigi     Gumma   Saitama     Chiba     Tokyo  Kanagawa   Niigata    Toya
  2004817   2024852   6938006   5926285  12064101   8489974   2475733   1120
 Ishikawa     Fukui Yamanashi    Nagano      Gifu  Shizuoka     Aichi
  1180977    828944    888172   2215168   2107700   3767393   7043300   1857
    Shiga     Kyoto     Osaka     Hyogo      Nara  Wakayama   Tottori   Shima
  1342832   2644391   8805081   5550574   1442795   1069912    613289    761
  Okayama Hiroshima Yamaguchi Tokushima    Kagawa     Ehime     Kochi   Fuku
  1950828   2878915   1527964    824108   1022890   1493092    813949   5015
     Saga  Nagasaki  Kumamoto     Ooita  Miyazaki Kagoshima   Okinawa
   876654   1516523   1859344   1221140   1170007   1786194   1318220
> ## plot and fitting
> plot(x)  # simple plot
```



souseisan
0e+00
2e+05
4e+05
6e+05
8e+05
2.0e+06
4.0e+06
6.0e+06
8.0e+06
1.0e+07
1.2e+07
jinkou

```
> plot(x,type="n")  # draw only frame
> text(x,rownames(x)) # draw labels
> f <- lsfit(x[,1],x[,2])  # least square fitting (kaiki-bunseki)
> abline(f)  # draw a fitted line
```

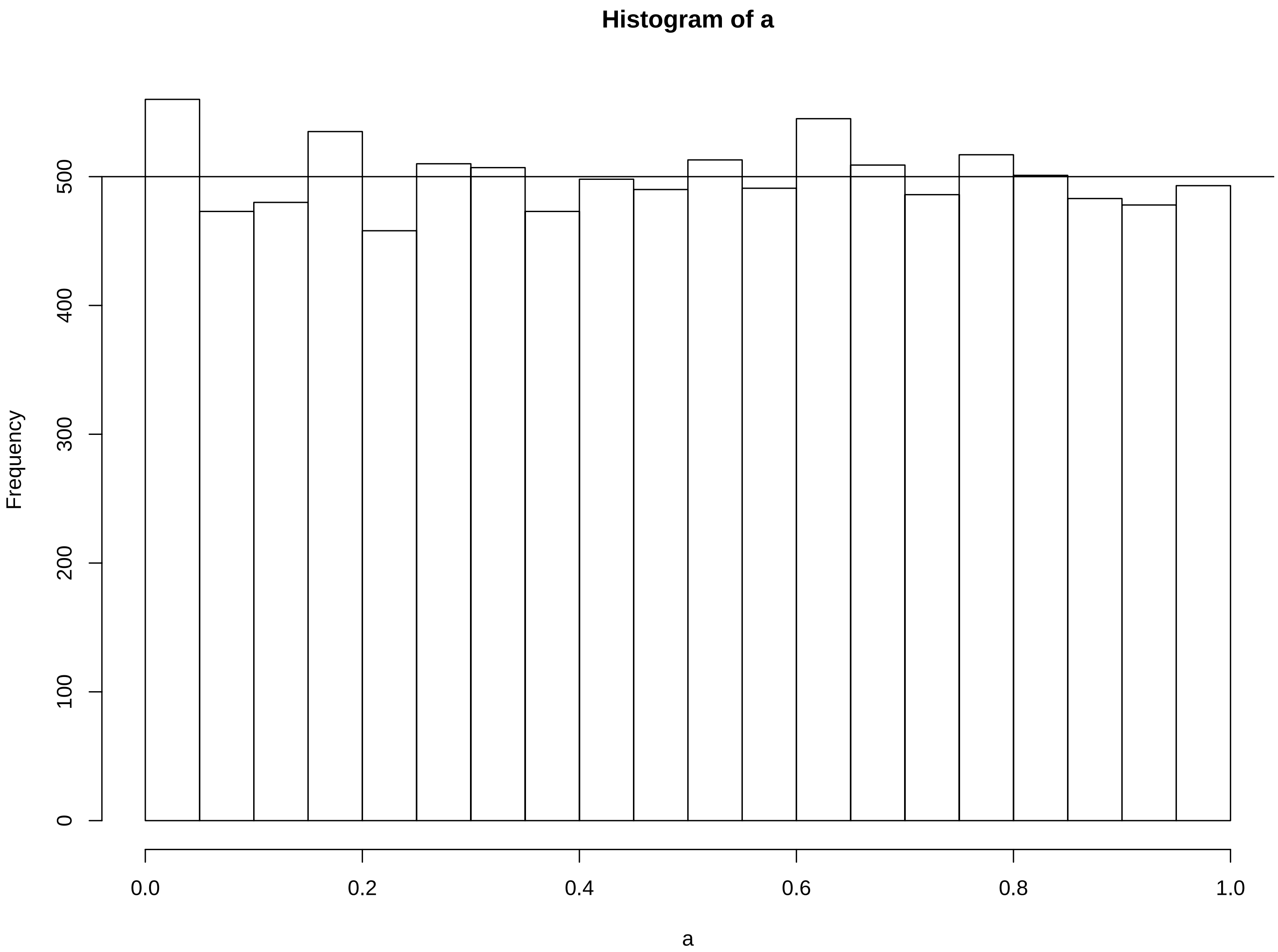

Tokyo
Osaka
Aichi
Kanagawa
Hyogo
Hokkaido
Chiba
Saitama
Fukuoka
Shizuoka
0e+00
2e+05
4e+05
6e+05
8e+05
souseisan
2.0e+06
4.0e+06
6.0e+06
8.0e+06
1.0e+07
1.2e+07
jinkou

```
> ## calculate statistics
> mean(x[,1])
[1] 2700550
> mean(x[,2])
[1] 105961.0
> apply(x,2,mean)
   jinkou souseisan
2700549.9  105961.0
> ## output postscript file
> postscript("ex01rg1.eps")
> plot(x)
> dev.off()
X11
  2
> postscript("ex01rg2.eps")
> plot(x,type="n")  # draw only frame
> text(x,rownames(x)) # draw labels
> abline(f)  # draw a fitted line
> dev.off()
```

```
> ### random number generation
> a <- runif(100)  # uniform distribution on (0,1)
> a
  [1] 0.33772072 0.95523453 0.11471802 0.45899514 0.25807340 0.91897002
  [7] 0.19894305 0.71841781 0.17071827 0.58036916 0.72244387 0.30885956
 [13] 0.39961291 0.44603197 0.49604300 0.08504009 0.02123887 0.71410722
 [19] 0.42955228 0.44309812 0.64121792 0.95145627 0.38858641 0.96265811
 [25] 0.29707709 0.04824197 0.29456821 0.45555714 0.43653072 0.09194056
 [31] 0.96184772 0.23232472 0.99816295 0.87468042 0.59191003 0.58080336
 [37] 0.75491096 0.15443375 0.13984498 0.51942845 0.68094018 0.91656951
 [43] 0.87344172 0.28951874 0.20323800 0.44015944 0.20591796 0.80711408
 [49] 0.30058366 0.70400184 0.15151447 0.36760816 0.87091817 0.90298059
 [55] 0.36557006 0.70513375 0.93172830 0.04053871 0.78096573 0.33618138
 [61] 0.17551581 0.49283572 0.47098055 0.85567305 0.42323136 0.42056184
 [67] 0.45873132 0.84085186 0.67309793 0.14937437 0.37588200 0.61308521
 [73] 0.27323279 0.15935226 0.07312308 0.26750706 0.31644778 0.50176397
 [79] 0.55026224 0.37149845 0.94189514 0.10848281 0.73368034 0.22186991
 [85] 0.45946215 0.80568116 0.41801127 0.46940970 0.71094321 0.91322983
 [91] 0.35198930 0.65997991 0.74573909 0.17367779 0.03160446 0.35358868
```

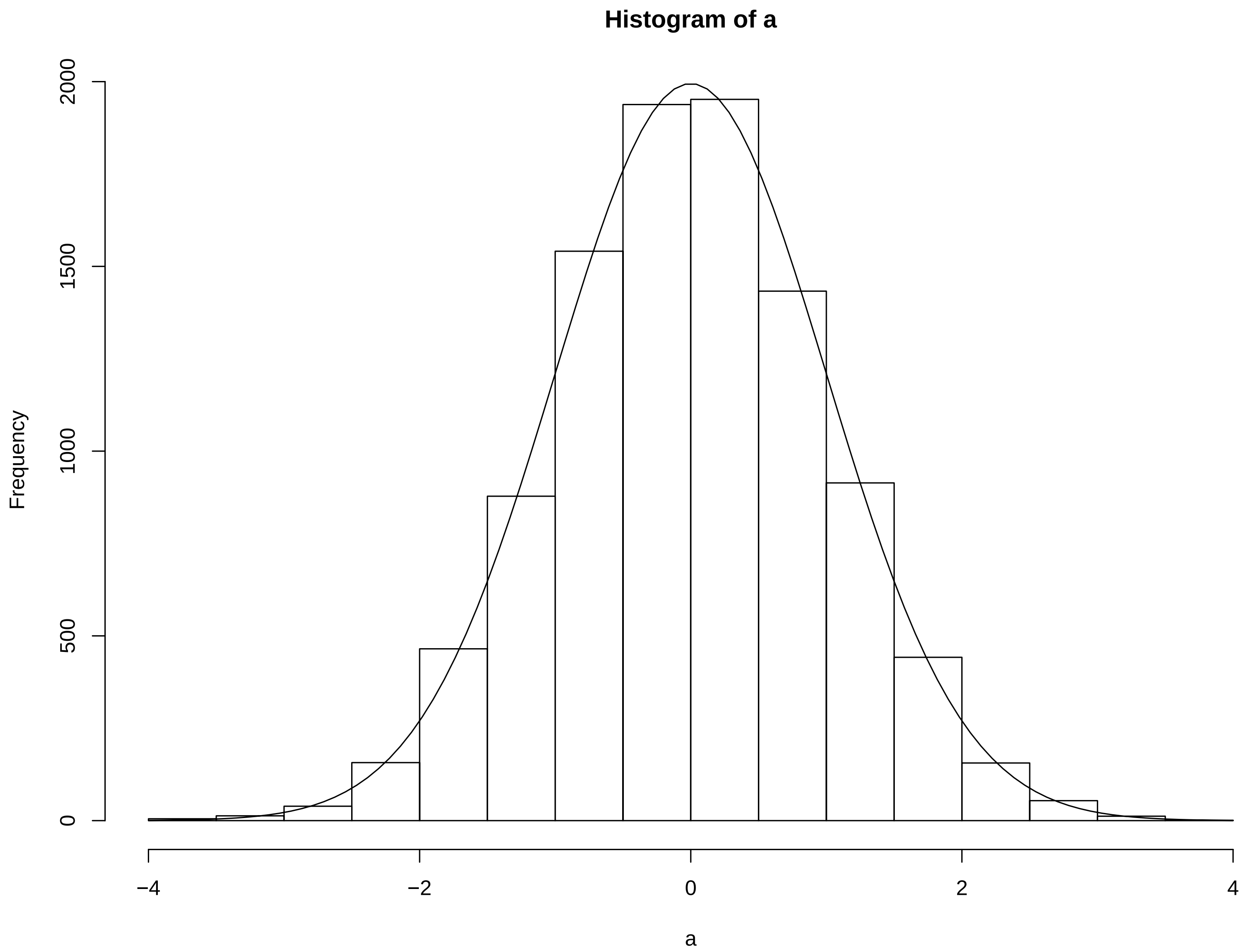
```
 [97] 0.39337573 0.75346727 0.02309114 0.91162517
> hist(a)
> a <- runif(1000)
> hist(a)
> a <- runif(10000)
> mean(a)
[1] 0.5010653
> var(a)
[1] 0.08278935
> a <- runif(10000)
> mean(a)
[1] 0.4979175
> var(a)
[1] 0.08332883
> hist(a)
> abline(h=500)
> postscript("ex01unif.eps")
> hist(a)
> abline(h=500)
```

```
> dev.off()
X11
  2
```


Histogram of a
Frequency
0
100
200
300
400
500
0.0
0.2
0.4
0.6
0.8
1.0
a

```
> a <- rnorm(100)  # normal distribution with mean 0 and varianc 1
> a
  [1] -0.82691765 -2.02067099  0.19400892 -0.30382863 -0.31811388 -0.77346330
  [7] -0.40153550  2.41079419  0.60562417 -0.97393404 -1.23733634  0.85196384
 [13] -0.60534823 -0.77889770 -0.07444445  2.66534621 -0.83451795  0.45235685
 [19] -0.10990285  1.08580316 -0.74960909  0.40406038  0.60829232  1.45375506
 [25]  0.75997487 -1.20344286 -0.85792115 -0.15464927  0.15831217  0.08548434
 [31]  0.50799391 -1.80017291  0.88274744 -1.15015568  0.01921664  2.05726484
 [37]  0.37508515 -0.49540912 -0.92401419  0.38382362  0.27878916 -1.00021783
 [43] -0.63664893  0.69261984 -0.32744108  0.01033082 -0.50170459  1.24632212
 [49]  1.52279633 -0.49338017  0.68571754 -0.70039005 -0.25592276 -1.85568359
 [55]  0.99690176  0.98597080  0.51932234  2.18836775  0.12552985  0.46521986
 [61] -1.33403257 -0.89277524  1.32653428 -0.35091993 -0.37484179  0.40620331
 [67]  1.42748708  0.65026413  0.42211847  1.34728761 -0.30578058  0.53137451
 [73]  0.15892649 -0.35528093  1.53916414  1.65100974  0.70355433  0.56355801
 [79] -0.24340207 -0.44164793  0.73611704  1.18361392 -0.87211264  1.08447142
 [85] -0.57204720  1.17112253 -0.50147376 -0.32345874  2.00594036  0.68166394
 [91] -0.65396266  0.24280340  0.89660829 -0.19244041  0.91239919  0.13789878
 [97] -1.45605476 -1.66931721 -0.66200807 -2.32467900
```

```
> hist(a)
> a <- rnorm(1000)
> hist(a)
> a <- rnorm(10000)
> hist(a)
> mean(a)
[1] -0.005828347
> var(a)
[1] 0.992512
> b <- seq(-4,4,length=100)
> lines(b,dnorm(b)*0.5*10000)
> postscript("ex01norm.eps")
> hist(a)
> lines(b,dnorm(b)*0.5*10000)
> dev.off()
X11
  2
```


Histogram of a
Frequency
0
500
1000
1500
2000
−4
−2
0
2
4
a

```
> ### function
> foo <- function(x) x*x
> foo
function(x) x*x
> foo(5)
[1] 25
> foo(1:10)
 [1]   1   4   9  16  25  36  49  64  81 100
> goo <- function(x,y) x*y
> goo(3,5)
[1] 15
> goo(1:10,2)
 [1]  2  4  6  8 10 12 14 16 18 20
> goo <- function(x,y=2) x*y
> goo(1:10,2)
 [1]  2  4  6  8 10 12 14 16 18 20
> goo(1:10)
 [1]  2  4  6  8 10 12 14 16 18 20
> foo <- function(x) {  # dont type the following "+" prompt marks
```

```
+ if(x > 0) y <- log(x)
+ else y <- log(-x)
+ y
+ }
> foo
function(x) {
if(x > 0) y <- log(x)
else y <- log(-x)
y
}
> foo(10)
[1] 2.302585
> foo(-5)
[1] 1.609438
> foo <- function(x) if(x>0) log(x) else log(-x)
> foo(-5)
[1] 1.609438
> foo <- function(x) log(abs(x))
> foo(-5)
```

```
[1] 1.609438
> ## end
> q()
Save workspace image? [y/n/c]: y

Process R finished at Fri Sep 20 00:47:40 2002
```