

```

1 -----
2 Laboratorio 01
3 -----
4 > Ciliegi<-read.table("Cherry.dat",col.names=c("diam","alt","vol"))
5 > Ciliegi
6   diam alt  vol
7 1   8.3  70 10.3
8 2   8.6  65 10.3
9 3   8.8  63 10.2
10 4  10.5  72 16.4
11 5  10.7  81 18.8
12 6  10.8  83 19.7
13 7  11.0  66 15.6
14 8  11.0  75 18.2
15 9  11.1  80 22.6
16 10 11.2  75 19.9
17 11 11.3  79 24.2
18 12 11.4  76 21.0
19 13 11.4  76 21.4
20 14 11.7  69 21.3
21 15 12.0  75 19.1
22 16 12.9  74 22.2
23 17 12.9  85 33.8
24 18 13.3  86 27.4
25 19 13.7  71 25.7
26 20 13.8  64 24.9
27 21 14.0  78 34.5
28 22 14.2  80 31.7
29 23 14.5  74 36.3
30 24 16.0  72 38.3
31 25 16.3  77 42.6
32 26 17.3  81 55.4
33 27 17.5  82 55.7
34 28 17.9  80 58.3
35 29 18.0  80 51.5
36 30 18.0  80 51.0
37 31 20.6  87 77.0
38 > attach(Ciliegi)
39 > vol
40 [1] 10.3 10.3 10.2 16.4 18.8 19.7 15.6 18.2 22.6 19.9 24.2 21.0 21.4 21.3 19.1
41 [16] 22.2 33.8 27.4 25.7 24.9 34.5 31.7 36.3 38.3 42.6 55.4 55.7 58.3 51.5 51.0
42 [31] 77.0
43 > dim(Ciliegi)
44 [1] 31 3
45 > dim(Ciliegi)[1]
46 [1] 31
47 > Ciliegi[7,1]
48 [1] 11
49 > Ciliegi[7,]
50   diam alt  vol
51 7   11  66 15.6
52 > Ciliegi[,2]
53 [1] 70 65 63 72 81 83 66 75 80 75 79 76 76 69 75 74 85 86 71 64 78 80 74 72 77
54 [26] 81 82 80 80 80 87
55 > Ciliegi$alt
56 [1] 70 65 63 72 81 83 66 75 80 75 79 76 76 69 75 74 85 86 71 64 78 80 74 72 77
57 [26] 81 82 80 80 80 87
58 > summary(alt)
59   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
60    63     72     76     76     80     87
61 > var(alt)
62 [1] 40.6
63 > hist(alt)
64 > help(hist)
65 > boxplot(alt)
66 > # Analisi grafica
67 >
68 > plot(diam,vol)
69 > cor(diam,vol)
70 [1] 0.9671194
71 > # Y = alpha + beta X + epsilon, epsilon : E(epsilon)=0, Var(epsilon)=sigma^2
72 >
73 > # Stima del modello
74 >
75 > # --> Metodo dei minimi quadrati
76 > # ^beta=cov(X,Y)/Var(X)
77 > # ^alpha=mean(Y)-^beta*mean(X)
78 >

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79 > beta<-(sum(diam*vol)/length(diam)-mean(diam)*mean(vol))/(mean(diam^2)-mean(diam)^2)
80 > n<-length(diam)
81 > n
82 [1] 31
83 > beta<-(sum(diam*vol)/n-mean(diam)*mean(vol))/(mean(diam^2)-mean(diam)^2)
84 > beta
85 [1] 5.065856
86 > beta<-cov(diam,vol)/((n-1)*var(diam)/n)
87 > beta
88 [1] 5.065856
89 > alpha<-mean(vol)-beta*mean(diam)
90 > alpha
91 [1] -36.94346
92 > abline(alpha,beta)
93 > abline(h=40)
94 > abline(v=14,lty="dashed")
95 >
96 >
97 > # Step 3: Analisi dei residui
98 > # res = y - y.stimati
99 >
100 > y.stimati<-alpha+beta*diam
101 > y.stimati
102 [1] 5.103149 6.622906 7.636077 16.248033 17.261205 17.767790 18.780962 18.780962
103 [9] 19.287547 19.794133 20.300718 20.807304 20.807304 22.327061 23.846818 28.406089
104 [17] 28.406089 30.432431 32.458774 32.965360 33.978531 34.991702 36.511459 44.110244
105 [25] 45.630001 50.695857 51.709028 53.735371 54.241956 54.241956 67.413183
106 > points(diam,y.stimati,pch="X")
107 > residui<-vol-y.stimati
108 > residui
109 [1] 5.1968508 3.6770939 2.5639226 0.1519667 1.5387954 1.9322098 -3.1809615
110 [8] -0.5809615 3.3124528 0.1058672 3.8992815 0.1926959 0.5926959 -1.0270610
111 [15] -4.7468179 -6.2060887 5.3939113 -3.0324313 -6.7587739 -8.0653595 0.5214692
112 [22] -3.2917021 -0.2114590 -5.8102436 -3.0300006 4.7041430 3.9909717 4.5646292
113 [29] -2.7419565 -3.2419565 9.5868168
114 > plot(residui)
115 > abline(h=0)
116 > summary(residui)
117 Min. 1st Qu. Median Mean 3rd Qu. Max.
118 -8.065e+00 -3.107e+00 1.520e-01 3.209e-15 3.495e+00 9.587e+00
119 > boxplot(residui)
120 > hist(residui)
121 >
122 > # R2 = 1 - Var(residui)/Var(Y)
123 >
124 > r2<-1-var(residui)/var(vol)
125 > r2
126 [1] 0.9353199
127 >
128 > # ipotesi di normalita' y ~ N(alpha + beta*X,sigma^2)
129 > # epsilon ~ N(0,sigma^2)
130 >
131 > alpha
132 [1] -36.94346
133 > beta
134 [1] 5.065856
135 > sigma2<-sum(residui^2)/n
136 > sigma2
137 [1] 16.91299
138 > s2<-n*sigma2/(n-2)
139 > s2
140 [1] 18.07940
141 > # NB: s2 e' la varianza corretta
142 >
143 > # (^alpha-alpha)/sqrt(var(^alpha)) ~ t_(n-2)
144 >
145 > var.alpha<-s2*(1/n+mean(diam)^2/sum((diam-mean(diam))^2))
146 > var.alpha
147 [1] 11.3242
148 > var.beta<-s2/(sum((diam-mean(diam))^2))
149 > var.beta
150 [1] 0.06119536
151 > # ^alpha +- t_(n-2) * sqrt(Var(^alpha))
152 > a1<-alpha-qt(.975,n-2)*sqrt(var.alpha)
153 > a1
154 [1] -43.82595
155 > a2<-alpha+qt(.975,n-2)*sqrt(var.alpha)
156 > a2

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157 [1] -30.06096
158 > # ^beta +- t_(n-2) * sqrt(Var(^beta))
159 > b1<-beta-qt(.975,n-2)*sqrt(var.beta)
160 > b1
161 [1] 4.559914
162 > b2<-beta+qt(.975,n-2)*sqrt(var.beta)
163 > b2
164 [1] 5.571799
165 >
166 > # test
167 > # H0 : beta = 0 , H1 : beta != 0
168 > # t = (^beta-0)/sqrt(var(beta)) ~H0 t_(n-2)
169 >
170 > test.t<-(beta-0)/sqrt(var.beta)
171 > test.t
172 [1] 20.47829
173 > qt(.975,n-2)
174 [1] 2.045230
175 > # a_oss = 2*min(P(T>t_oss),P(T<t_oss))
176 > 2*min(pt(test.t,n-2),1-pt(test.t,n-2))
177 [1] 0
178 > # rifiuto H0
179 >
180 > # test
181 > # H0 : alpha = 0 , H1 : alpha != 0
182 > # t = (^alpha-0)/sqrt(var(alpha)) ~H0 t_(n-2)
183 >
184 > test.t<-(alpha-0)/sqrt(var.alpha)
185 > test.t
186 [1] -10.97827
187 > 2*min(pt(test.t,n-2),1-pt(test.t,n-2))
188 [1] 7.621449e-12
189 > # rifiuto H0
190 >
191 > # Rifai l'esercizio con la trasformazione logaritmica dei dati
192 > # ln(vol)=alpha+beta*ln(diam)
193 > # =ln(e^alpha * diam^beta)
194 > # vol=e^alpha * diam^beta
195 >
196 > x <- log(diam)
197 > y <- log(vol)
198 > plot(x,y)
199 > beta<-cov(x,y)/var(x)
200 > alpha<-mean(y)-beta*mean(x)
201 > alpha
202 [1] -2.353325
203 > beta
204 [1] 2.19997
205 >
206 > plot(diam,vol)
207 > abline(alpha,beta)
208 > val.predetti<-exp(alpha)*diam^beta
209 > lines(diam,val.predetti)
210 > res<-vol-val.predetti
211 > var(res)
212 [1] 10.56006
213 > var(residui)
214 [1] 0.01277479
215 >
216 > detach(Ciliegi)
217 -----
218 Laboratorio 02
219 -----
220 > brainbod<-read.table('brainbod.dat',header=T)
221 > brainbod
222 species bodywt brainwt
223 1 afeleph 6654.00 5712.00
224 2 cow 465.00 423.00
225 3 donkey 187.00 419.00
226 4 man 62.00 1320.00
227 5 graywolf 36.33 119.50
228 6 redfox 4.24 50.40
229 7 narmadillo 3.50 10.80
230 8 echidna 3.00 25.00
231 9 phalanger 1.62 11.40
232 10 guineapig 1.04 5.50
233 11 euredghog 0.79 3.50
234 12 chinchilla 0.43 4.00

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235 13   ghamster    0.12    1.00
236 14   snmole     0.06    1.00
237 15   lbbat      0.01    0.25
238 >
239 > attach(brainbod)
240 >
241 > # Step1: Analisi preliminare dei dati
242 >
243 > summary(brainwt)
244   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
245   0.25   3.75   11.40  540.40  269.30 5712.00
246 > summary(bodywt)
247   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
248   0.01   0.61   3.00  494.60   49.17 6654.00
249 > par(mfrow=c(2,2))
250 > hist(bodywt)
251 > boxplot(bodywt)
252 > hist(brainwt)
253 > boxplot(brainwt)
254 >
255 >
256 > cor(bodywt,brainwt)
257 [1] 0.975509
258 > plot(bodywt,brainwt)
259 > identify(bodywt,brainwt,species)
260 [1] 1 2 3 4 5 6 7 8 9 12 15
261 >
262 > x<-log(bodywt)
263 > y<-log(brainwt)
264 >
265 > summary(x)
266   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
267 -4.6050 -0.5398  1.0990  1.4400  3.8600  8.8030
268 > summary(y)
269   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
270 -1.386   1.320   2.434   3.174   5.411   8.650
271 > hist(x)
272 > hist(y)
273 > boxplot(x)
274 > boxplot(y)
275 > cor(x,y)
276 [1] 0.9732277
277 > # y = alpha + beta x + epsilon?????????
278 >
279 > # Stima dei parametri
280 >
281 > n<-length(x)
282 > beta<-cov(x,y)/((n-1)*var(x)/n)
283 > beta
284 [1] 0.838046
285 > alpha<-mean(y)-beta*mean(x)
286 > alpha
287 [1] 1.96775
288 > plot(x,y)
289 > abline(alpha,beta)
290 >
291 > # Analisi dei residui
292 > val.pred<-alpha+beta*x
293 > res<-y-val.pred
294 > summary(res)
295   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
296 -1.068e+00 -4.156e-01 -1.909e-01  7.253e-16  3.602e-01  1.759e+00
297 > boxplot(res)
298 > max(res)
299 [1] 1.758908
300 > brainbod[4,]
301   species bodywt brainwt
302    4      man     62    1320
303 > plot(x,y)
304 > r2<-1-var(res)/var(y)
305 > r2
306 [1] 0.9423396
307 >
308 > qqnorm(res)
309 > qqline(res)
310 >
311 > # intervallo di confidenza
312 > sigma2<-sum(res^2)/n

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313 > sigma2
314 [1] 0.4492044
315 > s2<-sum(res^2)/(n-2)
316 > s2
317 [1] 0.5183127
318 > var.alpha<-s2*(1/n+mean(x)^2/sum((x-mean(x))^2))
319 > var.beta<-s2/sum((x-mean(x))^2)
320 > var.alpha
321 [1] 0.07924495
322 > var.beta
323 [1] 0.004435418
324 > alpha.lower<-alpha-qt(0.975,n-2)*sqrt(var.alpha)
325 > alpha.upper<-alpha+qt(0.975,n-2)*sqrt(var.alpha)
326 > alpha.lower
327 [1] 1.359596
328 > alpha.upper
329 [1] 2.575904
330 > beta.lower<-beta-qt(0.975,n-2)*sqrt(var.beta)
331 > beta.upper<-beta+qt(0.975,n-2)*sqrt(var.beta)
332 > beta.lower
333 [1] 0.6941678
334 > beta.upper
335 [1] 0.9819243
336 > # verifica di ipotesi: (beta-0)/sqrt(var.beta)
337 > beta/sqrt(var.beta)
338 [1] 15.65707
339 > qt(.975,n-2)
340 [1] 2.160369
341 > # 15 > 2 --> accetto l'ipotesi nulla
342 >
343 >
344 > #####
345 > # UOMO
346 > # elimino il dato scomodo
347 > x1<-x[-4]
348 > x1
349 [1] 8.80297346 6.14203741 5.23110862 3.59264385 1.44456327 1.25276297 1.09861229
350 [8] 0.48242615 0.03922071 -0.23572233 -0.84397007 -2.12026354 -2.81341072 -4.60517019
351 > y1<-y[-4]
352 > y1
353 [1] 8.650325 6.047372 6.037871 4.783316 3.919991 2.379546 3.218876 2.433613
354 [9] 1.704748 1.252763 1.386294 0.000000 0.000000 -1.386294
355 >
356 > cor(x,y)
357 [1] 0.9732277
358 >
359 > cor(x1,y1)
360 [1] 0.989434
361 >
362 > n1<-length(x1)
363 > beta1<-cov(x1,y1)/((n1-1)*var(x1)/14)
364 > beta1
365 [1] 0.80816
366 > alpha1<-mean(y1)-beta1*mean(x1)
367 > alpha1
368 [1] 1.879402
369 >
370 > plot(x,y)
371 > abline(alpha,beta)
372 > abline(alpha1,beta1,lty='dashed')
373 >
374 > res1<-y1-alpha1-beta1*x1
375 > par(mfrow=c(1,2))
376 > boxplot(res1)
377 > qqnorm(res1)
378 > qqline(res1)
379 >
380 -----
381 Laboratorio 03
382 -----
383 # Y = alpha + beta X + epsilon , epsilon ~ N(0,sigma^2)
384 > # costruiamo il nostro campione
385 >
386 > n<-30
387 > x<-1:30
388 > x
389 [1] 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
390 [29] 29 30

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```

391 > error<-rnorm(n,0,4) # sigma^2=16
392 > error
393 [1] 0.04406192 -2.78513488 -3.82533130 -7.47414116 -2.55828588 -8.81128405 10.57306139
394 [8] -1.00157483 -3.13954695 6.84054944 1.73122246 -2.20881372 -2.77174140 -5.27932086
395 [15] -1.87458175 1.09956605 -6.85715244 -1.71112577 -0.06596067 4.91313049 -4.76435622
396 [22] -1.04205041 -1.11789092 -3.23884442 1.96330506 0.43448044 4.65260502 0.84634824
397 [29] 0.33454760 2.94081540
398 > y<-5+3*x+error # alpha=5, beta=3
399 > y
400 [1] 8.044062 8.214865 10.174669 9.525859 17.441714 14.188716 36.573061 27.998425
401 [8] 28.860453 41.840549 39.731222 38.791186 41.228259 41.720679 48.125418 54.099566
402 [15] 49.142848 57.288874 61.934039 69.913130 63.235644 69.957950 72.882109 73.761156
403 [22] 81.963305 83.434480 90.652605 89.846348 92.334548 97.940815
404 >
405 > # step 1
406 > cor(x,y)
407 [1] 0.989372
408 > plot(x,y)
409 >
410 >
411 > # step 2
412 > beta<-cov(x,y)/var(x)
413 > beta
414 [1] 3.120524
415 > alpha<-mean(y)-beta*mean(x)
416 > alpha
417 [1] 2.326758
418 >
419 > abline(alpha,beta)
420 >
421 > # step 3 analisi modello
422 >
423 > res<- y-alpha-beta*x
424 > boxplot(res)
425 > qqnorm(res)
426 > qqline(res)
427 >
428 >
429 > # aumento sigma^2
430 > error<-rnorm(n,0,10) # sigma^2=100
431 > y<-5+3*x+error # alpha=5, beta=3
432 > cor(x,y)
433 [1] 0.940608
434 > plot(x,y)
435 > beta<-cov(x,y)/var(x)
436 > beta
437 [1] 2.946698
438 > alpha<-mean(y)-beta*mean(x)
439 > alpha
440 [1] 7.626219
441 >
442 >
443 > # diminuisco sigma^2
444 > error<-rnorm(n,0,.25) # sigma^2=0.0625
445 > y<-5+3*x+error # alpha=5, beta=3
446 > cor(x,y)
447 [1] 0.9999632
448 > plot(x,y)
449 > beta<-cov(x,y)/var(x)
450 > beta
451 [1] 3.003701
452 > alpha<-mean(y)-beta*mean(x)
453 > alpha
454 [1] 4.899634
455 >
456 >
457 > #-----#
458 > # Studio di simulazione #
459 > #-----#
460 >
461 > n<-30
462 > alpha<-5
463 > beta<-3
464 > sigma2<-16
465 >
466 > x<-1:30
467 >
468 > error<-rnorm(n,0,sqrt(sigma2))

```

```

469 > y<-5+3*x+error
470 >
471 > beta <-cov(x,y)/var(x)
472 > beta
473 [1] 3.017296
474 > error<-rnorm(n,0,sqrt(sigma2))
475 > y<-5+3*x+error
476 > beta <-cov(x,y)/var(x)
477 > beta
478 [1] 2.948699
479 >
480 > # numero tentativi = 1000
481 >
482 > beta.sim<-rep(0,1000)
483 > for (i in 1:1000) {
484 +     error<-rnorm(n,0,sqrt(sigma2))
485 +     y<-5+3*x+error
486 +     beta.sim[i]<-cov(x,y)/var(x)
487 + }
488 >
489 > mean(beta.sim)
490 [1] 2.997770
491 >
492 > # numero tentativi = 10000
493 >
494 > beta.sim<-rep(0,10000)
495 > for (i in 1:10000) {
496 +     error<-rnorm(n,0,sqrt(sigma2))
497 +     y<-5+3*x+error
498 +     beta.sim[i]<-cov(x,y)/var(x)
499 + }
500 > mean(beta.sim) # NB: vicinissima al vero valore del parametro
501 [1] 3.00149
502 >
503 > hist(beta.sim)
504 > boxplot(beta.sim)
505 >
506 > # sigma^2 / sum(x_i - var(x))^2
507 >
508 > var.beta<-sigma2/sum((x-mean(x))^2)
509 > var.beta
510 [1] 0.007119021
511 >
512 > # stima della densita'
513 > hist(beta.sim,prob=T)
514 > lines(density(beta.sim))
515 > lines(seq(2.7,3.3,.01),dnorm(seq(2.7,3.3,.01),3,sqrt(var.beta)))
516 > lines(seq(2.7,3.3,.01),dnorm(seq(2.7,3.3,.01),3,sqrt(var.beta)),col=2)
517 >
518 >
519 > #-----#
520 > # Livello di copertura degli IC per beta #
521 > #-----#
522 >
523 > n<-30
524 > x<-1:30
525 > error<-rnorm(n,0,4)
526 > y<-5+3*x+error
527 >
528 > # ^beta +- t_(n-2) * sqrt(var(beta))
529 >
530 > beta<-cov(x,y)/var(x)
531 > alpha<-mean(y)-beta*mean(x)
532 > res<-y-alpha-beta*x
533 > s2<-sum(res^2)/(n-2)
534 > beta.inf<-beta-qt(.975,n-2)*sqrt(var.beta)
535 > beta.inf
536 [1] 2.875947
537 > beta.sup<-beta+qt(.975,n-2)*sqrt(var.beta)
538 > beta.sup
539 [1] 3.21878
540 > # il 3 è compreso tra i due estremi
541 >
542 >
543 > #-----#
544 > # studio simulazione su livello copertura per beta #
545 > #-----#
546 >

```

```

547 > n<-30
548 > x<-1:30
549 >
550 > nt<-1000
551 >
552 > #valore iniziale
553 > beta.ic<-matrix(NA,ncol=2,nrow=nt) # NA sta per matrice vuota
554 >
555 > # simulazione
556 > for (i in 1:nt) {
557 +   error<-rnorm(n,0,4)
558 +   y<-5+3*x+error
559 +   beta<-cov(x,y)/var(x)
560 +   alpha<-mean(y)-beta*mean(x)
561 +   res<-y-alpha-beta*x
562 +   s2<-sum(res^2)/(n-2)
563 +   var.beta<-s2/sum((x-mean(x))^2)
564 +   beta.ic[i,1]<-beta-qt(.975,n-2)*sqrt(var.beta)
565 +   beta.ic[i,2]<-beta+qt(.975,n-2)*sqrt(var.beta)
566 + }
567 >
568 > # numero(beta.i<beta<beta.s)/nt
569 >
570 > sum( (beta.ic[,1]<=3)&(3<=beta.ic[,2]) )
571 [1] 948
572 > sum( (beta.ic[,1]<=3)&(3<=beta.ic[,2]) )/nt
573 [1] 0.948
574 >
575 >
576 > #-----#
577 > # studio simulazione su livello copertura per alpha #
578 > #-----#
579 >
580 > n<-30
581 > x<-1:30
582 >
583 > nt<-1000
584 >
585 > #valore iniziale
586 > alpha.ic<-matrix(NA,ncol=2,nrow=nt) # NA sta per matrice vuota
587 >
588 > # simulazione
589 >
590 >
591 > for (i in 1:nt) {
592 +   error<-rnorm(n,0,4)
593 +   y<-5+3*x+error
594 +   beta<-cov(x,y)/var(x)
595 +   alpha<-mean(y)-beta*mean(x)
596 +   res<-y-alpha-beta*x
597 +   s2<-sum(res^2)/(n-2)
598 +   var.alpha<-s2*(1/n+(mean(x)^2)/sum((x-mean(x))^2))
599 +   alpha.ic[i,1]<-alpha-qt(.975,n-2)*sqrt(var.alpha)
600 +   alpha.ic[i,2]<-alpha+qt(.975,n-2)*sqrt(var.alpha)
601 + }
602 >
603 > sum( (alpha.ic[,1]<=5)&(5<=alpha.ic[,2]) )
604 [1] 953
605 > sum( (alpha.ic[,1]<=5)&(5<=alpha.ic[,2]) )/nt
606 [1] 0.953
607 >
608 -----
609 Laboratorio 04
610 -----
611 > cement <- read.table("cement.dat",col.names=c("tempo", "resist"))
612 > attach(cement)
613 > cement
614   tempo resist
615 1      1  13.0
616 2      1  13.3
617 3      1  11.8
618 4      2  21.9
619 5      2  24.5
620 6      2  24.7
621 7      3  29.8
622 8      3  28.0
623 9      3  24.1
624 10     3  24.2

```



```

625 11      3    26.2
626 12      7    32.4
627 13      7    30.4
628 14      7    34.5
629 15      7    33.1
630 16      7    35.7
631 17     28    41.8
632 18     28    42.6
633 19     28    40.3
634 20     28    35.7
635 21     28    37.3
636 > # Analisi preliminare
637 >
638 > plot(tempo,resist)
639 > cor(tempo,resist)
640 [1] 0.7862442
641 >
642 > # la relazione non sembra lineare
643 >
644 > # trasformazione
645 > # variabile esplicativa
646 >
647 > # log(x), exp(x), x^r, x^(-r)
648 >
649 > par(mfrow=c(2,2))
650 >
651 > plot(log(tempo),resist)
652 > cor(log(tempo),resist)
653 [1] 0.9396814
654 >
655 > plot(1/tempo,resist)
656 > cor(1/tempo,resist)
657 [1] -0.9499735
658 >
659 > plot(1/sqrt(tempo),resist)
660 > cor(1/sqrt(tempo),resist)
661 [1] -0.9732841
662 >
663 > plot(sqrt(tempo),resist)
664 > cor(sqrt(tempo),resist)
665 [1] 0.8613284
666 >
667 > x<-1/sqrt(tempo)
668 >
669 > # Stima del modello lineare
670 > # resist = beta_1 + beta_2*x + epsilon
671 > # var esplicativa: x, var risposta y
672 >
673 > fit <- lm(resist~x) # il nome "fit" in inglese significa "stima"
674 >
675 > summary(fit)
676
677 Call:
678 lm(formula = resist ~ x)
679
680 Residuals:
681      Min       1Q   Median       3Q      Max
682 -3.79469 -1.25666 -0.05666  1.89544  3.10531
683
684 Coefficients:
685             Estimate Std. Error t value Pr(>|t|)
686 (Intercept)   45.655      1.023   44.63 < 2e-16 ***
687 x            -32.599      1.764  -18.48 1.34e-13 ***
688 ---
689 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
690
691 Residual standard error: 2.133 on 19 degrees of freedom
692 Multiple R-Squared: 0.9473, Adjusted R-squared: 0.9445
693 F-statistic: 341.4 on 1 and 19 DF, p-value: 1.337e-13
694 >
695 > # NB: -----
696 > # Stima del modello lineare senza intercetta
697 > # resist = beta_2*x + epsilon
698 > # var esplicativa: x, var risposta y
699 > # fit <- lm(resist~x-1)
700 > # -----
701 >
702 > # resist = 45.655 - 32.599 * X

```

```

703 > # H_0: alpha=0 vs H_1
704 > # sqrt(S^2)=2.133
705 > # R^2 = 1 - SOMMA_QUADRATI(res)/SOMMA_QUADRATI(y)
706 > # R^2 adjusted = 1 - (S_Q(res)/(n-2)) / (S_Q(y)/(n-1))
707 >
708 > # H_0: beta=0
709 >
710 > # coef, residuals, fitted, summary, deviance, predict, plot
711 >
712 > fit.val<-fit$fitted # valori stimati
713 > fit.val
714      1      2      3      4      5      6      7      8
715 13.05666 13.05666 13.05666 22.60456 22.60456 22.60456 26.83444 26.83444
716      9     10     11     12     13     14     15     16
717 26.83444 26.83444 26.83444 33.33414 33.33414 33.33414 33.33414 33.33414
718     17     18     19     20     21
719 39.49469 39.49469 39.49469 39.49469 39.49469
720 > par(mfrow=c(1,1))
721 > plot(resist,fit.val) # plot tra valori originali e valori stimati
722 > abline(0,1) # piu' sono vicini alla bisettrice e piu' il modello e' buono
723 >
724 >
725 > # valutazione della bonta' del modello
726 > # analisi dei residui
727 >
728 > res<-fit$residuals # residui standardizzati (media=0 e var=1)
729 > res
730      1      2      3      4      5      6
731 -0.05665701 0.24334299 -1.25665701 -0.70456225 1.89543775 2.09543775
732      7      8      9     10     11     12
733 2.96555873 1.16555873 -2.73444127 -2.63444127 -0.63444127 -0.93413660
734     13     14     15     16     17     18
735 -2.93413660 1.16586340 -0.23413660 2.36586340 2.30530942 3.10530942
736     19     20     21
737 0.80530942 -3.79469058 -2.19469058
738 > # altro comando
739 > res<-rstandard(fit) # residui standardizzati (media=0 e var=1)
740 > res
741      1      2      3      4      5      6
742 -0.02984778 0.12819679 -0.66202607 -0.34305540 0.92289950 1.02028065
743      7      8      9     10     11     12
744 1.42684868 0.56079683 -1.31564884 -1.26753485 -0.30525502 -0.45196818
745     13     14     15     16     17     18
746 -1.41963860 0.56408577 -0.11328353 1.14468802 1.15297119 1.55308101
747     19     20     21
748 0.40276526 -1.89786623 -1.09764658
749 >
750 > # summary, boxplot, hist
751 > boxplot(res)
752 > # c'e' un po' di asimmetria dei residui
753 >
754 > hist(res)
755 > # non molto campanulare
756 >
757 > # grafico(res)
758 > plot(res)
759 > abline(h=0)
760 >
761 > # grafico(res,stimati)
762 > plot(res,fit.val)
763 >
764 > # grafico(x,res)
765 > plot(x,res)
766 >
767 > # varianza sigma^2 non sembra costante
768 >
769 > qqnorm(res)
770 > qqline(res)
771 >
772 > # -----
773 > # R^2, qqnorm/hist(res), grafici(res)
774 >
775 > help(lm)
776 > lm(resist~I(x^2)) # la "I" serve per specificare la formula del modello
777
778 Call:
779 lm(formula = resist ~ I(x^2))
780

```

```

781 Coefficients:
782 (Intercept)      I(x^2)
783      37.87      -26.92
784
785 >
786 > fit$coeff
787 (Intercept)      x
788  45.65524  -32.59859
789 > plot(x,resist)
790 > abline(fit$coeff)
791 >
792 >
793 > #-----
794 > #-----
795 >
796 >
797 > windmill<-read.table("windmill.dat",header=T)
798 > windmill
799      wind    dc
800 1    5.00 1.582
801 2    6.00 1.822
802 3    3.40 1.057
803 4    2.70 0.500
804 5   10.00 2.236
805 6    9.70 2.386
806 7    9.55 2.294
807 8    3.05 0.558
808 9    8.15 2.166
809 10   6.20 1.866
810 11   2.90 0.653
811 12   6.35 1.930
812 13   4.60 1.562
813 14   5.80 1.737
814 15   7.40 2.088
815 16   3.60 1.137
816 17   7.85 2.179
817 18   8.80 2.112
818 19   7.00 1.800
819 20   5.45 1.501
820 21   9.10 2.303
821 22  10.20 2.310
822 23   4.10 1.194
823 24   3.95 1.144
824 25   2.45 0.123
825 >
826 > attach(windmill)
827 >
828 > # analisi preliminare
829 >
830 > plot(wind,dc)
831 > cor(wind,dc)
832 [1] 0.9351434
833 > # mmmh... sembra esserci un legame lineare!
834 >
835 > # stima del modello
836 > fit<-lm(dc~wind)
837 >
838 > summary(fit)
839
840 Call:
841 lm(formula = dc ~ wind)
842
843 Residuals:
844      Min       1Q   Median       3Q      Max
845 -0.59869 -0.14099  0.06059  0.17262  0.32184
846
847 Coefficients:
848             Estimate Std. Error t value Pr(>|t|)
849 (Intercept)  0.13088    0.12599   1.039    0.31
850 wind        0.24115    0.01905  12.659 7.55e-12 ***
851 ---
852 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
853
854 Residual standard error: 0.2361 on 23 degrees of freedom
855 Multiple R-Squared:  0.8745,    Adjusted R-squared:  0.869
856 F-statistic: 160.3 on 1 and 23 DF,  p-value: 7.546e-12
857
858 >

```

```

859 > # H_0: alpha=0
860 > qt(.975,23)
861 [1] 2.068658
862 >
863 > # dc = 0.24115*wind
864 > abline(fit$coef)
865 >
866 >
867 > # -----
868 > # senza intercetta (come esercizio)
869 >
870 > # bonta del modello
871 > fit<-lm(dc~wind-1)
872 > summary(fit)
873
874 Call:
875 lm(formula = dc ~ wind - 1)
876
877 Residuals:
878     Min       1Q   Median       3Q      Max
879 -0.51276 -0.17156  0.08675  0.20282  0.36832
880
881 Coefficients:
882             Estimate Std. Error t value Pr(>|t|)
883 wind    0.25949      0.00715   36.29  <2e-16 ***
884 ---
885 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
886
887 Residual standard error: 0.2364 on 24 degrees of freedom
888 Multiple R-Squared:  0.9821,    Adjusted R-squared:  0.9814
889 F-statistic: 1317 on 1 and 24 DF,  p-value: < 2.2e-16
890
891 >
892 > res<-fit$res
893 > qqnorm(res)
894 > qqline(res)
895 >
896 > plot(wind,res)
897 >
898 > # R^2 elevato, qqnorm soddisfacente, plot(x,res) ha un andamento poco
899 > # soddisfacente
900 > # --> bisogna riformulare il modello e ristimarlo
901 >
902 > # trasformazione della variabile x
903 >
904 > par(mfrow=c(2,2))
905 >
906 > plot(log(wind),dc)
907 > plot(exp(wind),dc)
908 > plot(wind^2,dc)
909 > plot(1/wind,dc)
910 >
911 > cor(log(wind),dc)
912 [1] 0.978454
913 > cor(1/wind,dc)
914 [1] -0.989962
915 >
916 > fit1<-lm(dc~I(1/wind))
917 > summary(fit1)
918
919 Call:
920 lm(formula = dc ~ I(1/wind))
921
922 Residuals:
923     Min       1Q   Median       3Q      Max
924 -0.20547 -0.04941  0.01100  0.08352  0.12204
925
926 Coefficients:
927             Estimate Std. Error t value Pr(>|t|)
928 (Intercept)   2.9789      0.0449   66.34  <2e-16 ***
929 I(1/wind)    -6.9345      0.2064  -33.59  <2e-16 ***
930 ---
931 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
932
933 Residual standard error: 0.09417 on 23 degrees of freedom
934 Multiple R-Squared:  0.98,    Adjusted R-squared:  0.9792
935 F-statistic: 1128 on 1 and 23 DF,  p-value: < 2.2e-16
936

```

```

937 >
938 > # dc = 2.47 - 6.93/wind # nuovo modello
939 > # bonta' del modello
940 > res1<-fit1$residuals
941 >
942 > par(mfrow=c(1,1))
943 > boxplot(res1)
944 >
945 > qqnorm(res1)
946 > qqline(res1)
947 >
948 > plot(1/wind,res1)
949 >
950 > # R^2, qqnorm
951 > plot(res1,fit1$fitted)
952 >
953 -----
954 Laboratorio 05
955 -----
956 > fruit<-read.table("Fruitfly.dat",col.names=c("RS","SS","NS"))
957 > fruit
958      RS    SS    NS
959 1  12.8  38.4  35.4
960 2  21.6  32.9  27.4
961 3  14.8  48.5  19.3
962 4  23.1  20.9  41.8
963 5  34.6  11.6  20.3
964 6  19.7  22.3  37.6
965 7  22.6  30.2  36.9
966 8  29.6  33.4  37.3
967 9  16.4  26.7  28.2
968 10 20.3  39.0  23.4
969 11 29.3  12.8  33.7
970 12 14.9  14.6  29.2
971 13 27.3  12.2  41.7
972 14 22.4  23.1  22.6
973 15 27.5  29.4  40.4
974 16 20.3  16.0  34.4
975 17 38.7  20.1  30.4
976 18 26.4  23.3  14.9
977 19 23.7  22.9  51.8
978 20 26.1  22.5  33.8
979 21 29.5  15.1  37.9
980 22 38.6  31.0  29.5
981 23 44.4  16.9  42.4
982 24 23.2  16.1  36.6
983 25 23.6  10.8  47.4
984 > attach(fruit)
985 > names(fruit)
986 [1] "RS" "SS" "NS"
987 >
988 > # Analisi preliminare (statistiche descrittivi/grafiche)
989 > summary(RS)
990   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
991  12.80   20.30   23.60   25.26   29.30   44.40
992 > summary(SS)
993   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
994   10.80   16.00   22.50   23.63   30.20   48.50
995 > summary(NS)
996   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
997   14.90   28.20   34.40   33.37   37.90   51.80
998 >
999 > boxplot(RS,SS,NS)
1000 >
1001 > # differenza (RS,SS) e NS
1002 > # differenza RS e SS
1003 >
1004 > ## Se  $Y1 \sim F(\theta_1)$  e  $Y2 \sim F(\theta_2)$ , devo confrontare  $\theta_1$  con  $\theta_2$ 
1005 > ##  $H_0: \mu_1 = \mu_2$ 
1006 >
1007 > RSS<-c(RS,SS)
1008 > RSS
1009 [1] 12.8 21.6 14.8 23.1 34.6 19.7 22.6 29.6 16.4 20.3 29.3 14.9 27.3 22.4 27.5
1010 [16] 20.3 38.7 26.4 23.7 26.1 29.5 38.6 44.4 23.2 23.6 38.4 32.9 48.5 20.9 11.6
1011 [31] 22.3 30.2 33.4 26.7 39.0 12.8 14.6 12.2 23.1 29.4 16.0 20.1 23.3 22.9 22.5
1012 [46] 15.1 31.0 16.9 16.1 10.8
1013 > # t-student  $\mu(RSS) = \mu(NS)$ 
1014 > # normalita',  $\sigma^2$  omoschedasticita'

```

```

1015 >
1016 > boxplot(RSS,NS)
1017 > hist(RSS,nclass=8)
1018 > hist(NS,nclass=8)
1019 >
1020 > qqnorm(RSS)
1021 > qqline(RSS)
1022 >
1023 > qqnorm(NS)
1024 > qqline(NS)
1025 >
1026 > var(RSS)
1027 [1] 77.00249
1028 > var(NS)
1029 [1] 79.9596
1030 >
1031 > # TRV (test rapporto di verosim. W(theta))
1032 > #      H0: sigma^2(RSS) = sigma^2(NS)
1033 > #      '--> H0: sigma^2(RSS)/sigma^2(NS)=1
1034 > #      '--> H0: tau=1
1035 > #      '--> H0: tau=S^2_1/S^2_2~F(n-1,m-1)=1
1036 > help(var.test)
1037 > var.test(RSS,NS)
1038
1039      F test to compare two variances
1040
1041 data:  RSS and NS
1042 F = 0.963, num df = 49, denom df = 24, p-value = 0.8833
1043 alternative hypothesis: true ratio of variances is not equal to 1
1044 95 percent confidence interval:
1045  0.4564086 1.8658070
1046 sample estimates:
1047 ratio of variances
1048      0.9630174
1049
1050 >
1051 > # test t H0: mu(RSS) = mu(NS)
1052 > # test t H0: mu(RSS) - mu(NS) = 0
1053 >
1054 > # t = (mean1 - mean2) - (mu1 - mu2) / sqrt(stima varianza)
1055 >
1056 > help(t.test)
1057 > t.test(RSS,NS,var.equal=T)
1058
1059      Two Sample t-test
1060
1061 data:  RSS and NS
1062 t = -4.1286, df = 73, p-value = 9.587e-05
1063 alternative hypothesis: true difference in means is not equal to 0
1064 95 percent confidence interval:
1065  -13.240812 -4.619188
1066 sample estimates:
1067 mean of x mean of y
1068    24.442    33.372
1069
1070 > # dal p-value --> rifiuto H0 --> le medie sono differenti
1071 >
1072 > boxplot(RS,SS,NS)
1073 >
1074 > # RS e NS sono uguali?
1075 >
1076 > qqnorm(RS);qqline(RS)
1077 >
1078 > var(RS)
1079 [1] 60.41007
1080 > var(NS)
1081 [1] 79.9596
1082 >
1083 > var.test(RS,NS)
1084
1085      F test to compare two variances
1086
1087 data:  RS and NS
1088 F = 0.7555, num df = 24, denom df = 24, p-value = 0.4974
1089 alternative hypothesis: true ratio of variances is not equal to 1
1090 95 percent confidence interval:
1091  0.3329286 1.7144557
1092 sample estimates:

```

```

1093 ratio of variances
1094     0.7555074
1095
1096 >
1097 > t.test(RS,NS,var.equal=T)
1098
1099     Two Sample t-test
1100
1101 data:  RS and NS
1102 t = -3.4251, df = 48, p-value = 0.001268
1103 alternative hypothesis: true difference in means is not equal to 0
1104 95 percent confidence interval:
1105  -12.880308  -3.351692
1106 sample estimates:
1107 mean of x mean of y
1108    25.256    33.372
1109
1110 >
1111 > # esercizio: SS-NS
1112 >
1113 > t.test(RS,NS)
1114
1115     Welch Two Sample t-test
1116
1117 data:  RS and NS
1118 t = -3.4251, df = 47.087, p-value = 0.001283
1119 alternative hypothesis: true difference in means is not equal to 0
1120 95 percent confidence interval:
1121  -12.882696  -3.349304
1122 sample estimates:
1123 mean of x mean of y
1124    25.256    33.372
1125
1126 >
1127 > boxplot(RS,SS,NS)
1128 >
1129 > # normalita'
1130 > qqnorm(SS);qqline(SS)
1131 >
1132 > # omoschedasticita'
1133 > var(RS)
1134 [1] 60.41007
1135 > var(SS)
1136 [1] 95.42293
1137 >
1138 > var.test(RS,SS)
1139
1140     F test to compare two variances
1141
1142 data:  RS and SS
1143 F = 0.6331, num df = 24, denom df = 24, p-value = 0.2698
1144 alternative hypothesis: true ratio of variances is not equal to 1
1145 95 percent confidence interval:
1146   0.2789774  1.4366273
1147 sample estimates:
1148 ratio of variances
1149     0.633077
1150
1151 >
1152 > t.test(RS,SS,var.equal=T)
1153
1154     Two Sample t-test
1155
1156 data:  RS and SS
1157 t = 0.6521, df = 48, p-value = 0.5175
1158 alternative hypothesis: true difference in means is not equal to 0
1159 95 percent confidence interval:
1160  -3.391875   6.647875
1161 sample estimates:
1162 mean of x mean of y
1163    25.256    23.628
1164
1165 >
1166 > boxplot(RS,SS,NS)
1167 > boxplot(log(RS),log(SS),log(NS))
1168 > qqnorm(log(RS));qqline(log(RS))
1169 >
1170 > detach()

```

```

1171 >
1172 > # -----
1173 > capto<-read.table("Capto.dat",header=T)
1174 > attach(capto)
1175 > capto
1176      Sp  Sd  Dp  Dd
1177 1  210 201 130 125
1178 2  169 165 122 121
1179 3  187 166 124 121
1180 4  160 157 104 106
1181 5  167 147 112 101
1182 6  176 145 101  85
1183 7  185 168 121  98
1184 8  206 180 124 105
1185 9  173 147 115 103
1186 10 146 136 102  98
1187 11 174 151  98  90
1188 12 201 168 119  98
1189 13 198 179 106 110
1190 14 148 129 107 103
1191 15 154 131 100  82
1192 >
1193 > # Y1 ~ N(m1,s1)
1194 > # Y2 ~ N(m2,s2)
1195 >
1196 > # D = Y1 - Y2 ~ N(m1-m2,s1+s2) # prima
1197 > # D = Y1 - Y2 ~ N(m1-m2,s1+s2-2*cov(Y1,Y2)) # adesso!
1198 > # D = ~ N(m,s) , m=m1-m2 , s=s1+s2-2*cov(Y1,Y2)
1199 > # H0: m=0
1200 >
1201 > # mean(D)-m / stima(varianza)
1202 >
1203 > SD<-Sd-Sp
1204 > DD<-Dd-Dp
1205 >
1206 > boxplot(SD)
1207 > qqnorm(SD);qqline(SD)
1208 > qqnorm(DD);qqline(DD)
1209 >
1210 > t.test(SD)
1211
1212      One Sample t-test
1213
1214 data:  SD
1215 t = -8.1228, df = 14, p-value = 1.146e-06
1216 alternative hypothesis: true mean is not equal to 0
1217 95 percent confidence interval:
1218  -23.93258 -13.93409
1219 sample estimates:
1220 mean of x
1221  -18.93333
1222
1223 >
1224 > t.test(Sd,Sp,paired=T) # fa la stessa cosa che ho fatto prima
1225
1226      Paired t-test
1227
1228 data:  Sd and Sp
1229 t = -8.1228, df = 14, p-value = 1.146e-06
1230 alternative hypothesis: true difference in means is not equal to 0
1231 95 percent confidence interval:
1232  -23.93258 -13.93409
1233 sample estimates:
1234 mean of the differences
1235  -18.93333
1236
1237 >
1238 > # H0: m >= 0
1239 > # H1: m < 0
1240 >
1241 > # H0: m <= 0
1242 > # H1: m > 0
1243 >
1244 > t.test(Sd,Sp,paired=T,alternative="g")
1245
1246      Paired t-test
1247
1248 data:  Sd and Sp

```



```

1249 t = -8.1228, df = 14, p-value = 1
1250 alternative hypothesis: true difference in means is greater than 0
1251 95 percent confidence interval:
1252 -23.03874      Inf
1253 sample estimates:
1254 mean of the differences
1255 -18.93333
1256
1257 >
1258 > # esercizio: test per la D
1259 > t.test(Dd,Dp,paired=T)
1260
1261      Paired t-test
1262
1263 data:  Dd and Dp
1264 t = -4.1662, df = 14, p-value = 0.000951
1265 alternative hypothesis: true difference in means is not equal to 0
1266 95 percent confidence interval:
1267 -14.037215 -4.496118
1268 sample estimates:
1269 mean of the differences
1270 -9.266667
1271
1272 >
1273 > t.test(Dd,Dp,paired=T,alternative="g")
1274
1275      Paired t-test
1276
1277 data:  Dd and Dp
1278 t = -4.1662, df = 14, p-value = 0.9995
1279 alternative hypothesis: true difference in means is greater than 0
1280 95 percent confidence interval:
1281 -13.18427      Inf
1282 sample estimates:
1283 mean of the differences
1284 -9.266667
1285
1286 -----
1287 Laboratorio 06
1288 -----
1289 > # caricamento dati
1290 > hook<-read.table('hook.dat',col.names=c('temp','press'))
1291 > hook
1292      temp  press
1293 1  210.8 29.211
1294 2  210.2 28.559
1295 3  208.4 27.972
1296 4  202.5 24.697
1297 5  200.6 23.726
1298 6  200.1 23.369
1299 7  199.5 23.030
1300 8  197.0 21.892
1301 9  196.4 21.928
1302 10 196.3 21.654
1303 11 195.6 21.605
1304 12 193.4 20.480
1305 13 193.6 20.212
1306 14 191.4 19.758
1307 15 191.1 19.490
1308 16 190.6 19.386
1309 17 189.5 18.869
1310 18 188.8 18.356
1311 19 188.5 18.507
1312 20 185.7 17.267
1313 21 186.0 17.221
1314 22 185.6 17.062
1315 23 184.1 16.959
1316 24 184.6 16.881
1317 25 184.1 16.817
1318 26 183.2 16.385
1319 27 182.4 16.235
1320 28 181.9 16.106
1321 29 181.9 15.928
1322 30 181.0 15.919
1323 31 180.6 15.376
1324 > attach(hook)
1325 >
1326 > # analisi preliminare: grafici

```

```

1327 >
1328 > plot(press,temp)
1329 > cor(press,temp)
1330 [1] 0.9958803
1331 >
1332 > # stima del modello
1333 > fit<-lm(temp~press) # y in funzione di x --> y~x
1334 > summary(fit)
1335
1336 Call:
1337 lm(formula = temp ~ press)
1338
1339 Residuals:
1340      Min       1Q   Median       3Q      Max
1341 -1.6735 -0.6805  0.2203  0.5296  1.3976
1342
1343 Coefficients:
1344             Estimate Std. Error t value Pr(>|t|)
1345 (Intercept) 146.67290    0.77641  188.91  <2e-16 ***
1346 press       2.25260    0.03809   59.14  <2e-16 ***
1347 ---
1348 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1349
1350 Residual standard error: 0.806 on 29 degrees of freedom
1351 Multiple R-Squared: 0.9918,    Adjusted R-squared: 0.9915
1352 F-statistic: 3498 on 1 and 29 DF,  p-value: < 2.2e-16
1353
1354 >
1355 > # temp = 146.6 + 2.25*press    ## modello dei minimi quadrati
1356 >
1357 > # analisi dei residui
1358 >
1359 > # riassunti
1360 > # analisi grafiche
1361 > res<-fit$res
1362 >
1363 > # temp = 146.6 + 2.25*press    ## modello dei minimi quadrati
1364 >
1365 > # analisi dei residui
1366 >
1367 > # riassunti
1368 > # analisi grafiche
1369 > ren<-fit$res
1370 > rm(ren)
1371 > res<-fit$res
1372 > boxplot(res)
1373 > plot(res)
1374 >
1375 > plot(press,res)
1376 >
1377 > par(mfrow=c(2,2))
1378 > plot(fit)
1379 >
1380 > # lieve asimmetria dei residui
1381 > # x vs residui mostra un andamento di tipo parabolico
1382 >
1383 > # rimedio: riformulare il modello con una trasformata della x
1384 >
1385 > plot(press,res)
1386 >
1387 > # y= a + bx + cx^2
1388 > fit1<-lm(temp~press+I(press^2),x=T) # I: funz. indicatrice
1389 > fit1$x
1390      (Intercept)  press I(press^2)
1391 1      1 29.211    853.2825
1392 2      1 28.559    815.6165
1393 3      1 27.972    782.4328
1394 4      1 24.697    609.9418
1395 5      1 23.726    562.9231
1396 6      1 23.369    546.1102
1397 7      1 23.030    530.3809
1398 8      1 21.892    479.2597
1399 9      1 21.928    480.8372
1400 10     1 21.654    468.8957
1401 11     1 21.605    466.7760
1402 12     1 20.480    419.4304
1403 13     1 20.212    408.5249
1404 14     1 19.758    390.3786

```

```

1405 15          1 19.490    379.8601
1406 16          1 19.386    375.8170
1407 17          1 18.869    356.0392
1408 18          1 18.356    336.9427
1409 19          1 18.507    342.5090
1410 20          1 17.267    298.1493
1411 21          1 17.221    296.5628
1412 22          1 17.062    291.1118
1413 23          1 16.959    287.6077
1414 24          1 16.881    284.9682
1415 25          1 16.817    282.8115
1416 26          1 16.385    268.4682
1417 27          1 16.235    263.5752
1418 28          1 16.106    259.4032
1419 29          1 15.928    253.7012
1420 30          1 15.919    253.4146
1421 31          1 15.376    236.4214
1422 attr("assign")
1423 [1] 0 1 2
1424 >
1425 > summary(fit1)
1426
1427 Call:
1428 lm(formula = temp ~ press + I(press^2), x = T)
1429
1430 Residuals:
1431      Min       1Q   Median       3Q      Max
1432 -0.79906 -0.26314 -0.01578  0.25139  0.73891
1433
1434 Coefficients:
1435              Estimate Std. Error t value Pr(>|t|)
1436 (Intercept) 126.701623   2.112363  59.981  < 2e-16 ***
1437 press       4.157627   0.199069  20.885  < 2e-16 ***
1438 I(press^2)  -0.043754   0.004552  -9.612 2.29e-10 ***
1439 ---
1440 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1441
1442 Residual standard error: 0.3956 on 28 degrees of freedom
1443 Multiple R-Squared: 0.9981, Adjusted R-squared: 0.998
1444 F-statistic: 7307 on 2 and 28 DF, p-value: < 2.2e-16
1445
1446 > plot(temp,fit1$fitted)
1447 > abline(0,1)
1448 >
1449 > # analisi dei residui
1450 >
1451 > res1<-fit1$res
1452 > plot(res1)
1453 >
1454 > plot(press,res1)
1455 > plot(I(press^2),res1)
1456 >
1457 > qqnorm(res1);qqline(res1)
1458 >
1459 > detach()
1460 >
1461 >
1462 > # -----
1463 > # cherry.dat
1464 > # caricamento dati
1465 > cherry<-read.table('cherry.dat',col.names=c('diam','alt','vol'))
1466 > attach(cherry)
1467 >
1468 > # analisi preliminare
1469 > par(mfrow=c(2,2))
1470 > plot(vol~diam)
1471 > plot(vol~alt)
1472 > cor(vol,diam)
1473 [1] 0.9671194
1474 > cor(vol,alt)
1475 [1] 0.5982497
1476 > plot(diam,alt)
1477 > cor(diam,alt)
1478 [1] 0.5192801
1479 > pairs(cbind(vol,diam,alt)) # riassume tutti i grafici di dispersione
1480 >
1481 > # volume ~ diametro * altezza
1482 > # log(volume) ~ log(diametro) + log(altezza)

```

```

1483 > pairs(cbind(log(vol),log(diam),log(alt)))
1484 > cor(log(vol),log(diam))
1485 [1] 0.976665
1486 > cor(log(vol),log(alt))
1487 [1] 0.6486377
1488 >
1489 > # ----- stima del modello -----
1490 > fit<-lm(log(vol)~log(diam)+log(alt))
1491 > summary(fit)
1492
1493 Call:
1494 lm(formula = log(vol) ~ log(diam) + log(alt))
1495
1496 Residuals:
1497     Min       1Q   Median       3Q      Max
1498 -0.168561 -0.048488  0.002431  0.063637  0.129223
1499
1500 Coefficients:
1501             Estimate Std. Error t value Pr(>|t|)
1502 (Intercept)  -6.63162     0.79979  -8.292 5.06e-09 ***
1503 log(diam)      1.98265     0.07501  26.432 < 2e-16 ***
1504 log(alt)       1.11712     0.20444   5.464 7.81e-06 ***
1505 ---
1506 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1507
1508 Residual standard error: 0.08139 on 28 degrees of freedom
1509 Multiple R-Squared:  0.9777,    Adjusted R-squared:  0.9761
1510 F-statistic: 613.2 on 2 and 28 DF,  p-value: < 2.2e-16
1511
1512 >
1513 > # log(volume) ~ -6.63 + 1.98*log(diametro) + 1.11*log(altezza)
1514 > plot(log(vol),fit$fitt)
1515 > abline(0,1)
1516 >
1517 > # analisi dei residui
1518 > res<-fit$res
1519 > boxplot(res)
1520 >
1521 > plot(res,log(diam))
1522 > plot(log(diam),res)
1523 > plot(log(alt),res)
1524 >
1525 > par(mfrow=c(2,2))
1526 > plot(fit)
1527 >
1528 >
1529 > ynew<-log(vol)[-18]
1530 > ynew
1531 [1] 2.332144 2.332144 2.322388 2.797281 2.933857 2.980619 2.747271 2.901422
1532 [9] 3.117950 2.990720 3.186353 3.044522 3.063391 3.058707 2.949688 3.100092
1533 [17] 3.520461 3.246491 3.214868 3.540959 3.456317 3.591818 3.645450 3.751854
1534 [25] 4.014580 4.019980 4.065602 3.941582 3.931826 4.343805
1535 > length(ynew)
1536 [1] 30
1537 > x1new<-log(diam)[-18]
1538 > x2new<-log(alt)[-18]
1539 >
1540 > fit1<-lm(ynew ~ x1new + x2new)
1541 > summary(fit1)
1542
1543 Call:
1544 lm(formula = ynew ~ x1new + x2new)
1545
1546 Residuals:
1547     Min       1Q   Median       3Q      Max
1548 -0.17500 -0.05706  0.00624  0.05940  0.11383
1549
1550 Coefficients:
1551             Estimate Std. Error t value Pr(>|t|)
1552 (Intercept)  -7.18549     0.78061  -9.205 8.14e-10 ***
1553 x1new          1.95816     0.07051  27.770 < 2e-16 ***
1554 x2new          1.26100     0.19984   6.310 9.39e-07 ***
1555 ---
1556 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1557
1558 Residual standard error: 0.07565 on 27 degrees of freedom
1559 Multiple R-Squared:  0.9814,    Adjusted R-squared:  0.98
1560 F-statistic: 712.3 on 2 and 27 DF,  p-value: < 2.2e-16

```

```

1561
1562 >
1563 > plot(fit)
1564 >
1565 > # altro modo senza ridefinire le variabili
1566 > fit1<-lm(log(vol)~log(diam)+log(alt),subset=-c(18))
1567 > summary(fit1)
1568
1569 Call:
1570 lm(formula = log(vol) ~ log(diam) + log(alt), subset = -c(18))
1571
1572 Residuals:
1573     Min       1Q   Median       3Q      Max
1574 -0.17500 -0.05706  0.00624  0.05940  0.11383
1575
1576 Coefficients:
1577             Estimate Std. Error t value Pr(>|t|)
1578 (Intercept)  -7.18549     0.78061  -9.205 8.14e-10 ***
1579 log(diam)      1.95816     0.07051  27.770 < 2e-16 ***
1580 log(alt)       1.26100     0.19984   6.310 9.39e-07 ***
1581 ---
1582 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1583
1584 Residual standard error: 0.07565 on 27 degrees of freedom
1585 Multiple R-Squared:  0.9814,    Adjusted R-squared:  0.98
1586 F-statistic: 712.3 on 2 and 27 DF,  p-value: < 2.2e-16
1587
1588 >
1589 > fit1<-lm(log(vol)~log(diam)+log(alt),subset=-c(11,15,16,17,18))
1590 > plot(fit1)
1591 > summary(fit1)
1592
1593 Call:
1594 lm(formula = log(vol) ~ log(diam) + log(alt), subset = -c(11,
1595     15, 16, 17, 18))
1596
1597 Residuals:
1598     Min       1Q   Median       3Q      Max
1599 -0.083857 -0.047953 -0.003806  0.039704  0.103097
1600
1601 Coefficients:
1602             Estimate Std. Error t value Pr(>|t|)
1603 (Intercept)  -6.55062     0.63479 -10.319 4.21e-10 ***
1604 log(diam)      1.99231     0.05569  35.773 < 2e-16 ***
1605 log(alt)       1.09469     0.16394   6.678 8.21e-07 ***
1606 ---
1607 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1608
1609 Residual standard error: 0.05729 on 23 degrees of freedom
1610 Multiple R-Squared:  0.9907,    Adjusted R-squared:  0.9899
1611 F-statistic: 1223 on 2 and 23 DF,  p-value: < 2.2e-16
1612
1613 >
1614 > par(mfrow=c(1,1))
1615 > qqnorm(fit1$res)
1616 >
1617 -----
1618 Laboratorio 07
1619 -----
1620 > hills<-read.table('hills.dat',header=T)
1621 > hills
1622
1623      dist climb  time
1624 Greenmantle    2.5   650  16.083
1625 Carnethy       6.0  2500  48.350
1626 Craig Dunain   6.0   900  33.650
1627 Ben Rha        7.5   800  45.600
1628 Ben Lomond     8.0  3070  62.267
1629 Goatfell       8.0  2866  73.217
1630 Bens of Jura  16.0  7500 204.617
1631 Cairnpapple    6.0   800  36.367
1632 Scolty         5.0   800  29.750
1633 Traprain       6.0   650  39.750
1634 Lairig Ghru    28.0  2100 192.667
1635 Dollar         5.0  2000  43.050
1636 Lomonds        9.5  2200  65.000
1637 Cairn Table    6.0   500  44.133
1638 Eildon Two     4.5  1500  26.933
1639 Cairngorm      10.0  3000  72.250

```

```

1639 Seven Hills      14.0  2200  98.417
1640 Knock Hill      3.0   350  78.650
1641 Black Hill      4.5  1000  17.417
1642 Creag Beag      5.5   600  32.567
1643 Kildcon Hill    3.0   300  15.950
1644 Meall Ant-Suidhe 3.5  1500  27.900
1645 Half Ben Nevis   6.0  2200  47.633
1646 Cow Hill        2.0   900  17.933
1647 N Berwick Law   3.0   600  18.683
1648 Creag Dubh       4.0  2000  26.217
1649 Burnswark        6.0   800  34.433
1650 Largo Law        5.0   950  28.567
1651 Criffel          6.5  1750  50.500
1652 Acmony           5.0   500  20.950
1653 Ben Nevis        10.0  4400  85.583
1654 Knockfarrel      6.0   600  32.383
1655 Two Breweries    18.0  5200 170.250
1656 Cockleroi        4.5   850  28.100
1657 Moffat Chase    20.0  5000 159.833
1658 > attach(hills)
1659 >
1660 > # -----
1661 > # time = ??
1662 >
1663 > # ---- Analisi preliminare ----
1664 > pairs(hills)
1665 >
1666 > # Y = X*beta + epsilon
1667 > # ^beta = (Xt X)^(-1) Xt y
1668 > # ^beta ~ N(0,sigma^2 * (Xt X)^(-1))
1669 > # Se le colonne di (Xt X) sono esprimibili tramite le sue righe
1670 > # il rango della matrice non e' piu' pieno --> cioa' si sballa tutto
1671 > # se ci sono delle variabili in relazione tra di loro
1672 >
1673 > # R2=1 --> ^beta_i ~ 0
1674 >
1675 > cor(hills)
1676           dist      climb      time
1677 dist  1.0000000  0.6523461  0.9195892
1678 climb 0.6523461  1.0000000  0.8052392
1679 time  0.9195892  0.8052392  1.0000000
1680 >
1681 > # Stima del modello
1682 >
1683 > fit<-lm(time~dist)
1684 > summary(fit)
1685
1686 Call:
1687 lm(formula = time ~ dist)
1688
1689 Residuals:
1690      Min       1Q   Median       3Q      Max
1691 -35.745  -9.037  -4.201   2.849  76.170
1692
1693 Coefficients:
1694             Estimate Std. Error t value Pr(>|t|)
1695 (Intercept)  -4.8407     5.7562  -0.841   0.406
1696 dist           8.3305     0.6196  13.446 6.08e-15 ***
1697 ---
1698 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1699
1700 Residual standard error: 19.96 on 33 degrees of freedom
1701 Multiple R-Squared:  0.8456,    Adjusted R-squared:  0.841
1702 F-statistic: 180.8 on 1 and 33 DF,  p-value: 6.084e-15
1703
1704 > # il modello non sara' piu': time = alpha + beta * dist
1705 > # ma: time = beta * dist
1706 >
1707 > fit1<-lm(time~dist -1) # tolgo l'intercetta
1708 > summary(fit1)
1709
1710 Call:
1711 lm(formula = time ~ dist - 1)
1712
1713 Residuals:
1714      Min       1Q   Median       3Q      Max
1715 -28.7646 -11.0285  -6.8327   0.5607  78.0847
1716

```

```

1717 Coefficients:
1718       Estimate Std. Error t value Pr(>|t|)
1719 dist    7.9083    0.3615   21.88  <2e-16 ***
1720 ---
1721 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1722
1723 Residual standard error: 19.87 on 34 degrees of freedom
1724 Multiple R-Squared: 0.9337,    Adjusted R-squared: 0.9317
1725 F-statistic: 478.6 on 1 and 34 DF,  p-value: < 2.2e-16
1726
1727 >
1728 > # NB: R2 e' cambiato --> R^2 = sum(y.stimati^2)/sum(y^2)
1729 > # modello: time = 7.90 * dist
1730 >
1731 > # ---- analisi bonta' del modello ----
1732 > # R^2
1733 > # analisi dei residui
1734 > # grafico (residui, variabile esclusa)
1735 >
1736 > res<-fit1$res
1737 > plot(res,climb)
1738 >
1739 > fit2<-lm(time~dist+climb-1)          # oppure:
1740 > fit2<-update(fit1, . ~ . + climb)
1741 >
1742 > summary(fit2)
1743
1744 Call:
1745 lm(formula = time ~ dist + climb - 1)
1746
1747 Residuals:
1748      Min       1Q   Median       3Q      Max
1749 -18.089 -10.053  -5.539   -3.180   58.235
1750
1751 Coefficients:
1752       Estimate Std. Error t value Pr(>|t|)
1753 dist  5.605651    0.551046  10.173 1.05e-11 ***
1754 climb 0.010280    0.002118   4.853 2.84e-05 ***
1755 ---
1756 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1757
1758 Residual standard error: 15.41 on 33 degrees of freedom
1759 Multiple R-Squared: 0.9613,    Adjusted R-squared: 0.959
1760 F-statistic: 409.8 on 2 and 33 DF,  p-value: < 2.2e-16
1761
1762 >
1763 > # time = 5.60*dist + 0.01*climb
1764 > # R2: 0.93 - 0.96
1765 > # Analisi della variaza # voglio vedere quale modello e' piu' efficace
1766 > # H0 : fit1
1767 > # H1 : fit2
1768 >
1769 > # F = ((SQR1-SQR2)/(n-p1-n+p2)) / (SQR2/(n-p2))
1770 >
1771 > anova(fit1,fit2)
1772 Analysis of Variance Table
1773
1774 Model 1: time ~ dist - 1
1775 Model 2: time ~ dist + climb - 1
1776    Res.Df    RSS Df Sum of Sq    F    Pr(>F)
1777 1      34 13423.2
1778 2      33  7832.5   1    5590.7 23.555 2.84e-05 ***
1779 ---
1780 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1781 > # rifiuto H0, conviene tener conto anche della seconda var esplicativa
1782 >
1783 > # time = 5.60*dist + 0.01*climb
1784 >
1785 > # analisi dei residui
1786 > res2<-fit2$res
1787 > boxplot(res2)
1788 >
1789 > qqnorm(res2);qqline(res2)
1790 >
1791 > plot(res2,fitted(fit2))
1792 > identify(res2,fitted(fit2),dimnames(hills)[[1]])
1793 [1]  7 11 33 35
1794 >

```

```

1795 > fit3<-lm(time~dist+climb-1,subset=-c(7,11,33,35))
1796 > summary(fit3)
1797
1798 Call:
1799 lm(formula = time ~ dist + climb - 1, subset = -c(7, 11, 33,
1800     35))
1801
1802 Residuals:
1803     Min       1Q   Median       3Q      Max
1804 -14.161  -4.120  -2.137   1.415  59.386
1805
1806 Coefficients:
1807             Estimate Std. Error t value Pr(>|t|)
1808 dist    5.762763    0.779834   7.390 3.84e-08 ***
1809 climb  0.005645    0.002886   1.956  0.0602 .
1810 ---
1811 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1812
1813 Residual standard error: 12.29 on 29 degrees of freedom
1814 Multiple R-Squared:  0.9364,    Adjusted R-squared:  0.932
1815 F-statistic: 213.6 on 2 and 29 DF,  p-value: < 2.2e-16
1816
1817 >
1818 > fit3<-lm(time~dist+climb-1,subset=-c(7,11,33,35))
1819 > summary(fit3)
1820
1821 Call:
1822 lm(formula = time ~ dist + climb - 1, subset = -c(7, 11, 33,
1823     35))
1824
1825 Residuals:
1826     Min       1Q   Median       3Q      Max
1827 -14.161  -4.120  -2.137   1.415  59.386
1828
1829 Coefficients:
1830             Estimate Std. Error t value Pr(>|t|)
1831 dist    5.762763    0.779834   7.390 3.84e-08 ***
1832 climb  0.005645    0.002886   1.956  0.0602 .
1833 ---
1834 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1835
1836 Residual standard error: 12.29 on 29 degrees of freedom
1837 Multiple R-Squared:  0.9364,    Adjusted R-squared:  0.932
1838 F-statistic: 213.6 on 2 and 29 DF,  p-value: < 2.2e-16
1839
1840 > detach()
1841 >
1842 >
1843 >
1844 > # -----
1845 > # dati - gasoline
1846 > gaso<-read.table("gasoline.dat")
1847 > names(gaso)
1848 [1] "V1" "V2" "V3" "V4" "V5"
1849 > names(gaso)<-c('y','x1','x2','x3','x4')
1850 > ls()
1851 [1] "fit" "fit1" "fit2" "fit3" "gaso" "hills" "res" "res2"
1852 > attach(gaso)
1853 > y
1854 [1]  6.9 14.4  7.4  8.5  8.0  2.8  5.0 12.2 10.0 15.2 26.8 14.0 14.7  6.4 17.6
1855 [16] 22.3 24.8 26.0 34.9 18.2 23.2 18.0 13.1 16.1 32.1 34.7 31.7 33.6 30.4 26.6
1856 [31] 27.8 45.7
1857 >
1858 > # analisi preliminare
1859 > pairs(gaso)
1860 >
1861 > # (x2,x3)
1862 >
1863 > cor(gaso)
1864           y           x1           x2           x3           x4
1865 y    1.0000000  0.2463260  0.3840706 -0.3150243  0.7115262
1866 x1  0.2463260  1.0000000  0.6205867 -0.7001539 -0.3216782
1867 x2  0.3840706  0.6205867  1.0000000 -0.9062248 -0.2979843
1868 x3 -0.3150243 -0.7001539 -0.9062248  1.0000000  0.4122466
1869 x4  0.7115262 -0.3216782 -0.2979843  0.4122466  1.0000000
1870 > # (x2,x3)
1871 >
1872 > # stima del modello

```



```

1873 > fit1<-lm(y~x4)
1874 > summary(fit1)
1875
1876 Call:
1877 lm(formula = y ~ x4)
1878
1879 Residuals:
1880      Min       1Q   Median       3Q      Max
1881 -14.75837  -6.27829   0.05255   5.16243  17.84805
1882
1883 Coefficients:
1884             Estimate Std. Error t value Pr(>|t|)
1885 (Intercept) -16.66206     6.68721  -2.492   0.0185 *
1886 x4           0.10937     0.01972   5.546 4.98e-06 ***
1887 ---
1888 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1889
1890 Residual standard error: 7.659 on 30 degrees of freedom
1891 Multiple R-Squared:  0.5063,    Adjusted R-squared:  0.4898
1892 >
1893 >
1894 > # y = -16.66 + 0.10*x4
1895 >
1896 > fit11<-update(fit1, . ~ .+x1)
1897 > fit12<-update(fit1, . ~ .+x2)
1898 > fit13<-update(fit1, . ~ .+x3)
1899 >
1900 > anova(fit1,fit11)
1901 Analysis of Variance Table
1902
1903 Model 1: y ~ x4
1904 Model 2: y ~ x4 + x1
1905      Res.Df    RSS Df Sum of Sq    F    Pr(>F)
1906 1         30 1759.69
1907 2         29  861.95  1    897.75 30.204 6.4e-06 ***
1908 ---
1909 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1910 > anova(fit1,fit12)
1911 Analysis of Variance Table
1912
1913 Model 1: y ~ x4
1914 Model 2: y ~ x4 + x2
1915      Res.Df    RSS Df Sum of Sq    F    Pr(>F)
1916 1         30 1759.69
1917 2         29  369.87  1   1389.83 108.97 2.468e-11 ***
1918 ---
1919 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1920 > anova(fit1,fit13)
1921 Analysis of Variance Table
1922
1923 Model 1: y ~ x4
1924 Model 2: y ~ x4 + x3
1925      Res.Df    RSS Df Sum of Sq    F    Pr(>F)
1926 1         30 1759.69
1927 2         29  170.61  1   1589.08 270.11 3.111e-16 ***
1928 ---
1929 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1930 >
1931 > # scelgo il trezo fit perche' ha il 'Sum of Sq' maggiore --> maggiore R2
1932 >
1933 > summary(fit3)
1934
1935 Call:
1936 lm(formula = time ~ dist + climb - 1, subset = -c(7, 11, 33,
1937      35))
1938
1939 Residuals:
1940      Min       1Q   Median       3Q      Max
1941 -14.161  -4.120  -2.137   1.415  59.386
1942
1943 Coefficients:
1944             Estimate Std. Error t value Pr(>|t|)
1945 dist    5.762763     0.779834   7.390 3.84e-08 ***
1946 climb  0.005645     0.002886   1.956  0.0602 .
1947 ---
1948 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1949
1950 Residual standard error: 12.29 on 29 degrees of freedom

```

```

1951 Multiple R-Squared: 0.9364,      Adjusted R-squared: 0.932
1952 F-statistic: 213.6 on 2 and 29 DF,  p-value: < 2.2e-16
1953
1954 >
1955 > # -----
1956 >
1957 > # y = -18.46 + 0.155*x4 - 0.209*x3
1958 >
1959 > fit131<-update(fit13, . ~ .+x1)
1960 > fit132<-update(fit13, . ~ .+x2)
1961 >
1962 > anova(fit13,fit131)
1963 Analysis of Variance Table
1964
1965 Model 1: y ~ x4 + x3
1966 Model 2: y ~ x4 + x3 + x1
1967   Res.Df    RSS Df Sum of Sq      F Pr(>F)
1968 1         29 170.61
1969 2         28 146.00  1      24.61 4.7198 0.03844 *
1970 ---
1971 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
1972 > anova(fit13,fit132)
1973 Analysis of Variance Table
1974
1975 Model 1: y ~ x4 + x3
1976 Model 2: y ~ x4 + x3 + x2
1977   Res.Df    RSS Df Sum of Sq      F Pr(>F)
1978 1         29 170.612
1979 2         28 160.620  1      9.992 1.7419 0.1976
1980 >
1981 > # scelgo la fit131
1982 >
1983 > summary(fit131)
1984
1985 Call:
1986 lm(formula = y ~ x4 + x3 + x1)
1987
1988 Residuals:
1989     Min       1Q   Median       3Q      Max
1990 -3.5303 -1.3606 -0.2681  1.3911  4.7658
1991
1992 Coefficients:
1993             Estimate Std. Error t value Pr(>|t|)
1994 (Intercept)  4.032034   7.223341   0.558   0.5811
1995 x4          0.156527   0.006462  24.224 < 2e-16 ***
1996 x3         -0.186571   0.015922 -11.718 2.61e-12 ***
1997 x1          0.221727   0.102061   2.173   0.0384 *
1998 ---
1999 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2000
2001 Residual standard error: 2.283 on 28 degrees of freedom
2002 Multiple R-Squared: 0.959,      Adjusted R-squared: 0.9546
2003 F-statistic: 218.5 on 3 and 28 DF,  p-value: < 2.2e-16
2004
2005 >
2006 > # -----
2007 >
2008 > fit131bis<-update(fit131, . ~ .-1)
2009 > summary(fit131bis)
2010
2011 Call:
2012 lm(formula = y ~ x4 + x3 + x1 - 1)
2013
2014 Residuals:
2015     Min       1Q   Median       3Q      Max
2016 -3.6075 -1.3229 -0.3831  1.7549  4.9115
2017
2018 Coefficients:
2019             Estimate Std. Error t value Pr(>|t|)
2020 x4    0.157168      0.006283  25.017 < 2e-16 ***
2021 x3   -0.179328      0.009116 -19.672 < 2e-16 ***
2022 x1    0.274133      0.039548   6.932 1.28e-07 ***
2023 ---
2024 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2025
2026 Residual standard error: 2.256 on 29 degrees of freedom
2027 Multiple R-Squared: 0.9907,      Adjusted R-squared: 0.9898
2028 F-statistic: 1034 on 3 and 29 DF,  p-value: < 2.2e-16

```

```

2029
2030 > # y = 0.15*x4 - 0.17*x3 + 0.27*x1
2031 >
2032 >
2033 >
2034 > # -----
2035 > # Altro metodo Hyper veloce!!
2036 > # y = alpha + b1*x1 + b2*x2 + b3*x3 + b4*x4
2037 >
2038 > fit<-lm(y~x1+x2+x3+x4)
2039 > summary(fit)
2040
2041 Call:
2042 lm(formula = y ~ x1 + x2 + x3 + x4)
2043
2044 Residuals:
2045      Min       1Q   Median       3Q      Max
2046 -3.5804 -1.5223 -0.1098  1.4237  4.6214
2047
2048 Coefficients:
2049             Estimate Std. Error t value Pr(>|t|)
2050 (Intercept) -6.820774   10.123152  -0.674   0.5062
2051 x1           0.227246    0.099937   2.274   0.0311 *
2052 x2           0.553726    0.369752   1.498   0.1458
2053 x3          -0.149536    0.029229  -5.116 2.23e-05 ***
2054 x4           0.154650    0.006446  23.992 < 2e-16 ***
2055 ---
2056 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2057
2058 Residual standard error: 2.234 on 27 degrees of freedom
2059 Multiple R-Squared: 0.9622,    Adjusted R-squared: 0.9566
2060 F-statistic: 171.7 on 4 and 27 DF,  p-value: < 2.2e-16
2061
2062 >
2063 > fit1<-lm(y~x1+x2+x3+x4-1)
2064 > summary(fit1)
2065
2066 Call:
2067 lm(formula = y ~ x1 + x2 + x3 + x4 - 1)
2068
2069 Residuals:
2070      Min       1Q   Median       3Q      Max
2071 -3.6693 -1.2920 -0.1271  1.2348  4.5478
2072
2073 Coefficients:
2074             Estimate Std. Error t value Pr(>|t|)
2075 x1  0.182249      0.073618   2.476  0.0196 *
2076 x2  0.375377      0.255639   1.468  0.1531
2077 x3 -0.167438      0.012061 -13.882 4.45e-14 ***
2078 x4  0.154725      0.006382  24.245 < 2e-16 ***
2079 ---
2080 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2081
2082 Residual standard error: 2.213 on 28 degrees of freedom
2083 Multiple R-Squared: 0.9914,    Adjusted R-squared: 0.9902
2084 F-statistic: 806.6 on 4 and 28 DF,  p-value: < 2.2e-16
2085
2086 >
2087 > # --> Elimino la x2 perche' l'alpha oss e' il piu' grande ed e' > 0.05
2088 >
2089 > fit2<-lm(y~x1+x3+x4-1)
2090 > summary(fit2)
2091
2092 Call:
2093 lm(formula = y ~ x1 + x3 + x4 - 1)
2094
2095 Residuals:
2096      Min       1Q   Median       3Q      Max
2097 -3.6075 -1.3229 -0.3831  1.7549  4.9115
2098
2099 Coefficients:
2100             Estimate Std. Error t value Pr(>|t|)
2101 x1  0.274133      0.039548   6.932 1.28e-07 ***
2102 x3 -0.179328      0.009116 -19.672 < 2e-16 ***
2103 x4  0.157168      0.006283  25.017 < 2e-16 ***
2104 ---
2105 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2106

```

```

2107 Residual standard error: 2.256 on 29 degrees of freedom
2108 Multiple R-Squared: 0.9907, Adjusted R-squared: 0.9898
2109 F-statistic: 1034 on 3 and 29 DF, p-value: < 2.2e-16
2110
2111 >
2112 > # ora il modello va bene, viva la Ventura!
2113 >
2114 > # analisi dei residui
2115 > res<-fit2$res
2116 > boxplot(res)
2117 > qqnorm(res);qqline(res)
2118 >
2119 > par(mfrow=c(2,2))
2120 > plot(res,x1)
2121 > plot(res,x2)
2122 > plot(res,x3)
2123 > plot(res,x4)
2124 >
2125 -----
2126 Laboratorio 08
2127 -----
2128 > # sturdy.dat
2129 > x1<-scan('sturdy.dat')
2130 Read 26 items
2131 > x1
2132 [1] 2.34 2.46 2.83 2.04 2.69 2.64 3.00 3.19 3.83 2.61 2.07 2.80 2.58 2.98 2.30
2133 [16] 1.32 1.62 1.92 0.88 1.50 1.30 0.41 0.83 0.58 0.32 1.62
2134 >
2135 > group<-c(rep("A",5),rep("B",4),rep("C",6),rep("D",6),rep("E",5))
2136 > group
2137 [1] "A" "A" "A" "A" "A" "B" "B" "B" "B" "C" "C" "C" "C" "C" "C" "D" "D" "D" "D"
2138 [20] "D" "D" "E" "E" "E" "E" "E"
2139 >
2140 > group<-factor(group) # fattorizzazione dei gruppi
2141 > group
2142 [1] A A A A A B B B B C C C C C D D D D D E E E E E
2143 Levels: A B C D E
2144 >
2145 > # ----- Esistono delle differenze tra le marche ???
2146 >
2147 > # t_i ~ N(mu_i,sigma^2_i)
2148 >
2149 > # normalita', varianze uguali
2150 > # H0: mu_i = mu_j
2151 >
2152 > stu<-data.frame(x1,group) # creazione del dataframe = read.table ('file.dat')
2153 > stu
2154      x1 group
2155 1  2.34    A
2156 2  2.46    A
2157 3  2.83    A
2158 4  2.04    A
2159 5  2.69    A
2160 6  2.64    B
2161 7  3.00    B
2162 8  3.19    B
2163 9  3.83    B
2164 10 2.61    C
2165 11 2.07    C
2166 12 2.80    C
2167 13 2.58    C
2168 14 2.98    C
2169 15 2.30    C
2170 16 1.32    D
2171 17 1.62    D
2172 18 1.92    D
2173 19 0.88    D
2174 20 1.50    D
2175 21 1.30    D
2176 22 0.41    E
2177 23 0.83    E
2178 24 0.58    E
2179 25 0.32    E
2180 26 1.62    E
2181 >
2182 > attach(stu)
2183 > # analisi preliminare
2184 > plot(x1~group)

```

```

2185 > # --> normalita' ok! (abbiamo pero' pochi dati)
2186 > # boxplot
2187 > var(x1[group=="A"]) # seleziono i valori di x1 = 'A'
2188 [1] 0.09497
2189 > var(x1[group=="B"])
2190 [1] 0.2485667
2191 > var(x1[group=="C"])
2192 [1] 0.1089067
2193 > var(x1[group=="D"])
2194 [1] 0.1224667
2195 > var(x1[group=="E"])
2196 [1] 0.27317
2197 >
2198 > # ----- test TRV per verificare l'omoschedasticita'
2199 > # '--> test di Bartlett
2200 > help(bartlett.test)
2201 >
2202 > # '--> l'ipotesi di omoschedasticita' puo' essere assunta!
2203 >
2204 >
2205 > stu.lm<-lm(x1~group,x=T)
2206 > stu.lm$x
2207 (Intercept) groupB groupC groupD groupE
2208 1 1 0 0 0 0
2209 2 1 0 0 0 0
2210 3 1 0 0 0 0
2211 4 1 0 0 0 0
2212 5 1 0 0 0 0
2213 6 1 1 0 0 0
2214 7 1 1 0 0 0
2215 8 1 1 0 0 0
2216 9 1 1 0 0 0
2217 10 1 0 1 0 0
2218 11 1 0 1 0 0
2219 12 1 0 1 0 0
2220 13 1 0 1 0 0
2221 14 1 0 1 0 0
2222 15 1 0 1 0 0
2223 16 1 0 0 1 0
2224 17 1 0 0 1 0
2225 18 1 0 0 1 0
2226 19 1 0 0 1 0
2227 20 1 0 0 1 0
2228 21 1 0 0 1 0
2229 22 1 0 0 0 1
2230 23 1 0 0 0 1
2231 24 1 0 0 0 1
2232 25 1 0 0 0 1
2233 26 1 0 0 0 1
2234 attr("assign")
2235 [1] 0 1 1 1 1
2236 attr("contrasts")
2237 attr("contrasts")$group
2238 [1] "contr.treatment"
2239
2240 >
2241 > #  $x_i = \alpha + b_1 \cdot d_1 + b_2 \cdot d_2 + b_3 \cdot d_3 + b_4 \cdot d_4$ 
2242 > #  $\alpha$  : E(A)
2243 > #  $\alpha + b_1$  : E(B)
2244 > #  $\alpha + b_2$  : E(C)
2245 > #  $\alpha + b_3$  : E(D)
2246 > #  $\alpha + b_4$  : E(E)
2247 >
2248 > summary(stu.lm)
2249
2250 Call:
2251 lm(formula = x1 ~ group, x = T)
2252
2253 Residuals:
2254 Min 1Q Median 3Q Max
2255 -0.543333 -0.235500 0.005667 0.212667 0.868000
2256
2257 Coefficients:
2258 Estimate Std. Error t value Pr(>|t|)
2259 (Intercept) 2.47200 0.17929 13.788 5.40e-12 ***
2260 groupB 0.69300 0.26893 2.577 0.017583 *
2261 groupC 0.08467 0.24276 0.349 0.730733
2262 groupD -1.04867 0.24276 -4.320 0.000302 ***

```



```

2341      tempo veleno trattamento
2342 1      0.31      I      A
2343 2      0.82      I      B
2344 3      0.43      I      C
2345 4      0.45      I      D
2346 5      0.45      I      A
2347 6      1.10      I      B
2348 7      0.45      I      C
2349 8      0.71      I      D
2350 9      0.46      I      A
2351 10     0.88      I      B
2352 11     0.63      I      C
2353 12     0.66      I      D
2354 13     0.43      I      A
2355 14     0.72      I      B
2356 15     0.76      I      C
2357 16     0.62      I      D
2358 17     0.36     II     A
2359 18     0.92     II     B
2360 19     0.44     II     C
2361 20     0.56     II     D
2362 21     0.29     II     A
2363 22     0.61     II     B
2364 23     0.35     II     C
2365 24     1.02     II     D
2366 25     0.40     II     A
2367 26     0.49     II     B
2368 27     0.31     II     C
2369 28     0.71     II     D
2370 29     0.23     II     A
2371 30     1.24     II     B
2372 31     0.40     II     C
2373 32     0.38     II     D
2374 33     0.22     III    A
2375 34     0.30     III    B
2376 35     0.23     III    C
2377 36     0.30     III    D
2378 37     0.21     III    A
2379 38     0.37     III    B
2380 39     0.25     III    C
2381 40     0.36     III    D
2382 41     0.18     III    A
2383 42     0.38     III    B
2384 43     0.24     III    C
2385 44     0.31     III    D
2386 45     0.23     III    A
2387 46     0.29     III    B
2388 47     0.22     III    C
2389 48     0.33     III    D
2390 >
2391 > topi$veleno<-factor(topi$veleno)
2392 > topi$tratt<-factor(topi$tratt)
2393 > attach(topi)
2394 >
2395 > # effetto del trattamento sul veleno II # W la Ventura
2396 > topi2<-data.frame(tempo=tempo[veleno=='II'],trattamento=trattamento[veleno=='II'])
2397 > attach(topi2)
2398 >
2399 > plot(tempo,trattamento)
2400 > plot(tempo~trattamento)
2401 >
2402 > bartlett.test(tempo,trattamento)
2403
2404      Bartlett test for homogeneity of variances
2405
2406 data:  tempo and trattamento
2407 Bartlett's K-squared = 9.5432, df = 3, p-value = 0.02288
2408
2409 >
2410 > # ipotesi non soddisfatte: casa fare????
2411 > # '--> trasformo i dati con la potenza della Ventura
2412 > # log(tempo), exp(tempo), tempo^p, tempo^-p
2413 >
2414 > plot(1/tempo~trattamento)
2415 > bartlett.test(1/tempo~trattamento)
2416
2417      Bartlett test for homogeneity of variances
2418

```

```

2419 data: 1/tempo by trattamento
2420 Bartlett's K-squared = 1.2807, df = 3, p-value = 0.7337
2421
2422 > # ----- ipotesi di normalita' soddisfatta
2423 > # '--> anche i qqnorm
2424 >
2425 > topi.aov<-aov(1/tempo~trattamento)
2426 > summary(topi.aov)
2427           Df Sum Sq Mean Sq F value    Pr(>F)
2428 trattamento  3  9.1424   3.0475   7.3913 0.004594 **
2429 Residuals    12  4.9477   0.4123
2430 ---
2431 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2432 >
2433 > # H0: mu1=mu2=mu3=mu4 , alpha_oss<0.05 --> rifiuto H0
2434 >
2435 > detach()
2436 >
2437 >
2438 > mor<-read.table('Morley.dat',header=T)
2439 > mor$Expt<-factor(mor$Expt)
2440 > attach(mor)
2441 >
2442 > plot(Speed~Expt)
2443 > # c'e' un comportamento anomalo nel gruppo 3, medie simili
2444 >
2445 > # verifica della normalita'
2446 > par(mfrow=c(2,3))
2447 > qqnorm(Speed[Expt==1]);qqline(Speed[Expt==1])
2448 > qqnorm(Speed[Expt==2]);qqline(Speed[Expt==2])
2449 > qqnorm(Speed[Expt==3]);qqline(Speed[Expt==3])
2450 > qqnorm(Speed[Expt==4]);qqline(Speed[Expt==4])
2451 > qqnorm(Speed[Expt==5]);qqline(Speed[Expt==5])
2452 > # risultati poco soddisfacenti
2453 >
2454 > bartlett.test(Speed,Expt)
2455
2456           Bartlett test for homogeneity of variances
2457
2458 data: Speed and Expt
2459 Bartlett's K-squared = 11.5518, df = 4, p-value = 0.02102
2460
2461 > bartlett.test(1/Speed,Expt)
2462
2463           Bartlett test for homogeneity of variances
2464
2465 data: 1/Speed and Expt
2466 Bartlett's K-squared = 13.0758, df = 4, p-value = 0.01091
2467
2468 > bartlett.test(log(Speed),Expt)
2469
2470           Bartlett test for homogeneity of variances
2471
2472 data: log(Speed) and Expt
2473 Bartlett's K-squared = 11.7615, df = 4, p-value = 0.01922
2474
2475 > bartlett.test(Speed^2,Expt)
2476
2477           Bartlett test for homogeneity of variances
2478
2479 data: Speed^2 and Expt
2480 Bartlett's K-squared = 12.3319, df = 4, p-value = 0.01505
2481
2482 >
2483 > # non trovo una trasformata adatta!!
2484 > # si usa allora (grazie alla Ventura che ce lo ha detto!) un test non
2485 > # parametrico per il confronto delle medie
2486 > # '--> non assumo nessuna distrib per i dati
2487 > # ==> test di Kruskal Wallis
2488 >
2489 > kruskal.test(Speed,Expt)
2490
2491           Kruskal-Wallis rank sum test
2492
2493 data: Speed and Expt
2494 Kruskal-Wallis chi-squared = 15.0221, df = 4, p-value = 0.004656
2495
2496 >

```



```

2497
2498 -----
2499 Riassunto:
2500 * Controllo le ipotesi: di normalita' e omoschedasticita'
2501 * Se sono verificate faccio i test altrimenti provo delle trasformate
2502 * se funziona e' tutto ok e faccio i test, altrimenti uso il test Kruskal
2503
2504 -----
2505 Laboratorio 09
2506 -----
2507 > # ---- penicillin.dat
2508 > pen<-read.table("penicillin.dat",header=T)
2509 > pen
2510      miscela modo penicillina
2511 1          I    A           89
2512 2          I    B           88
2513 3          I    C           97
2514 4          I    D           94
2515 5         II    A           84
2516 6         II    B           77
2517 7         II    C           92
2518 8         II    D           79
2519 9        III    A           81
2520 10       III    B           87
2521 11       III    C           87
2522 12       III    D           85
2523 13        IV    A           87
2524 14        IV    B           92
2525 15        IV    C           89
2526 16        IV    D           84
2527 17         V    A           79
2528 18         V    B           81
2529 19         V    C           80
2530 20         V    D           88
2531 > # disegno fatto con 5x4 livelli complessivi, con 1 replicaz
2532 > attach(pen)
2533 > miscela
2534 [1] I  I  I  I  II II II II III III III III IV IV IV IV V  V  V
2535 [20] V
2536 Levels:  I II III IV V
2537 > modo
2538 [1] A B C D A B C D A B C D A B C D A B C D
2539 Levels:  A B C D
2540 > is.factor(miscela)
2541 [1] TRUE
2542 > is.factor(modo)
2543 [1] TRUE
2544 > # penicillina = miscela + errore
2545 > # penicillina = modo + errore
2546 > # penicillina = miscela + modo + errore
2547 >
2548 > # anova 1 fattore
2549 > # analisi preliminare
2550 > plot(penicillina~modo)
2551 >
2552 > # penicillina = modo + errore
2553 > # errore ~ N(0, sigma^2)
2554 >
2555 > # H0: mu_1 = mu_2 = mu_3 = mu_4
2556 >
2557 > bartlett.test(penicillina,modo)
2558
2559      Bartlett test for homogeneity of variances
2560
2561 data:  penicillina and modo
2562 Bartlett's K-squared = 0.6901, df = 3, p-value = 0.8755
2563
2564 > # H0: mu_1 = mu_2 = mu_3 = mu_4
2565 >
2566 > # TRV funzione monotona crescente F
2567 > # F = [SS(tra i campioni)/(J-1)]/[SS(entra i campioni)/(n-J)] # SS e' la somma
2568 > # F ~ F_(J-1),(n-J) # F di Schnedecor # dei quadrati
2569 >
2570 >
2571 > # aov
2572 > summary(aov(penicillina~modo))
2573      Df Sum Sq Mean Sq F value Pr(>F)
2574 modo    3  70.00   23.33   0.7619 0.5318

```

```

2575 Residuals    16 490.00    30.62
2576 >
2577 > # penicillina = modo + errore
2578 > # accettiamo H0
2579 >
2580 > # pen_ij = cost + alpha_j + err_ij
2581 >
2582 > fit<-lm(penicillina~modo,x=T)
2583 > fit$x
2584      (Intercept) modoB modoC modoD
2585 1             1      0      0      0
2586 2             1      1      0      0
2587 3             1      0      1      0
2588 4             1      0      0      1
2589 5             1      0      0      0
2590 6             1      1      0      0
2591 7             1      0      1      0
2592 8             1      0      0      1
2593 9             1      0      0      0
2594 10            1      1      0      0
2595 11            1      0      1      0
2596 12            1      0      0      1
2597 13            1      0      0      0
2598 14            1      1      0      0
2599 15            1      0      1      0
2600 16            1      0      0      1
2601 17            1      0      0      0
2602 18            1      1      0      0
2603 19            1      0      1      0
2604 20            1      0      0      1
2605 attr("assign")
2606 [1] 0 1 1 1
2607 attr("contrasts")
2608 attr("contrasts")$modo
2609 [1] "contr.treatment"
2610
2611 >
2612 > summary(fit)
2613
2614 Call:
2615 lm(formula = penicillina ~ modo, x = T)
2616
2617 Residuals:
2618      Min       1Q   Median       3Q      Max
2619 -9.000e+00 -3.250e+00  3.002e-15  3.000e+00  8.000e+00
2620
2621 Coefficients:
2622             Estimate Std. Error t value Pr(>|t|)
2623 (Intercept)    84.000      2.475   33.941 2.45e-16 ***
2624 modoB           1.000      3.500    0.286   0.779
2625 modoC           5.000      3.500    1.429   0.172
2626 modoD           2.000      3.500    0.571   0.576
2627 ---
2628 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2629
2630 Residual standard error: 5.534 on 16 degrees of freedom
2631 Multiple R-Squared:  0.125,    Adjusted R-squared: -0.03906
2632 F-statistic: 0.7619 on 3 and 16 DF,  p-value: 0.5318
2633
2634 > # H0: alpha_1 = alpha_2 = alpha_3 = 0
2635 >
2636 > anova(fit) # confronto tra i due modelli di regressione
2637 Analysis of Variance Table
2638
2639 Response: penicillina
2640      Df Sum Sq Mean Sq F value Pr(>F)
2641 modo    3  70.00   23.33   0.7619 0.5318
2642 Residuals 16 490.00   30.62
2643 > # '--> stesso risultato di prima!
2644 >
2645 > plot(penicillina~miscela)
2646 > bartlett.test(penicillina,miscela)
2647
2648      Bartlett test for homogeneity of variances
2649
2650 data:  penicillina and miscela
2651 Bartlett's K-squared = 2.3859, df = 4, p-value = 0.6652
2652

```

```

2653 > # p-value elevato --> accetto l'ipotesi di omoscedasticita'
2654 > summary(aov(penicillina-miscela))
2655           Df Sum Sq Mean Sq F value Pr(>F)
2656 miscela    4 264.000  66.000  3.3446 0.03801 *
2657 Residuals  15 296.000  19.733
2658 ---
2659 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2660 >
2661 > # -----
2662 > # pen_(ijk) = cost + alpha_j + beta_k + errore_(ijk)
2663 >
2664 > summary(aov(penicillina-modo+miscela))
2665           Df Sum Sq Mean Sq F value Pr(>F)
2666 modo        3  70.000  23.333  1.2389 0.33866
2667 miscela      4 264.000  66.000  3.5044 0.04075 *
2668 Residuals   12 226.000  18.833
2669 ---
2670 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2671 > # e' come se avessimo fatto una scomposizione del tipo:
2672 > # Var(Y) = Var(modo) + Var(miscela) + Var(residua)
2673 >
2674 > fit1<-lm(penicillina~modo+miscela,x=T)
2675 > fit$x
2676      (Intercept) modoB modoC modoD
2677 1             1      0      0      0
2678 2             1      1      0      0
2679 3             1      0      1      0
2680 4             1      0      0      1
2681 5             1      0      0      0
2682 6             1      1      0      0
2683 7             1      0      1      0
2684 8             1      0      0      1
2685 9             1      0      0      0
2686 10            1      1      0      0
2687 11            1      0      1      0
2688 12            1      0      0      1
2689 13            1      0      0      0
2690 14            1      1      0      0
2691 15            1      0      1      0
2692 16            1      0      0      1
2693 17            1      0      0      0
2694 18            1      1      0      0
2695 19            1      0      1      0
2696 20            1      0      0      1
2697 attr("assign")
2698 [1] 0 1 1 1
2699 attr("contrasts")
2700 attr("contrasts")$modo
2701 [1] "contr.treatment"
2702
2703 >
2704 > summary(fit1)
2705
2706 Call:
2707 lm(formula = penicillina ~ modo + miscela, x = T)
2708
2709 Residuals:
2710      Min       1Q   Median       3Q      Max
2711  -5.00  -2.25  -0.50   2.25   6.00
2712
2713 Coefficients:
2714             Estimate Std. Error t value Pr(>|t|)
2715 (Intercept)   90.000     2.745  32.791 4.1e-13 ***
2716 modoB          1.000     2.745   0.364  0.72194
2717 modoC          5.000     2.745   1.822  0.09351 .
2718 modoD          2.000     2.745   0.729  0.48018
2719 miscelaII     -9.000     3.069  -2.933  0.01254 *
2720 miscelaIII    -7.000     3.069  -2.281  0.04159 *
2721 miscelaIV     -4.000     3.069  -1.304  0.21686
2722 miscelaV     -10.000     3.069  -3.259  0.00684 **
2723 ---
2724 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2725
2726 Residual standard error: 4.34 on 12 degrees of freedom
2727 Multiple R-Squared:  0.5964,    Adjusted R-squared:  0.361
2728 F-statistic: 2.534 on 7 and 12 DF,  p-value: 0.07535
2729
2730 > # il modo non influenza i risultati

```

```

2731 > # miscela I : Y=90
2732 > # miscela II : Y=90-9=81
2733 > # miscela III : Y=90-7=83
2734 > # miscela IV : Y=90=90 # il -4 non e' significativo!
2735 > # miscela V : Y=90-10=80
2736 >
2737 > # H0: alpha=beta=0
2738 >
2739 > anova(fit1)
2740 Analysis of Variance Table
2741
2742 Response: penicillina
2743      Df Sum Sq Mean Sq F value Pr(>F)
2744 modo    3  70.000  23.333   1.2389 0.33866
2745 miscela  4 264.000  66.000   3.5044 0.04075 *
2746 Residuals 12 226.000  18.833
2747 ---
2748 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2749 >
2750 > # -----
2751 > # la F sopra, deriva dal seguente test:
2752 > #  $F = [(\sim\sigma - \hat{\sigma})/(p-p_0)] / [\hat{\sigma}/(n-p)]$ 
2753 >
2754 > # Var(mod0)
2755 > # Y = cost + alpha + beta + errore
2756 > # H0: alpha = 0
2757 > # SQ(mod0)
2758 >
2759 > # H0: beta = 0
2760 >
2761 > detach()
2762 > # -----
2763 >
2764 > topi<-read.table("rats.dat",header=T)
2765 > topi
2766      tempo veleno trattamento
2767 1    0.31      I           A
2768 2    0.82      I           B
2769 3    0.43      I           C
2770 4    0.45      I           D
2771 5    0.45      I           A
2772 6    1.10      I           B
2773 7    0.45      I           C
2774 8    0.71      I           D
2775 9    0.46      I           A
2776 10   0.88      I           B
2777 11   0.63      I           C
2778 12   0.66      I           D
2779 13   0.43      I           A
2780 14   0.72      I           B
2781 15   0.76      I           C
2782 16   0.62      I           D
2783 17   0.36     II          A
2784 18   0.92     II          B
2785 19   0.44     II          C
2786 20   0.56     II          D
2787 21   0.29     II          A
2788 22   0.61     II          B
2789 23   0.35     II          C
2790 24   1.02     II          D
2791 25   0.40     II          A
2792 26   0.49     II          B
2793 27   0.31     II          C
2794 28   0.71     II          D
2795 29   0.23     II          A
2796 30   1.24     II          B
2797 31   0.40     II          C
2798 32   0.38     II          D
2799 33   0.22    III          A
2800 34   0.30    III          B
2801 35   0.23    III          C
2802 36   0.30    III          D
2803 37   0.21    III          A
2804 38   0.37    III          B
2805 39   0.25    III          C
2806 40   0.36    III          D
2807 41   0.18    III          A
2808 42   0.38    III          B

```

```

2809 43 0.24 III C
2810 44 0.31 III D
2811 45 0.23 III A
2812 46 0.29 III B
2813 47 0.22 III C
2814 48 0.33 III D
2815 > # disegno fattoriale 3x4, con 4 replicazioni
2816 >
2817 > attach(topi)
2818 > is.factor(veleno)
2819 [1] TRUE
2820 > is.factor(trattamento)
2821 [1] TRUE
2822 >
2823 > # -----
2824 > # analisi preliminare
2825 > plot(tempo~veleno+trattamento)
2826 Hit <Return> to see next plot:
2827 Hit <Return> to see next plot:
2828 >
2829 > help(interaction.plot)
2830 > interaction.plot(veleno,trattamento,tempo)
2831 > interaction.plot(trattamento,veleno,tempo)
2832 >
2833 > # -----
2834 > # Risp = Effetto(costante) + Effetto(trattamento) + Effetto(veleno) +
2835 > # Effetto(trattamento/veleno) + Effetto(residuo)
2836 > summary(aov(tempo~trattamento + veleno + trattamento:veleno))
2837
      Df Sum Sq Mean Sq F value    Pr(>F)
2838 trattamento      3  0.92121  0.30707  13.8056 3.777e-06 ***
2839 veleno            2  1.03301  0.51651  23.2217 3.331e-07 ***
2840 trattamento:veleno  6  0.25014  0.04169   1.8743  0.1123
2841 Residuals        36  0.80073  0.02224
2842 ---
2843 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2844 > # lo stesso e' con:
2845 > summary(aov(tempo~trattamento * veleno))
2846
      Df Sum Sq Mean Sq F value    Pr(>F)
2847 trattamento      3  0.92121  0.30707  13.8056 3.777e-06 ***
2848 veleno            2  1.03301  0.51651  23.2217 3.331e-07 ***
2849 trattamento:veleno  6  0.25014  0.04169   1.8743  0.1123
2850 Residuals        36  0.80073  0.02224
2851 ---
2852 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2853 >
2854 > # H0: trattamento non ha effetto
2855 > # y_ijk ~ N(mu_ijk,sigma^2)
2856 > # H0: mu1_jk = mu2_jk = mu3_jk
2857 > # i: trattamento # j: veleno # k: interazione tra trattamento e veleno
2858 >
2859 > # y_ijk = mu + alpha_i + beta_j + delta_ij + epsilon
2860 >
2861 > g<-lm(tempo~trattamento * veleno)
2862 > summary(g)
2863
2864 Call:
2865 lm(formula = tempo ~ trattamento * veleno)
2866
2867 Residuals:
2868      Min       1Q   Median       3Q      Max
2869 -0.32500 -0.04875  0.00500  0.04312  0.42500
2870
2871 Coefficients:
2872
      Estimate Std. Error t value Pr(>|t|)
2873 (Intercept)      0.41250     0.07457   5.532 2.94e-06 ***
2874 trattamentoB      0.46750     0.10546   4.433 8.37e-05 ***
2875 trattamentoC      0.15500     0.10546   1.470  0.1503
2876 trattamentoD      0.19750     0.10546   1.873  0.0692 .
2877 velenoII           -0.09250     0.10546  -0.877  0.3862
2878 velenoIII          -0.20250     0.10546  -1.920  0.0628 .
2879 trattamentoB:velenoII  0.02750     0.14914   0.184  0.8547
2880 trattamentoC:velenoII -0.10000     0.14914  -0.671  0.5068
2881 trattamentoD:velenoII  0.15000     0.14914   1.006  0.3212
2882 trattamentoB:velenoIII -0.34250     0.14914  -2.297  0.0276 *
2883 trattamentoC:velenoIII -0.13000     0.14914  -0.872  0.3892
2884 trattamentoD:velenoIII -0.08250     0.14914  -0.553  0.5836
2885 ---
2886 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```

2887
2888 Residual standard error: 0.1491 on 36 degrees of freedom
2889 Multiple R-Squared: 0.7335, Adjusted R-squared: 0.6521
2890 F-statistic: 9.01 on 11 and 36 DF, p-value: 1.986e-07
2891
2892 >
2893 > # il trattamento A e' quello di riferimento
2894 > # C e D si comportano come A --> non sono significativi
2895 > # il veleno significativo e' il II
2896 > # l'interazione significativa e' solo B:III
2897 > anova(g)
2898 Analysis of Variance Table
2899
2900 Response: tempo
2901      Df Sum Sq Mean Sq F value    Pr(>F)
2902 trattamento    3  0.92121  0.30707  13.8056 3.777e-06 ***
2903 veleno          2  1.03301  0.51651  23.2217 3.331e-07 ***
2904 trattamento:veleno  6  0.25014  0.04169   1.8743  0.1123
2905 Residuals      36  0.80073  0.02224
2906 ---
2907 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2908 >
2909 > # H0: alpha_i = 0
2910 > # H0: beta_i = 0
2911 > # H0: delta_ij = 0
2912 >
2913 > # '--> y_ijk = mu + alpha_i + beta_j + epsilon
2914 > g0<-lm(tempo~trattamento+veleno)
2915 >
2916 > # A, I : Y = 0.45
2917 > # A, II: Y = 0.45 # xche' il veleno II non e' significativo
2918 > # A, III: Y = 0.45 - 0.34 = 0.11
2919 > # B, I: Y = 0.45 + 0.36 = 81
2920 > # ecc...
2921 >
2922 >
2923 > # -----
2924 > # analisi dei residui
2925 >
2926 > qqnorm(g0$res);qqline(g0$res)
2927 > plot(g0$fitted,g0$res)
2928 > # cosa fare wuando i residui non sono soddisfacenti???
2929 > # '--> riformulo il modello!
2930 >
2931 > g1<-lm(1/tempo~veleno * trattamento)
2932 > anova(g1)
2933 Analysis of Variance Table
2934
2935 Response: 1/tempo
2936      Df Sum Sq Mean Sq F value    Pr(>F)
2937 veleno          2  34.877  17.439  72.6347 2.310e-13 ***
2938 trattamento    3  20.414   6.805  28.3431 1.376e-09 ***
2939 veleno:trattamento  6   1.571   0.262   1.0904  0.3867
2940 Residuals      36   8.643   0.240
2941 ---
2942 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2943 >
2944 > qqnorm(g1$res);qqline(g1$res)
2945 > plot(g1$fitted,g1$res)
2946 >
2947 -----
2948 Laboratorio 10
2949 -----
2950 > cats<-read.table('cats.dat',col.names=c('B','H','S'))
2951 > cats
2952      B      H S
2953 1  2.3   9.6 1
2954 2  3.0  10.6 1
2955 3  2.9   9.9 1
2956 4  2.4   8.7 1
2957 5  2.3  10.1 1
2958 6  2.0   7.0 1
2959 7  2.2  11.0 1
2960 8  2.1   8.2 1
2961 9  2.3   9.0 1
2962 10 2.1   7.3 1
2963 11 2.1   8.5 1
2964 12 2.2   9.7 1

```



```

3043 >
3044 > # t-Student
3045 > # H0: mu_1 = mu_2
3046 > # H1: mu_1 < mu_2
3047 >
3048 > t.test(H[S==1],H[S==2],alternative="less",var.equal=T)
3049
3050         Two Sample t-test
3051
3052 data:  H[S == 1] and H[S == 2]
3053 t = -4.8419, df = 46, p-value = 7.455e-06
3054 alternative hypothesis: true difference in means is less than 0
3055 95 percent confidence interval:
3056      -Inf -1.412780
3057 sample estimates:
3058 mean of x mean of y
3059      8.8875  11.0500
3060
3061 > # -----
3062 > # mi aspetto che ci sia una relazione tra il peso ed il cuore
3063 > # proviamo:
3064 > plot(H~B)
3065 > cor(H,B)
3066 [1] 0.7335559
3067 >
3068 > # evidenziamo sul grafico i maschi e le femmine con colori diversi
3069 > points(B[S==1],H[S==1],col='red')
3070 > points(B[S==2],H[S==2],col='blue')
3071 >
3072 > # ----- H = alpha + alpha_j(S) + beta * B + beta_j * (S:B) + err
3073 > # S:B=interazione tra S e B
3074 >
3075 > # S = (1,0) # 1=F, 0=M
3076 > # (S:B) = (1,0)
3077 > #
3078 > # H_F = (alpha + alpha_1) + (beta+beta_1)*B
3079 > # H_M = alpha + beta*B
3080 >
3081 > # H0: alpha_1=beta_1=0
3082 > # F = ((~sigma^2 - ^sigma^2)/(p-p0))/(^sigma^2/(n-p))
3083 >
3084 > fit<-lm(H~S + B + S:B,x=T)
3085 > fit$x
3086      (Intercept) S2      B S2:B
3087 1             1  0  2.3  0.0
3088 2             1  0  3.0  0.0
3089 3             1  0  2.9  0.0
3090 4             1  0  2.4  0.0
3091 5             1  0  2.3  0.0
3092 6             1  0  2.0  0.0
3093 7             1  0  2.2  0.0
3094 8             1  0  2.1  0.0
3095 9             1  0  2.3  0.0
3096 10            1  0  2.1  0.0
3097 11            1  0  2.1  0.0
3098 12            1  0  2.2  0.0
3099 13            1  0  2.0  0.0
3100 14            1  0  2.3  0.0
3101 15            1  0  2.2  0.0
3102 16            1  0  2.3  0.0
3103 17            1  0  2.1  0.0
3104 18            1  0  2.0  0.0
3105 19            1  0  2.9  0.0
3106 20            1  0  2.7  0.0
3107 21            1  0  2.6  0.0
3108 22            1  0  2.3  0.0
3109 23            1  0  2.6  0.0
3110 24            1  0  2.1  0.0
3111 25            1  1  2.9  2.9
3112 26            1  1  2.4  2.4
3113 27            1  1  2.2  2.2
3114 28            1  1  2.9  2.9
3115 29            1  1  2.5  2.5
3116 30            1  1  3.1  3.1
3117 31            1  1  3.0  3.0
3118 32            1  1  2.5  2.5
3119 33            1  1  3.4  3.4
3120 34            1  1  3.0  3.0

```



```

3121 35      1  1 2.6  2.6
3122 36      1  1 2.5  2.5
3123 37      1  1 2.8  2.8
3124 38      1  1 3.1  3.1
3125 39      1  1 3.0  3.0
3126 40      1  1 2.7  2.7
3127 41      1  1 2.8  2.8
3128 42      1  1 2.1  2.1
3129 43      1  1 3.3  3.3
3130 44      1  1 3.4  3.4
3131 45      1  1 2.8  2.8
3132 46      1  1 2.7  2.7
3133 47      1  1 3.2  3.2
3134 48      1  1 3.0  3.0
3135 attr("assign")
3136 [1] 0 1 2 3
3137 attr("contrasts")
3138 attr("contrasts")$S
3139 [1] "contr.treatment"
3140
3141 >
3142 > # ----- H = alpha + alpha_j(S) + beta * B + beta_j * (S:B) + err
3143 > # H_F = alpha + beta * B
3144 > # H_M = alpha + alpha_1*1 + beta * B + beta_1*B
3145 > summary(fit)
3146
3147 Call:
3148 lm(formula = H ~ S + B + S:B, x = T)
3149
3150 Residuals:
3151      Min       1Q   Median       3Q      Max
3152 -1.9813 -0.9589 -0.1629  0.8573  2.6277
3153
3154 Coefficients:
3155             Estimate Std. Error t value Pr(>|t|)
3156 (Intercept)   2.9318     2.1105   1.389  0.17178
3157 S2            -0.2849     3.0313  -0.094  0.92554
3158 B             2.5525     0.8975   2.844  0.00674 **
3159 S2:B          0.4177     1.1784   0.354  0.72466
3160 ---
3161 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
3162
3163 Residual standard error: 1.28 on 44 degrees of freedom
3164 Multiple R-Squared: 0.5664, Adjusted R-squared: 0.5368
3165 F-statistic: 19.16 on 3 and 44 DF, p-value: 4.269e-08
3166
3167 > fit<-lm(H~S * B,x=T) # stessa cosa
3168 > summary(fit)
3169
3170 Call:
3171 lm(formula = H ~ S * B, x = T)
3172
3173 Residuals:
3174      Min       1Q   Median       3Q      Max
3175 -1.9813 -0.9589 -0.1629  0.8573  2.6277
3176
3177 Coefficients:
3178             Estimate Std. Error t value Pr(>|t|)
3179 (Intercept)   2.9318     2.1105   1.389  0.17178
3180 S2            -0.2849     3.0313  -0.094  0.92554
3181 B             2.5525     0.8975   2.844  0.00674 **
3182 S2:B          0.4177     1.1784   0.354  0.72466
3183 ---
3184 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
3185
3186 Residual standard error: 1.28 on 44 degrees of freedom
3187 Multiple R-Squared: 0.5664, Adjusted R-squared: 0.5368
3188 F-statistic: 19.16 on 3 and 44 DF, p-value: 4.269e-08
3189
3190 > # '---> H = 2.55*B
3191 > fit1<-lm(H~B - 1)
3192 > summary(fit1)
3193
3194 Call:
3195 lm(formula = H ~ B - 1)
3196
3197 Residuals:
3198      Min       1Q   Median       3Q      Max

```

```

3199 -2.0372 -0.9521 -0.0969 0.8620 3.0732
3200
3201 Coefficients:
3202 Estimate Std. Error t value Pr(>|t|)
3203 B 3.8507 0.0714 53.93 <2e-16 ***
3204 ---
3205 Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
3206
3207 Residual standard error: 1.292 on 47 degrees of freedom
3208 Multiple R-Squared: 0.9841, Adjusted R-squared: 0.9838
3209 F-statistic: 2909 on 1 and 47 DF, p-value: < 2.2e-16
3210
3211 > # '---> H = 3.85*B
3212 >
3213 > anova(fit1,fit)
3214 Analysis of Variance Table
3215
3216 Model 1: H ~ B - 1
3217 Model 2: H ~ S + B + S:B
3218 Res.Df RSS Df Sum of Sq F Pr(>F)
3219 1 47 78.488
3220 2 44 72.073 3 6.415 1.3055 0.2846
3221 >
3222 > qqnorm(fit1$res);qqline(fit1$res)
3223 > plot(fit1$fitted,fit1$res)
3224 >
3225 > detach()
3226 >
3227 > # -----
3228 > insu<-read.table('insulate.dat',col.names=c('quando','temp','cons'))
3229 > insu
3230 quando temp cons
3231 1 prima -0.8 7.2
3232 2 prima -0.7 6.9
3233 3 prima 0.4 6.4
3234 4 prima 2.5 6.0
3235 5 prima 2.9 5.8
3236 6 prima 3.2 5.8
3237 7 prima 3.6 5.6
3238 8 prima 3.9 4.7
3239 9 prima 4.2 5.8
3240 10 prima 4.3 5.2
3241 11 prima 5.4 4.9
3242 12 prima 6.0 4.9
3243 13 prima 6.0 4.3
3244 14 prima 6.0 4.4
3245 15 prima 6.2 4.5
3246 16 prima 6.3 4.6
3247 17 prima 6.9 3.7
3248 18 prima 7.0 3.9
3249 19 prima 7.4 4.2
3250 20 prima 7.5 4.0
3251 21 prima 7.5 3.9
3252 22 prima 7.6 3.5
3253 23 prima 8.0 4.0
3254 24 prima 8.5 3.6
3255 25 prima 9.1 3.1
3256 26 prima 10.2 2.6
3257 27 dopo -0.7 4.8
3258 28 dopo 0.8 4.6
3259 29 dopo 1.0 4.7
3260 30 dopo 1.4 4.0
3261 31 dopo 1.5 4.2
3262 32 dopo 1.6 4.2
3263 33 dopo 2.3 4.1
3264 34 dopo 2.5 4.0
3265 35 dopo 2.5 3.5
3266 36 dopo 3.1 3.2
3267 37 dopo 3.9 3.9
3268 38 dopo 4.0 3.5
3269 39 dopo 4.0 3.7
3270 40 dopo 4.2 3.5
3271 41 dopo 4.3 3.5
3272 42 dopo 4.6 3.7
3273 43 dopo 4.7 3.5
3274 44 dopo 4.9 3.4
3275 45 dopo 4.9 3.7
3276 46 dopo 4.9 4.0

```

```

3277 47    dopo  5.0  3.6
3278 48    dopo  5.3  3.7
3279 49    dopo  6.2  2.8
3280 50    dopo  7.1  3.0
3281 51    dopo  7.2  2.8
3282 52    dopo  7.5  2.6
3283 53    dopo  8.0  2.7
3284 54    dopo  8.7  2.8
3285 55    dopo  8.8  1.3
3286 56    dopo  9.7  1.5
3287 >
3288 > is.factor(insu$quando)
3289 [1] TRUE
3290 > attach(insu)
3291 >
3292 > # analisi preliminare
3293 > plot(cons~temp)
3294 > cor(cons,temp)
3295 [1] -0.6832545
3296 >
3297 > # evidenziamo i punti a seconda del quando:
3298 > points(temp[quando=='prima'],cons[quando=='prima'],col='red')
3299 > points(temp[quando=='dopo'],cons[quando=='dopo'],col='blue')
3300 >
3301 > cor(temp[quando=='prima'],cons[quando=='prima'])
3302 [1] -0.9714978
3303 > cor(temp[quando=='dopo'],cons[quando=='dopo'])
3304 [1] -0.9017078
3305 >
3306 > # -----
3307 > # cons = alpha + alpha_1*quando + beta*temp + beta_1*(quando:temp) + err
3308 > fit<-lm(cons~quando * temp,x=T) # si considerano gli effetti marginali del
3309 >                                     # quando e della temperatura
3310 > fit$x
3311      (Intercept) quandoprima temp quandoprima:temp
3312 1              1          1 -0.8             -0.8
3313 2              1          1 -0.7             -0.7
3314 3              1          1  0.4              0.4
3315 4              1          1  2.5              2.5
3316 5              1          1  2.9              2.9
3317 6              1          1  3.2              3.2
3318 7              1          1  3.6              3.6
3319 8              1          1  3.9              3.9
3320 9              1          1  4.2              4.2
3321 10             1          1  4.3              4.3
3322 11             1          1  5.4              5.4
3323 12             1          1  6.0              6.0
3324 13             1          1  6.0              6.0
3325 14             1          1  6.0              6.0
3326 15             1          1  6.2              6.2
3327 16             1          1  6.3              6.3
3328 17             1          1  6.9              6.9
3329 18             1          1  7.0              7.0
3330 19             1          1  7.4              7.4
3331 20             1          1  7.5              7.5
3332 21             1          1  7.5              7.5
3333 22             1          1  7.6              7.6
3334 23             1          1  8.0              8.0
3335 24             1          1  8.5              8.5
3336 25             1          1  9.1              9.1
3337 26             1          1 10.2             10.2
3338 27             1          0 -0.7             0.0
3339 28             1          0  0.8             0.0
3340 29             1          0  1.0             0.0
3341 30             1          0  1.4             0.0
3342 31             1          0  1.5             0.0
3343 32             1          0  1.6             0.0
3344 33             1          0  2.3             0.0
3345 34             1          0  2.5             0.0
3346 35             1          0  2.5             0.0
3347 36             1          0  3.1             0.0
3348 37             1          0  3.9             0.0
3349 38             1          0  4.0             0.0
3350 39             1          0  4.0             0.0
3351 40             1          0  4.2             0.0
3352 41             1          0  4.3             0.0
3353 42             1          0  4.6             0.0
3354 43             1          0  4.7             0.0

```

```

3355 44          1          0 4.9          0.0
3356 45          1          0 4.9          0.0
3357 46          1          0 4.9          0.0
3358 47          1          0 5.0          0.0
3359 48          1          0 5.3          0.0
3360 49          1          0 6.2          0.0
3361 50          1          0 7.1          0.0
3362 51          1          0 7.2          0.0
3363 52          1          0 7.5          0.0
3364 53          1          0 8.0          0.0
3365 54          1          0 8.7          0.0
3366 55          1          0 8.8          0.0
3367 56          1          0 9.7          0.0
3368 attr(,"assign")
3369 [1] 0 1 2 3
3370 attr(,"contrasts")
3371 attr(,"contrasts")$quando
3372 [1] "contr.treatment"
3373
3374 >
3375 > # '---> cons_prima = alpha+alpha_1 + (beta+beta_1)*temp
3376 > # '---> cons_dopo = alpha + beta*temp
3377 >
3378 > # H0: alpha_1=beta_1=0
3379 > summary(fit)
3380
3381 Call:
3382 lm(formula = cons ~ quando * temp, x = T)
3383
3384 Residuals:
3385      Min       1Q   Median       3Q      Max
3386 -0.97802 -0.18011  0.03757  0.20930  0.63803
3387
3388 Coefficients:
3389             Estimate Std. Error t value Pr(>|t|)
3390 (Intercept)    4.72385    0.11810  40.000 < 2e-16 ***
3391 quandoprima    2.12998    0.18009  11.827 2.32e-16 ***
3392 temp          -0.27793    0.02292 -12.124 < 2e-16 ***
3393 quandoprima:temp -0.11530    0.03211  -3.591 0.00073 ***
3394 ---
3395 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
3396
3397 Residual standard error: 0.323 on 52 degrees of freedom
3398 Multiple R-Squared: 0.9277, Adjusted R-squared: 0.9235
3399 F-statistic: 222.3 on 3 and 52 DF, p-value: < 2.2e-16
3400
3401 >
3402 > # cons_prima = alpha+alpha_1 + (beta+beta_1)*temp = 6.84-0.38*temp
3403 > # cons_dopo = 4.72 - 0.27 * temp
3404 >
3405 > fit1<-lm(cons~temp)
3406 > anova(fit1,fit)
3407 Analysis of Variance Table
3408
3409 Model 1: cons ~ temp
3410 Model 2: cons ~ quando + temp + quando:temp
3411    Res.Df    RSS Df Sum of Sq    F    Pr(>F)
3412 1         54 39.995
3413 2         52  5.425  2    34.570 165.67 < 2.2e-16 ***
3414 ---
3415 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
3416 >
3417 > abline(6.84,-0.38)
3418 > abline(4.72,-0.27)
3419 >
3420 > # analisi dei residui
3421 > qqnorm(fit$res);qqline(fit$res)
3422 > plot(fit$fitted,fit$res)
3423 >
3424 > # -----
3425 > fit2<-lm(cons~temp,subset=(quando=='prima'))
3426 > summary(fit2)
3427
3428 Call:
3429 lm(formula = cons ~ temp, subset = (quando == "prima"))
3430
3431 Residuals:
3432      Min       1Q   Median       3Q      Max

```

```

3433 -0.62020 -0.19947  0.06068  0.16770  0.59778
3434
3435 Coefficients:
3436             Estimate Std. Error t value Pr(>|t|)
3437 (Intercept)  6.85383    0.11842   57.88  <2e-16 ***
3438 temp       -0.39324    0.01959  -20.08  <2e-16 ***
3439 ---
3440 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
3441
3442 Residual standard error: 0.2813 on 24 degrees of freedom
3443 Multiple R-Squared: 0.9438,    Adjusted R-squared: 0.9415
3444 F-statistic: 403.1 on 1 and 24 DF,  p-value: < 2.2e-16
3445
3446 >
3447 > fit2<-lm(cons~temp,subset=(quando=='dopo'))
3448 > summary(fit2)
3449
3450 Call:
3451 lm(formula = cons ~ temp, subset = (quando == "dopo"))
3452
3453 Residuals:
3454      Min       1Q   Median       3Q      Max
3455 -0.97802 -0.11082  0.02672  0.25294  0.63803
3456
3457 Coefficients:
3458             Estimate Std. Error t value Pr(>|t|)
3459 (Intercept)  4.72385    0.12974   36.41  < 2e-16 ***
3460 temp       -0.27793    0.02518  -11.04 1.05e-11 ***
3461 ---
3462 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
3463
3464 Residual standard error: 0.3548 on 28 degrees of freedom
3465 Multiple R-Squared: 0.8131,    Adjusted R-squared: 0.8064
3466 F-statistic: 121.8 on 1 and 28 DF,  p-value: 1.046e-11
3467
3468 >
3469 > # H0: beta_1 = beta_2
3470 >
3471

```