pruebas ar(1)

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Generamos la función para calcular la Corelación integral

```
# Definir la función para calcular la Corelación integral
correlation_integral <- function(data, r, d) {
  N <- length(data)
  count <- 0

  # Iterar sobre todos los pares (i, j) tal que 1 <= i < j <= N-d+1
  for (i in 1:(N-d)) {
    for (j in (i+1):(N-d+1)) {
      # Crear los vectores u_i^d y u_j^d
      u_i_d <- data[i:(i+d-1)]
      u_j_d <- data[j:(j+d-1)]

      # Calcular la distancia euclidiana entre u_i^d y u_j^d
      distance <- sqrt(sum((u_i_d - u_j_d)^2))

      # Verificar si la distancia es menor que r
      if (distance < r) {
        count <- count + 1
      }
    }
  }

  # Calcular C_N(r, d)
  C_N <- (2 / (N^2)) * count
  return(C_N)
}
```

Ahora generamos la función para el X_n(r,d)

```
# Definir la función X_N(r, d)
X_N <- function(data, r, d) {
  C_N_d <- correlation_integral(data, r, d)
  C_N_d_minus_1 <- correlation_integral(data, r, d-1)
  C_N_d_plus_1 <- correlation_integral(data, r, d+1)

  X_N_value <- (C_N_d^2) / (C_N_d_minus_1 * C_N_d_plus_1)
  return(X_N_value)
}
```

```r
# Caso especial para d = 1
X_N_d_1 <- function(data, r) {
  C_N_1 <- correlation_integral(data, r, 1)
  C_N_2 <- correlation_integral(data, r, 2)

  X_N_value <- (C_N_1^2) / C_N_2
  return(X_N_value)
}
```

pruebas con caso AR(1)

Generamos 1000 series de 1000 observaciones

```r
set.seed(125)  # Fijamos la semilla

# Definimos parámetros
n_series <- 1000   # Número de series a generar
n_obs <- 1000      # Número de observaciones por serie
phi <- 0.5         # Coeficiente AR(1)
sigma <- 1         # Desviación estándar del ruido

# Matriz para almacenar las series AR(1)
ar1_series <- matrix(0, nrow = n_obs, ncol = n_series)

# Generamos las series AR(1)
for (i in 1:n_series) {
  ar1_series[, i] <- arima.sim(n = n_obs, list(ar = phi), sd = sigma)
}
```

Obtenemos los valores de $X_N(r, d)$ para los casos d=1 hasta d=5

```r
# Parámetros
r <- 1  # Umbral para la norma
d_values <- 1:5  # Valores de d

# Inicializar listas para almacenar los resultados
X_N_results_ar <- matrix(0, nrow = n_series, ncol = length(d_values))
colnames(X_N_results_ar) <- paste("d =", d_values)

# Calcular X_{N}(r,d) para cada serie y para cada valor de d
for (i in 1:n_series) {
  series <- ar1_series[i, ]

  # Caso especial para d = 1
  X_N_results_ar[i, 1] <- X_N_d_1(series, r)

  # Calcular X_{N}(r,d) para d = 2, 3, 4, 5
  for (d in 2:length(d_values)) {
    X_N_results_ar[i, d] <- X_N(series, r, d_values[d])
  }
}

# Ver los resultados
head(X_N_results_ar)
```

```
##         d = 1    d = 2    d = 3    d = 4    d = 5
## [1,] 1.227202 1.165312 1.149121 1.093141 1.096733
## [2,] 1.229623 1.159305 1.136260 1.065084 1.091703
## [3,] 1.230952 1.193624 1.113393 1.085511 1.038592
## [4,] 1.233810 1.166031 1.095355 1.120412 1.079079
## [5,] 1.248054 1.173693 1.120600 1.066303 1.050376
## [6,] 1.251253 1.151497 1.130670 1.070827 1.077997
```

```
X_N_results_ar
```

```
##            d = 1    d = 2    d = 3    d = 4     d = 5
##    [1,] 1.227202 1.165312 1.149121 1.093141 1.0967330
##    [2,] 1.229623 1.159305 1.136260 1.065084 1.0917028
##    [3,] 1.230952 1.193624 1.113393 1.085511 1.0385925
##    [4,] 1.233810 1.166031 1.095355 1.120412 1.0790790
##    [5,] 1.248054 1.173693 1.120600 1.066303 1.0503758
##    [6,] 1.251253 1.151497 1.130670 1.070827 1.0779973
##    [7,] 1.235518 1.156911 1.135782 1.107756 1.0624251
##    [8,] 1.238010 1.167939 1.107932 1.113138 1.1438308
##    [9,] 1.237938 1.154925 1.157509 1.075829 1.1217983
##   [10,] 1.227096 1.163900 1.121680 1.087332 1.1180256
##   [11,] 1.242101 1.167325 1.126097 1.082104 1.0680353
##   [12,] 1.225548 1.177546 1.116398 1.096858 1.1215950
##   [13,] 1.237889 1.144721 1.108313 1.095145 1.0260852
##   [14,] 1.230976 1.177597 1.135601 1.099198 1.0649193
##   [15,] 1.235276 1.175101 1.120012 1.125186 1.0155855
##   [16,] 1.246237 1.174288 1.115356 1.104871 0.9261637
##   [17,] 1.230391 1.154632 1.115929 1.118096 1.1322692
##   [18,] 1.242929 1.165292 1.144558 1.115934 1.1562500
##   [19,] 1.245662 1.165180 1.126609 1.101671 0.9957461
##   [20,] 1.242276 1.162944 1.128033 1.128723 1.0093233
##   [21,] 1.237143 1.155909 1.126877 1.140042 1.0818434
##   [22,] 1.236965 1.159011 1.130771 1.128862 1.1143459
##   [23,] 1.235219 1.164252 1.119856 1.125817 1.0179728
##   [24,] 1.224111 1.148262 1.129876 1.086142 1.1314644
##   [25,] 1.224493 1.171002 1.137010 1.109349 1.1077899
##   [26,] 1.230034 1.155407 1.124942 1.120618 1.1196453
##   [27,] 1.221787 1.156657 1.133583 1.103942 1.1335687
##   [28,] 1.231697 1.163187 1.127522 1.127219 1.1668850
##   [29,] 1.243750 1.181879 1.123013 1.090477 1.0588036
##   [30,] 1.236520 1.178470 1.128649 1.109404 1.1779636
##   [31,] 1.230895 1.161223 1.113862 1.107660 1.1347838
##   [32,] 1.229816 1.177754 1.144422 1.126239 1.1586853
##   [33,] 1.259318 1.149190 1.118940 1.104228 1.0117233
##   [34,] 1.231623 1.160917 1.144201 1.121228 1.0923844
##   [35,] 1.245891 1.170380 1.118161 1.105671 1.0696688
##   [36,] 1.234344 1.154989 1.120510 1.072493 1.0867168
##   [37,] 1.227432 1.157306 1.115125 1.111471 1.0297653
##   [38,] 1.227973 1.151225 1.114032 1.121350 1.0680214
##   [39,] 1.238595 1.138787 1.119076 1.083759 1.0754757
##   [40,] 1.254039 1.167256 1.131297 1.112314 1.0516182
##   [41,] 1.241383 1.174292 1.105207 1.108143 1.1018744
##   [42,] 1.243463 1.159096 1.137510 1.122999 1.0509969
##   [43,] 1.237980 1.149978 1.146976 1.116803 1.0741386
```

```
##   [44,] 1.215651 1.143260 1.138030 1.094259 1.0596669
##   [45,] 1.240338 1.189375 1.130124 1.117215 1.0964291
##   [46,] 1.233638 1.153013 1.119277 1.126432 1.1433752
##   [47,] 1.247839 1.176416 1.115949 1.145079 1.1539414
##   [48,] 1.245180 1.163402 1.119949 1.110351 1.1618783
##   [49,] 1.232406 1.155671 1.116388 1.117812 0.9944239
##   [50,] 1.231669 1.169014 1.111736 1.132049 1.1195722
##   [51,] 1.240891 1.161917 1.116113 1.078904 1.0579548
##   [52,] 1.240430 1.159622 1.120183 1.135056 1.2213050
##   [53,] 1.258030 1.167757 1.151165 1.120987 1.2002644
##   [54,] 1.234085 1.165285 1.121010 1.087735 1.1354284
##   [55,] 1.238623 1.152418 1.132055 1.076874 1.0475885
##   [56,] 1.239417 1.163456 1.129628 1.057084 1.0608970
##   [57,] 1.233412 1.165030 1.110410 1.093877 1.1049584
##   [58,] 1.237270 1.163726 1.110277 1.053019 1.1202913
##   [59,] 1.230710 1.183130 1.140459 1.107975 1.1164039
##   [60,] 1.239396 1.155770 1.131165 1.083050 1.1344982
##   [61,] 1.204714 1.181167 1.137983 1.131482 1.1146693
##   [62,] 1.228005 1.171645 1.131112 1.104857 1.0935209
##   [63,] 1.242480 1.157978 1.133331 1.130281 1.0892830
##   [64,] 1.229864 1.161315 1.122790 1.100808 1.1007771
##   [65,] 1.238870 1.150672 1.146387 1.099945 1.1768453
##   [66,] 1.239011 1.179278 1.121468 1.115284 1.0903141
##   [67,] 1.252485 1.165942 1.129185 1.101861 1.0617438
##   [68,] 1.234162 1.168069 1.104311 1.084823 1.0960023
##   [69,] 1.231704 1.173039 1.140482 1.104001 1.0615288
##   [70,] 1.215737 1.174191 1.138276 1.090654 1.1366932
##   [71,] 1.252351 1.174375 1.143235 1.071496 1.1317326
##   [72,] 1.245260 1.170485 1.145340 1.089890 1.1601641
##   [73,] 1.238134 1.148184 1.128518 1.092346 1.0768535
##   [74,] 1.233532 1.160468 1.115881 1.106061 1.0968423
##   [75,] 1.226499 1.171970 1.125940 1.066168 1.0242471
##   [76,] 1.242074 1.181661 1.121346 1.108577 1.1115063
##   [77,] 1.228896 1.171752 1.103820 1.120599 1.0950427
##   [78,] 1.235802 1.172401 1.109773 1.064465 1.0827597
##   [79,] 1.234782 1.157938 1.119861 1.142237 1.1466650
##   [80,] 1.239817 1.149358 1.122267 1.069806 1.0598500
##   [81,] 1.243318 1.149153 1.126746 1.061482 1.0199272
##   [82,] 1.241705 1.166827 1.155687 1.089759 1.0871977
##   [83,] 1.240561 1.156201 1.136084 1.098471 1.0789878
##   [84,] 1.236510 1.159766 1.105391 1.109494 1.1586405
##   [85,] 1.224145 1.178438 1.097944 1.110729 1.0841087
##   [86,] 1.239801 1.173868 1.134710 1.120947 1.0349800
##   [87,] 1.239363 1.168101 1.124397 1.097219 1.0619204
##   [88,] 1.216469 1.140531 1.132310 1.094120 1.1774923
##   [89,] 1.240556 1.177699 1.120428 1.125637 1.1383793
##   [90,] 1.252954 1.170684 1.129058 1.127887 1.0394682
##   [91,] 1.237927 1.154833 1.110560 1.115158 0.9986289
##   [92,] 1.225749 1.174413 1.092702 1.112948 1.0269366
##   [93,] 1.233543 1.154331 1.127507 1.096955 1.1174533
##   [94,] 1.230080 1.160791 1.118907 1.140628 1.1559465
##   [95,] 1.220423 1.151040 1.139616 1.068840 1.0686600
##   [96,] 1.233518 1.180537 1.138019 1.087130 0.9834944
##   [97,] 1.250042 1.167597 1.122817 1.094906 1.0866268
```

```
##   [98,] 1.246795 1.168792 1.133396 1.114585 1.0593114
##   [99,] 1.239492 1.160378 1.130262 1.054750 1.1324182
##  [100,] 1.248148 1.137536 1.133180 1.102144 1.1337309
##  [101,] 1.238570 1.146972 1.113765 1.082565 1.0693665
##  [102,] 1.223910 1.176122 1.117003 1.122527 1.0960065
##  [103,] 1.249714 1.158652 1.110058 1.106690 1.0863527
##  [104,] 1.224717 1.141677 1.130385 1.121758 1.0789783
##  [105,] 1.233676 1.149289 1.112097 1.052231 1.1292278
##  [106,] 1.213410 1.146334 1.095304 1.117467 1.0538584
##  [107,] 1.246365 1.161289 1.127430 1.065973 1.1017638
##  [108,] 1.235012 1.144034 1.126610 1.126228 1.0478430
##  [109,] 1.234017 1.167025 1.121813 1.100431 1.0260309
##  [110,] 1.248785 1.176148 1.117763 1.146745 1.0455036
##  [111,] 1.235983 1.189280 1.111132 1.097089 1.0921234
##  [112,] 1.231026 1.167480 1.150915 1.108146 1.0647894
##  [113,] 1.234715 1.160111 1.141319 1.130875 1.0788063
##  [114,] 1.235569 1.165171 1.099637 1.134285 1.1177599
##  [115,] 1.234597 1.180913 1.134982 1.132254 1.1023371
##  [116,] 1.236286 1.153018 1.133349 1.122324 1.1218608
##  [117,] 1.232482 1.162653 1.109322 1.093550 1.0654713
##  [118,] 1.234813 1.173241 1.116529 1.084176 1.0147443
##  [119,] 1.238950 1.177289 1.116598 1.126357 1.1267251
##  [120,] 1.240654 1.171351 1.114339 1.106571 0.9585190
##  [121,] 1.241858 1.165878 1.147787 1.105254 1.1233797
##  [122,] 1.248945 1.156216 1.104270 1.135776 1.1133558
##  [123,] 1.235412 1.175489 1.144059 1.121887 1.0757009
##  [124,] 1.250103 1.185835 1.125882 1.104397 1.1254419
##  [125,] 1.243785 1.156287 1.097162 1.143351 1.1238450
##  [126,] 1.227546 1.147122 1.111529 1.078227 1.0369301
##  [127,] 1.243192 1.158623 1.101908 1.098231 1.1037167
##  [128,] 1.242103 1.169734 1.129790 1.073192 1.0577065
##  [129,] 1.239495 1.178388 1.122893 1.113248 1.0500981
##  [130,] 1.247669 1.156706 1.132566 1.093959 1.1883610
##  [131,] 1.225629 1.144369 1.106545 1.109182 1.0519671
##  [132,] 1.239853 1.178881 1.122459 1.114005 1.0868301
##  [133,] 1.235153 1.165508 1.146673 1.125341 1.0627376
##  [134,] 1.232081 1.173351 1.136978 1.111218 1.0534892
##  [135,] 1.243848 1.156952 1.099550 1.091215 1.1062775
##  [136,] 1.228870 1.168281 1.123392 1.085093 1.1638020
##  [137,] 1.248043 1.164790 1.142043 1.112737 1.0742257
##  [138,] 1.238814 1.148092 1.121240 1.144053 1.0637252
##  [139,] 1.230884 1.159995 1.114151 1.114649 1.0378663
##  [140,] 1.237788 1.177020 1.124253 1.105338 1.0808762
##  [141,] 1.221305 1.170776 1.137585 1.116813 1.1195606
##  [142,] 1.252022 1.162161 1.090746 1.066509 1.0437308
##  [143,] 1.238531 1.170493 1.122707 1.110570 1.1344799
##  [144,] 1.219379 1.153300 1.137743 1.079380 1.0669792
##  [145,] 1.233715 1.158411 1.138041 1.116357 1.0377206
##  [146,] 1.213854 1.154595 1.133426 1.097300 1.0355699
##  [147,] 1.232325 1.166118 1.097062 1.133421 1.0734994
##  [148,] 1.243406 1.160196 1.108301 1.090440 1.1953363
##  [149,] 1.255632 1.155530 1.127324 1.113505 1.1742034
##  [150,] 1.232412 1.169686 1.134118 1.058784 1.1439936
##  [151,] 1.250839 1.154407 1.136923 1.101845 1.0483499
```

```
##  [152,] 1.257507 1.180505 1.113054 1.115728 1.2057095
##  [153,] 1.234831 1.155378 1.126694 1.123708 1.1111453
##  [154,] 1.223536 1.149795 1.120835 1.034106 1.0893974
##  [155,] 1.240642 1.179973 1.107630 1.127079 1.0967667
##  [156,] 1.235850 1.167464 1.121306 1.106720 1.1126579
##  [157,] 1.235108 1.159096 1.130944 1.073578 1.0651455
##  [158,] 1.227117 1.152266 1.099560 1.077818 1.0874572
##  [159,] 1.224260 1.153641 1.111890 1.106182 1.0881774
##  [160,] 1.248378 1.171730 1.104199 1.126641 1.1488701
##  [161,] 1.249667 1.177431 1.108628 1.082101 1.0088633
##  [162,] 1.225181 1.146011 1.119226 1.107961 1.0269465
##  [163,] 1.229596 1.165559 1.144396 1.102400 1.1051663
##  [164,] 1.234693 1.156590 1.115546 1.100402 1.1392404
##  [165,] 1.252211 1.169073 1.105075 1.124676 1.0796440
##  [166,] 1.237548 1.169818 1.086450 1.123615 1.0494700
##  [167,] 1.246901 1.183203 1.113164 1.063642 1.0796678
##  [168,] 1.244949 1.162940 1.101611 1.057251 1.0645061
##  [169,] 1.237366 1.170913 1.120773 1.071923 1.0977695
##  [170,] 1.230170 1.168193 1.150836 1.121817 1.1056117
##  [171,] 1.261080 1.153585 1.123607 1.105076 1.1885303
##  [172,] 1.238241 1.169725 1.117733 1.076230 1.0955193
##  [173,] 1.239531 1.172604 1.109999 1.129077 1.0883740
##  [174,] 1.247492 1.161020 1.141861 1.085897 1.0274693
##  [175,] 1.228602 1.178454 1.150877 1.121698 1.1033616
##  [176,] 1.230996 1.144266 1.132608 1.067192 1.0125135
##  [177,] 1.213748 1.162817 1.108266 1.068406 1.0357106
##  [178,] 1.240136 1.165622 1.139743 1.134505 1.0610390
##  [179,] 1.237185 1.150044 1.132477 1.070361 1.0757954
##  [180,] 1.222890 1.160157 1.106822 1.075885 1.1071553
##  [181,] 1.223552 1.170550 1.102560 1.108942 1.0529924
##  [182,] 1.243173 1.164514 1.111703 1.103005 1.0831340
##  [183,] 1.220111 1.165104 1.118863 1.090285 1.1608964
##  [184,] 1.224795 1.133659 1.118319 1.103785 1.1316917
##  [185,] 1.235292 1.159594 1.111897 1.092531 1.0281136
##  [186,] 1.241536 1.160242 1.125940 1.149458 1.1585472
##  [187,] 1.238741 1.158119 1.137365 1.080859 1.1495064
##  [188,] 1.242135 1.157594 1.098159 1.101080 1.0118531
##  [189,] 1.229966 1.168070 1.143430 1.096624 1.0223596
##  [190,] 1.218058 1.169345 1.118701 1.095270 1.1107854
##  [191,] 1.238781 1.159335 1.117156 1.119794 1.0837946
##  [192,] 1.230145 1.137402 1.106565 1.101708 1.0668012
##  [193,] 1.220270 1.187156 1.122835 1.134918 1.0551692
##  [194,] 1.238354 1.147371 1.125774 1.084532 1.0957159
##  [195,] 1.242217 1.182253 1.125540 1.075743 1.0589272
##  [196,] 1.217710 1.173118 1.119516 1.143906 1.1640358
##  [197,] 1.239664 1.176455 1.114462 1.077985 1.1121121
##  [198,] 1.251106 1.149200 1.120977 1.101334 1.1067184
##  [199,] 1.236709 1.167483 1.139976 1.037406 1.0571765
##  [200,] 1.228466 1.165761 1.132124 1.114870 1.1175649
##  [201,] 1.223345 1.146482 1.125260 1.118549 1.1571317
##  [202,] 1.237030 1.160467 1.115224 1.143214 1.0843673
##  [203,] 1.232156 1.170892 1.127993 1.101038 1.1124574
##  [204,] 1.242845 1.171342 1.118721 1.080093 1.1327544
##  [205,] 1.245613 1.170418 1.138029 1.110478 1.0832495
```

```
##  [206,] 1.235750 1.148086 1.117279 1.113630 1.0871174
##  [207,] 1.226957 1.154168 1.119911 1.092782 1.0891401
##  [208,] 1.219933 1.162929 1.122831 1.055585 1.1151832
##  [209,] 1.245111 1.171772 1.134506 1.107421 1.0080545
##  [210,] 1.226013 1.156424 1.149443 1.091910 1.1199298
##  [211,] 1.215958 1.179149 1.145420 1.112993 1.0555895
##  [212,] 1.229501 1.141240 1.131374 1.128418 1.0694217
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##  [983,] 1.219147 1.157383 1.125690 1.063377 1.0456113
##  [984,] 1.241053 1.169746 1.117422 1.137743 1.1198449
##  [985,] 1.252258 1.170481 1.122856 1.086746 1.0404376
##  [986,] 1.233303 1.162847 1.127053 1.087474 1.1221980
##  [987,] 1.231654 1.157110 1.155035 1.082306 1.0494838
##  [988,] 1.244928 1.182253 1.122169 1.159755 1.0600804
##  [989,] 1.241163 1.169861 1.138644 1.081331 1.1107241
##  [990,] 1.239003 1.142681 1.119416 1.089333 1.1522184
##  [991,] 1.234692 1.170423 1.101555 1.102742 1.0772947
##  [992,] 1.234435 1.158428 1.112198 1.091552 1.0739256
##  [993,] 1.243301 1.156631 1.109206 1.064766 1.0782336
##  [994,] 1.245609 1.140988 1.144677 1.096309 1.0368463
##  [995,] 1.221598 1.170894 1.134475 1.105785 1.1330615
##  [996,] 1.234011 1.178741 1.127726 1.088931 1.0556348
##  [997,] 1.246721 1.152403 1.127192 1.094146 1.1844759
##  [998,] 1.232346 1.171634 1.119783 1.114021 1.0672718
##  [999,] 1.240807 1.156180 1.130819 1.112842 1.0337487
## [1000,] 1.237345 1.154270 1.121803 1.062194 1.1266228
```
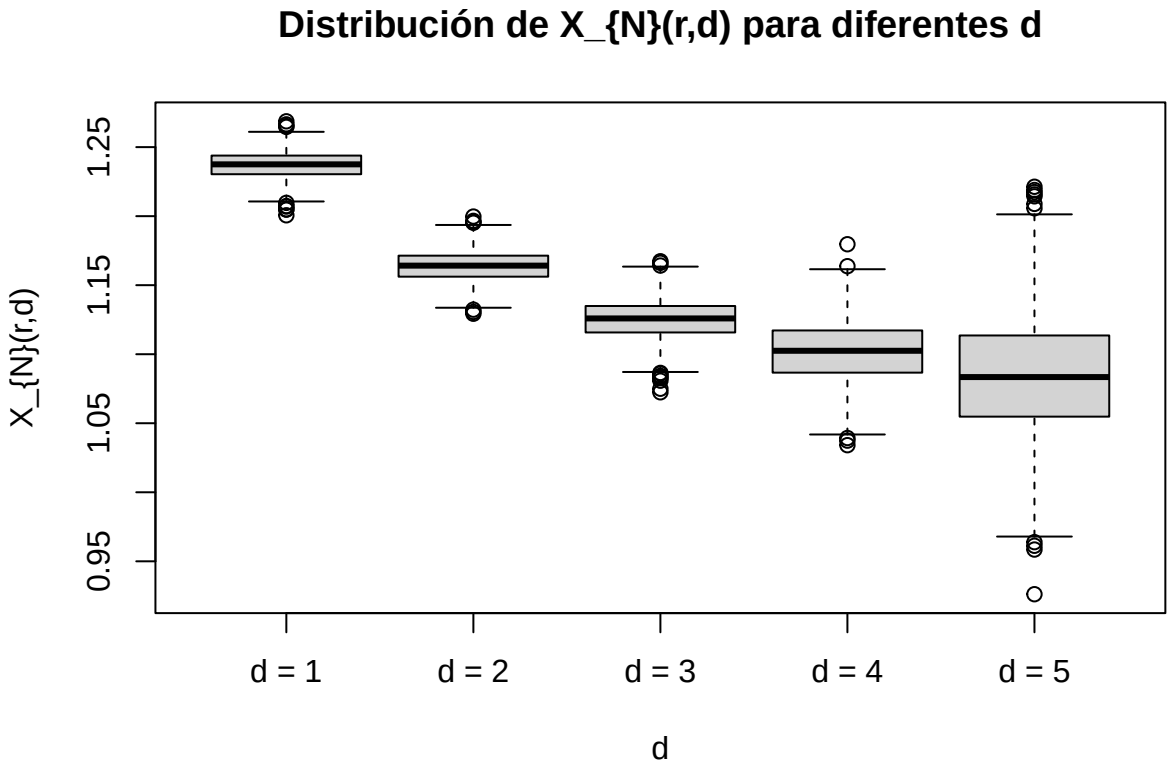

Veamos como se comporta $X_N(r, d)$ para este caso

```
# Resumen de los resultados
summary(X_N_results_ar)
```

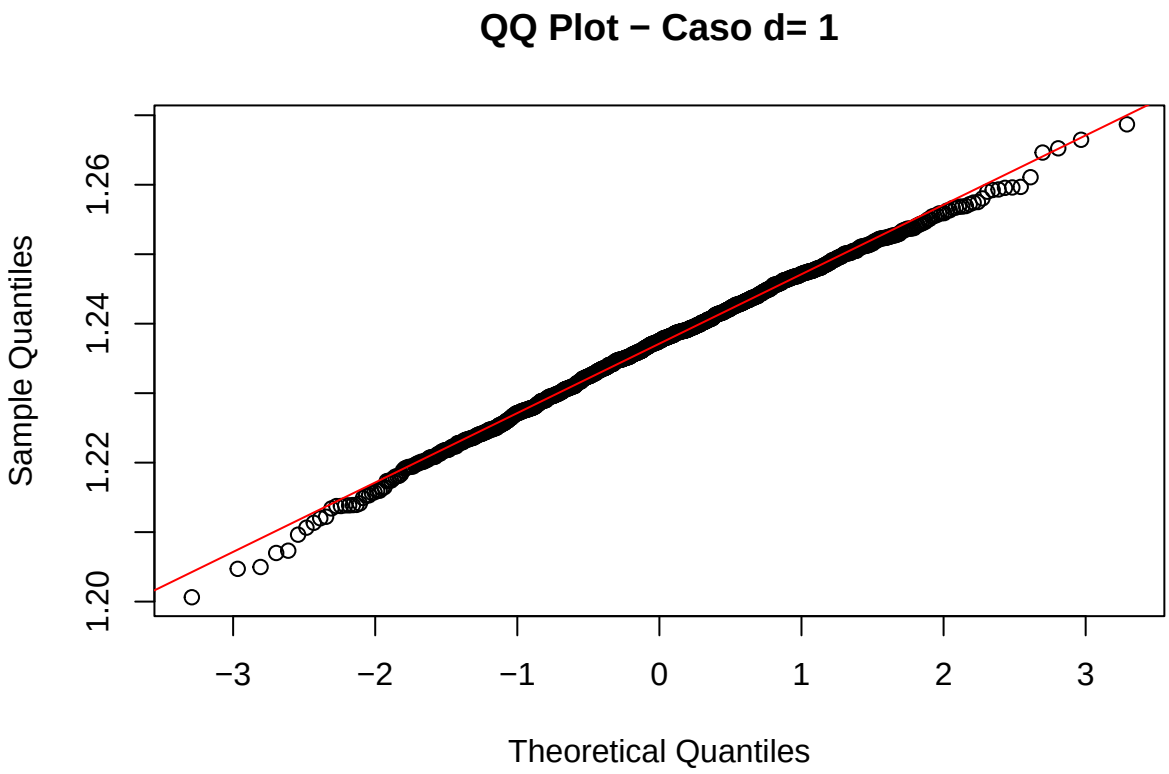
```
##      d = 1           d = 2           d = 3           d = 4
##  Min.   :1.201   Min.   :1.129   Min.   :1.072   Min.   :1.034
##  1st Qu.:1.230   1st Qu.:1.156   1st Qu.:1.116   1st Qu.:1.087
##  Median :1.238   Median :1.164   Median :1.126   Median :1.102
##  Mean   :1.237   Mean   :1.164   Mean   :1.125   Mean   :1.102
##  3rd Qu.:1.244   3rd Qu.:1.171   3rd Qu.:1.135   3rd Qu.:1.117
##  Max.   :1.269   Max.   :1.200   Max.   :1.167   Max.   :1.180
##      d = 5
```

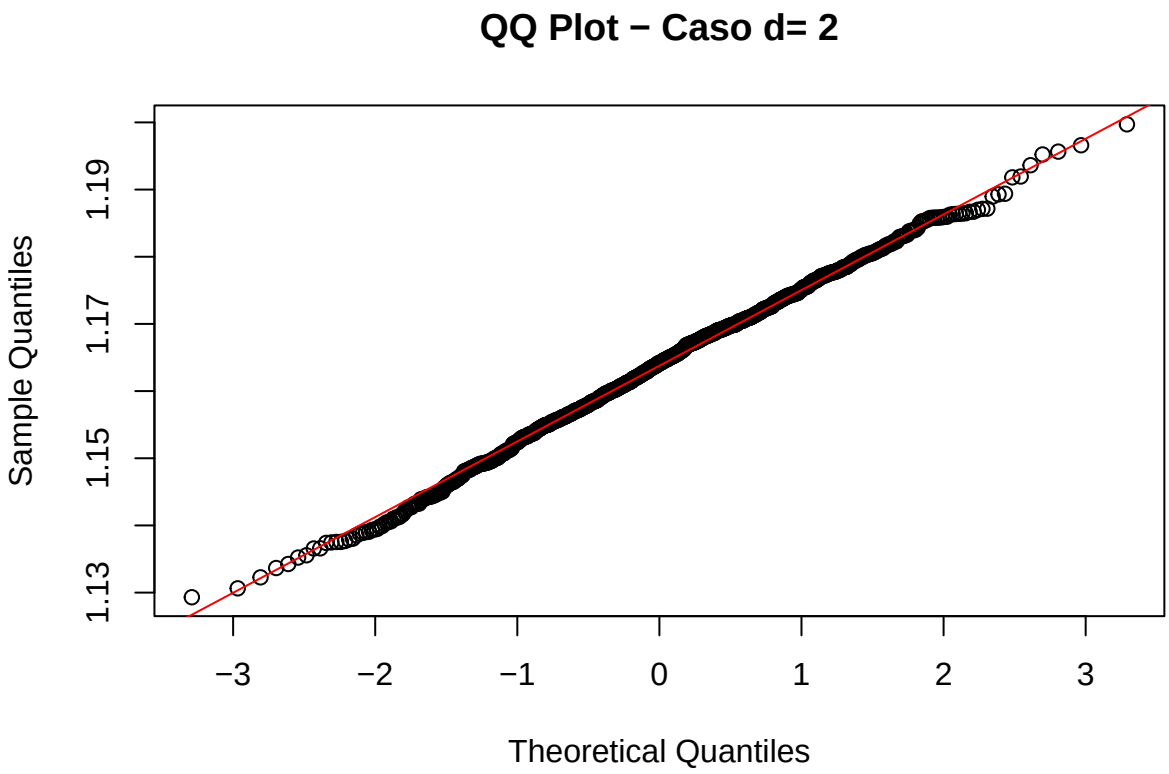
```
##  Min.   :0.9262
##  1st Qu.:1.0548
##  Median :1.0834
##  Mean   :1.0851
##  3rd Qu.:1.1136
##  Max.   :1.2213
```

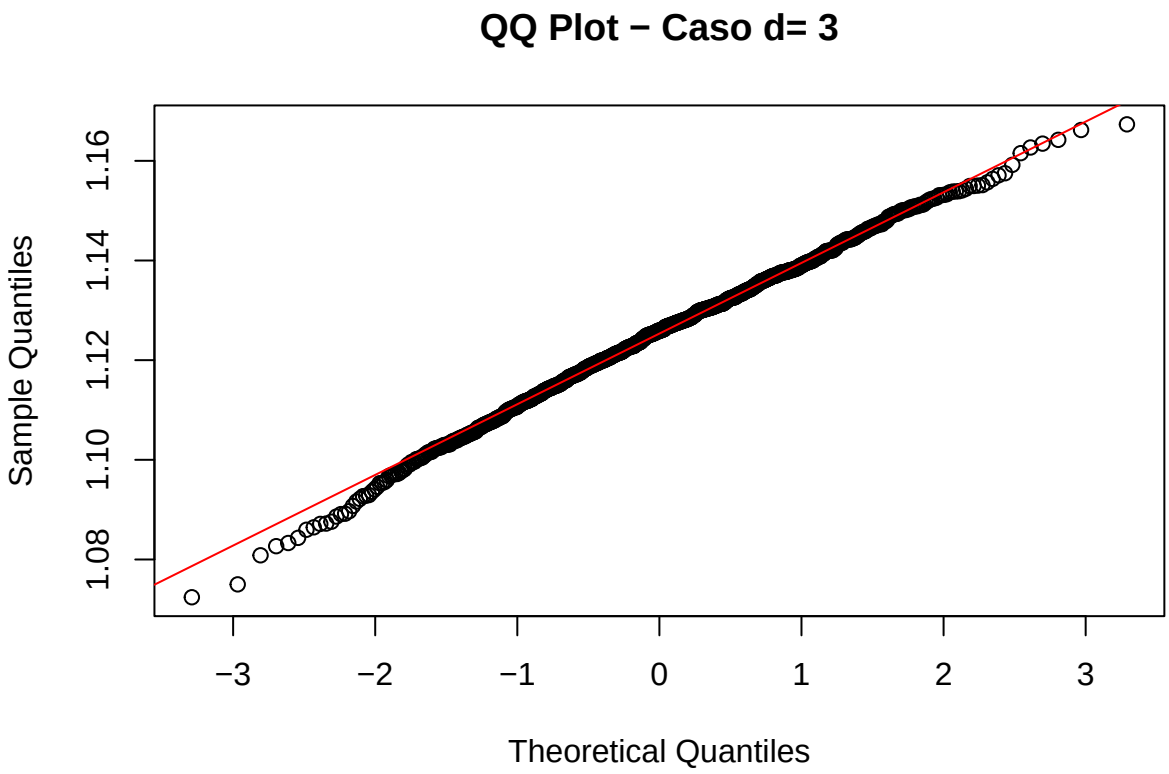
```r
# Graficar los resultados
boxplot(X_N_results_ar, main="Distribución de X_{N}(r,d) para diferentes d", ylab="X_{N}(r,d)", xlab="d
```

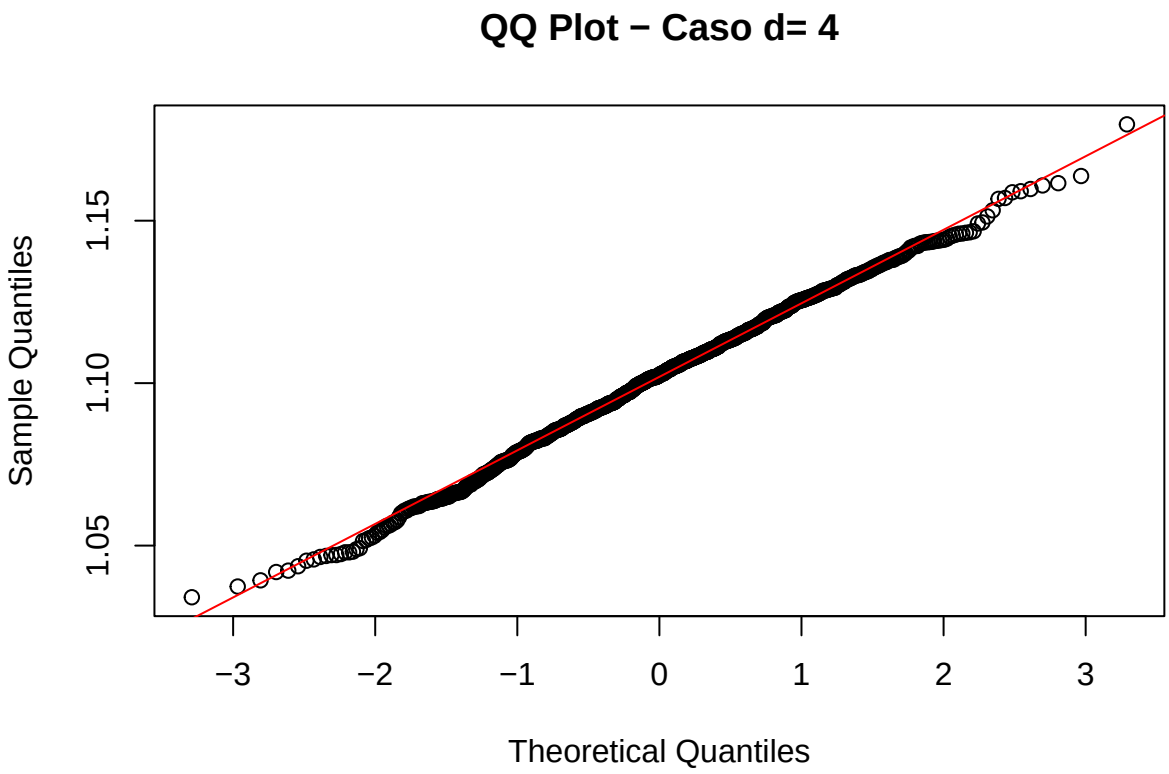


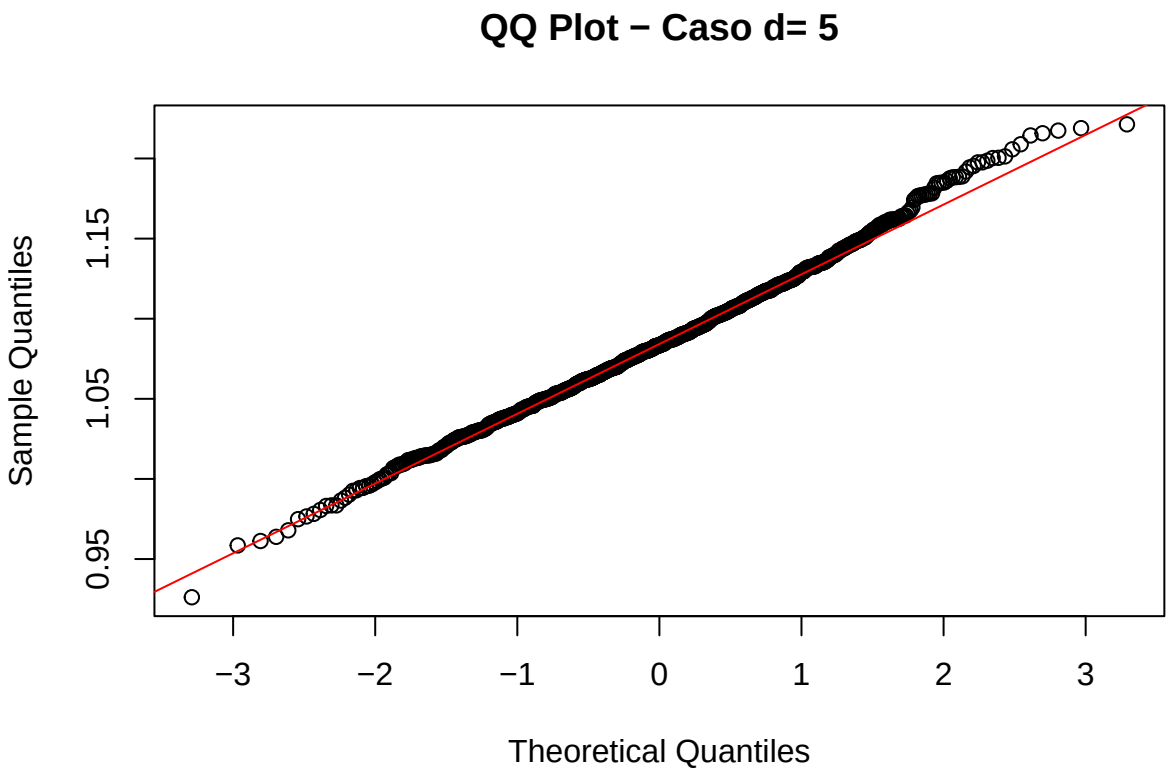

```r
# Crear el QQ plot

for (i in 1:ncol(X_N_results_ar)) {
  qqnorm(X_N_results_ar[, i], main = paste("QQ Plot - Caso d=", i))
  qqline(X_N_results_ar[, i], col = "red")
}
```


QQ Plot − Caso d= 1
Sample Quantiles
1.20
1.22
1.24
1.26
−3
−2
−1
0
1
2
3
Theoretical Quantiles


QQ Plot − Caso d= 2
Sample Quantiles
1.13
1.15
1.17
1.19
−3
−2
−1
0
1
2
3
Theoretical Quantiles


QQ Plot − Caso d= 3
Sample Quantiles
1.08
1.10
1.12
1.14
1.16
−3
−2
−1
0
1
2
3
Theoretical Quantiles


QQ Plot − Caso d= 4
Sample Quantiles
1.05
1.10
1.15
−3
−2
−1
0
1
2
3
Theoretical Quantiles



Se puedo observar en los gráficos que se mantiene y hasta se ve de manera mas clara la tendencia.

```
# Longitud de cada serie
N <- 1000

# Calcular sqrt(N)
sqrt_N <- sqrt(N)

# Calcular sqrt(N) * ln(X_{N}(r,d)) para cada serie y cada valor de d
sqrt_N_ln_X_N_ar <- sqrt_N * log(X_N_results_ar)

# Ver los resultados
head(sqrt_N_ln_X_N_ar)
```

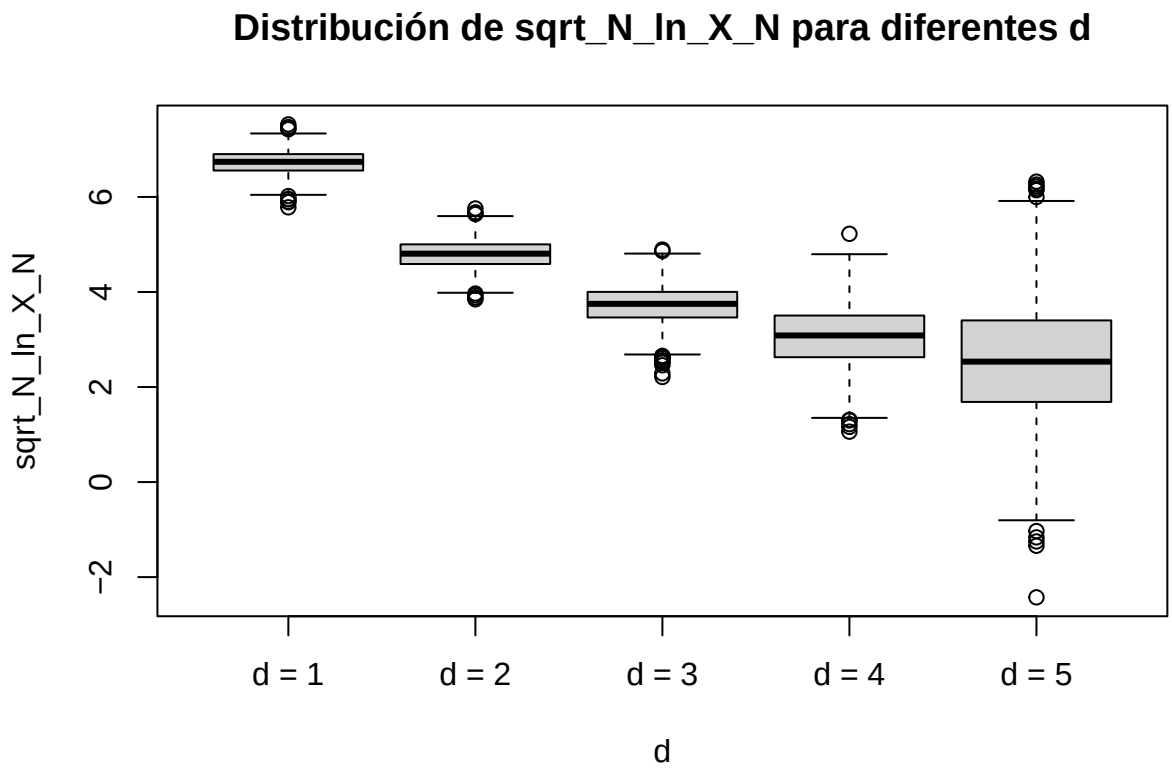
```
##         d = 1    d = 2    d = 3    d = 4    d = 5
## [1,] 6.474355 4.837946 4.395469 2.816168 2.919915
## [2,] 6.536680 4.674509 4.039552 1.993927 2.774539
## [3,] 6.570840 5.597032 3.396660 2.594679 1.197441
## [4,] 6.644166 4.857441 2.880144 3.595397 2.406744
## [5,] 7.007156 5.064557 3.600712 2.030113 1.554196
## [6,] 7.088098 4.460808 3.883607 2.163972 2.375028
```

y vemos como se comporta:

```r
# Resumen de los resultados
summary(sqrt_N_ln_X_N_ar)
```

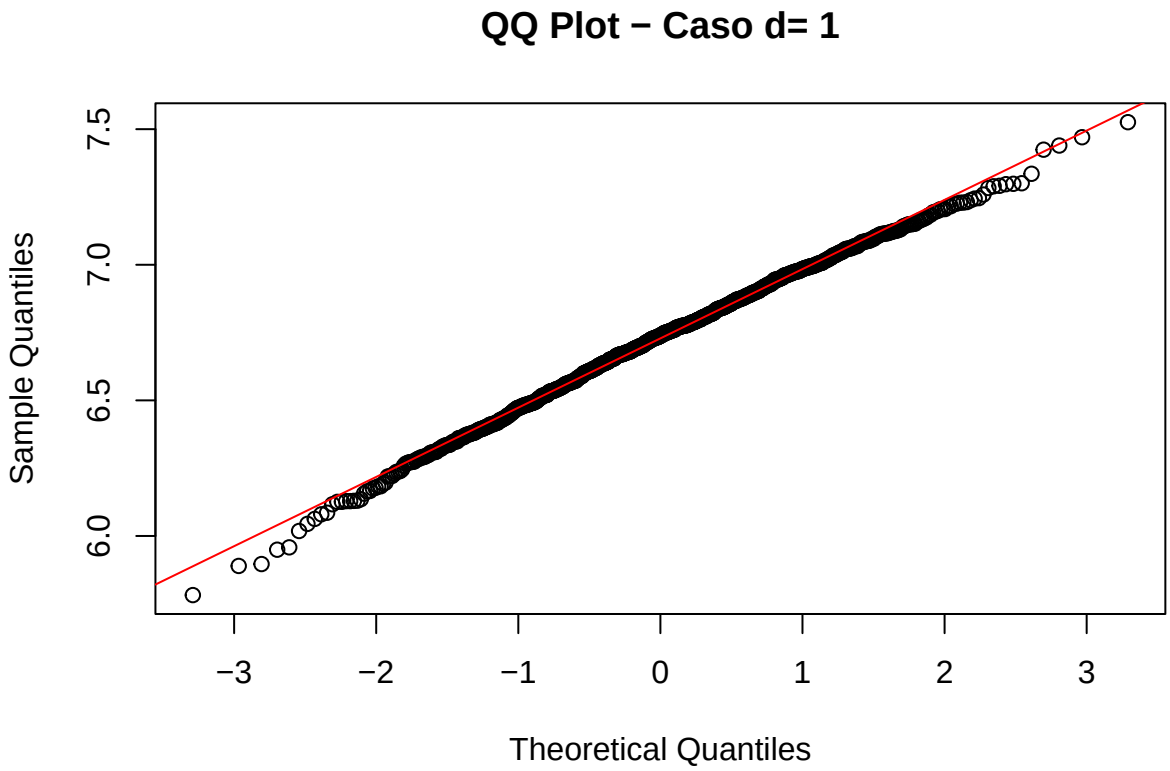
```
##      d = 1           d = 2           d = 3           d = 4
##  Min.   :5.782   Min.   :3.846   Min.   :2.211   Min.   :1.061
##  1st Qu.:6.556   1st Qu.:4.589   1st Qu.:3.464   1st Qu.:2.629
##  Median :6.739   Median :4.807   Median :3.751   Median :3.086
##  Mean   :6.726   Mean   :4.795   Mean   :3.726   Mean   :3.056
##  3rd Qu.:6.901   3rd Qu.:5.002   3rd Qu.:4.002   3rd Qu.:3.505
##  Max.   :7.526   Max.   :5.758   Max.   :4.892   Max.   :5.225
##      d = 5
##  Min.   :-2.426
##  1st Qu.: 1.688
##  Median : 2.534
##  Mean   : 2.557
##  3rd Qu.: 3.401
##  Max.   : 6.322
```

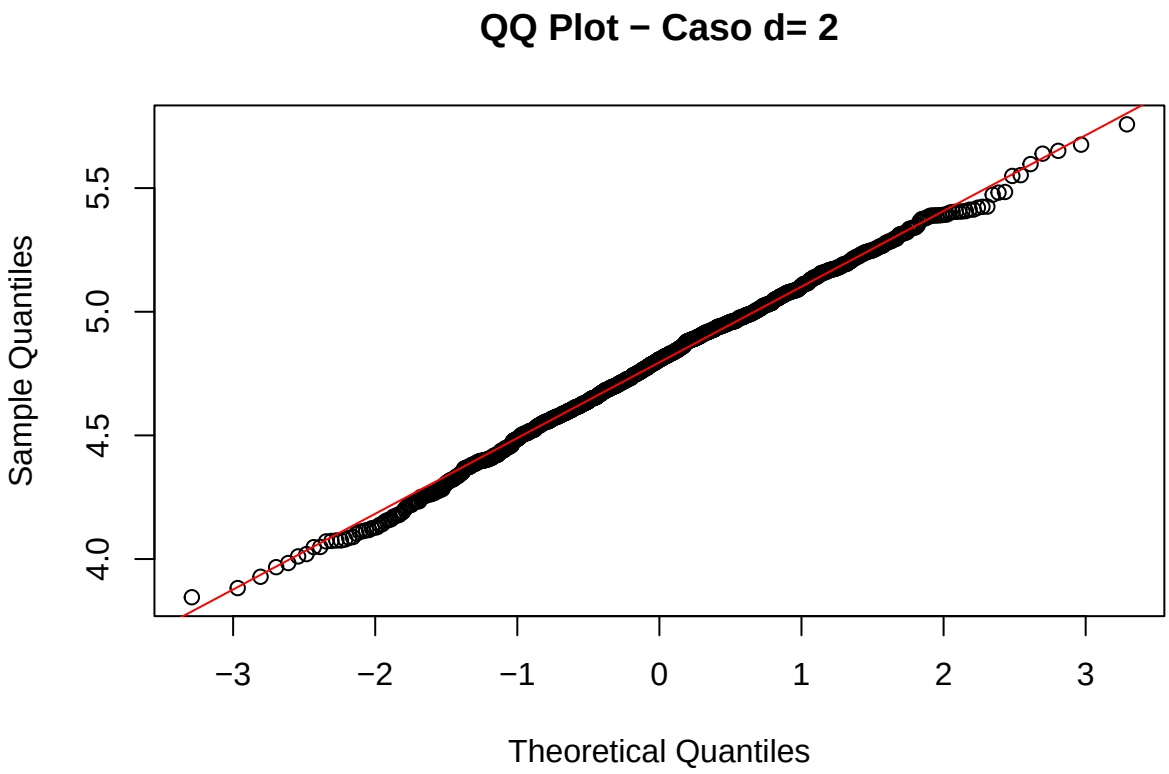
```r
# Graficar los resultados
boxplot(sqrt_N_ln_X_N_ar, main="Distribución de sqrt_N_ln_X_N para diferentes d", ylab="sqrt_N_ln_X_N",
```

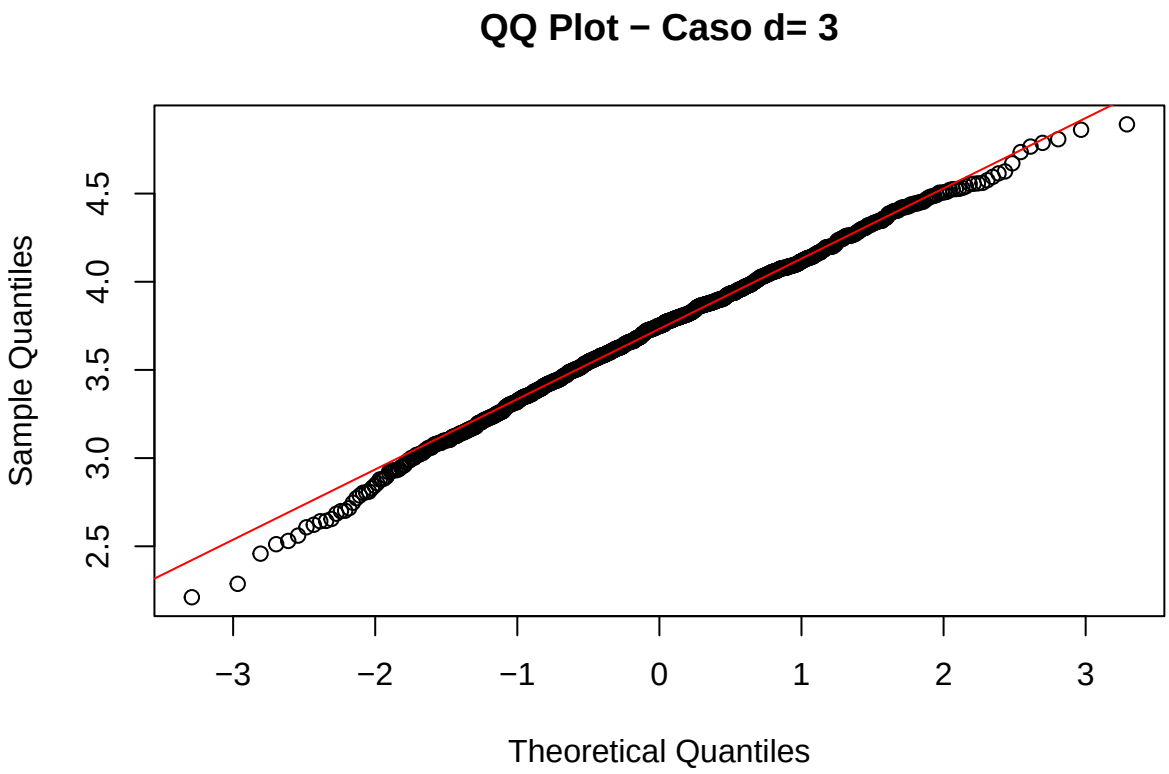


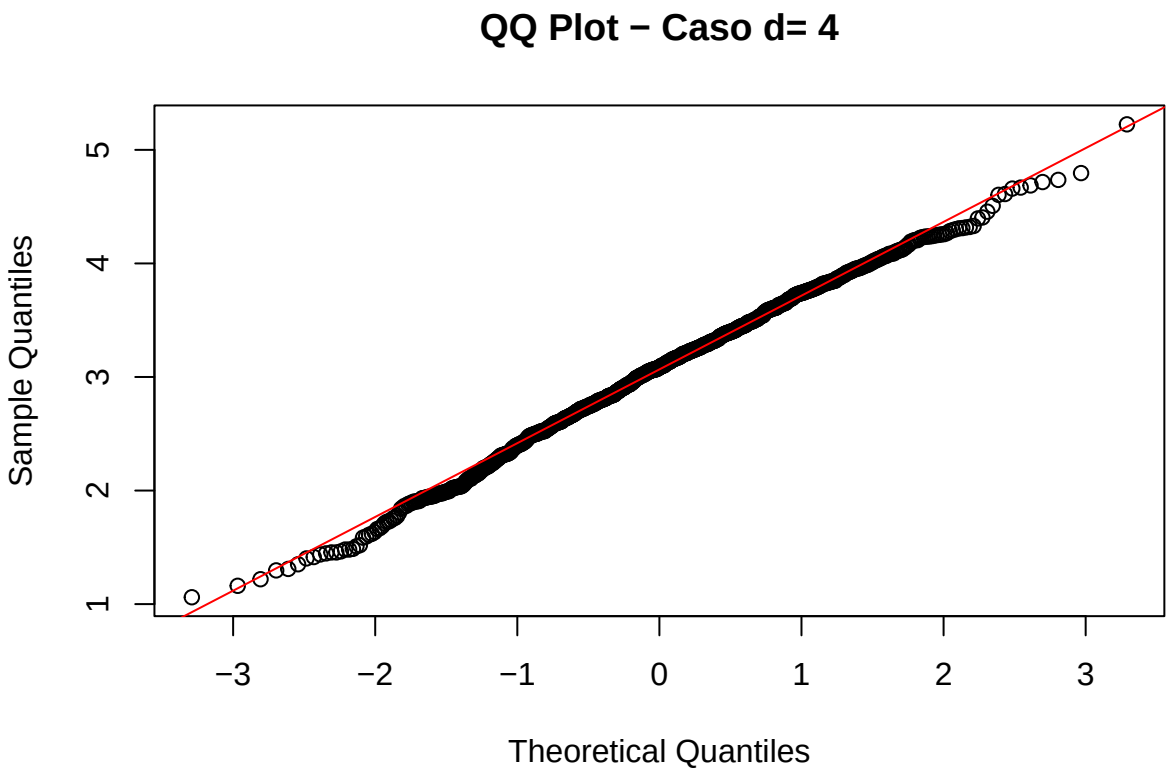

```r
# Crear el QQ plot

for (i in 1:ncol(sqrt_N_ln_X_N_ar)) {
```

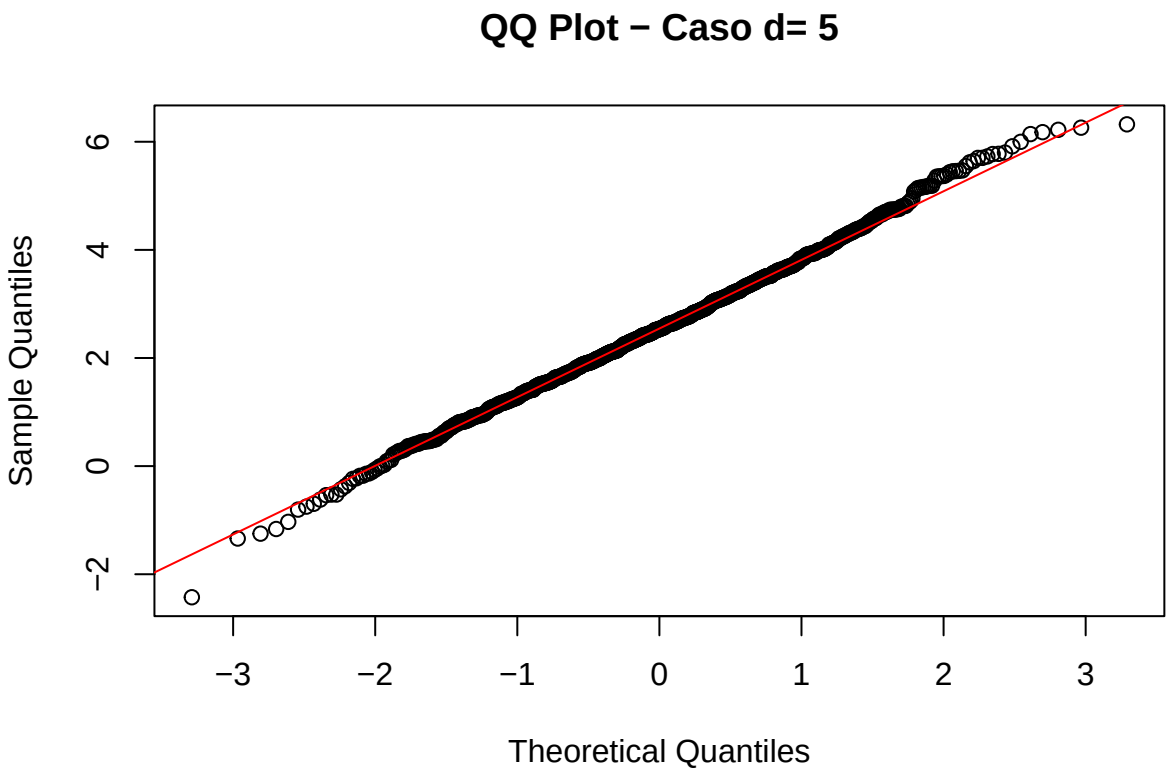
```
  qqnorm(sqrt_N_ln_X_N_ar[, i], main = paste("QQ Plot - Caso d=", i))
  qqline(sqrt_N_ln_X_N_ar[, i], col = "red")
}
```




QQ Plot − Caso d= 2
Sample Quantiles
4.0
4.5
5.0
5.5
−3
−2
−1
0
1
2
3
Theoretical Quantiles


QQ Plot − Caso d= 3
Sample Quantiles
2.5
3.0
3.5
4.0
4.5
−3
−2
−1
0
1
2
3
Theoretical Quantiles


QQ Plot − Caso d= 4
Sample Quantiles
Theoretical Quantiles
1
2
3
4
5
−3
−2
−1
0
1
2
3



Para el caso $AR(1)$ también se pudo observar que $\sqrt{N}ln(X_N(r,d))$ mantenía una tendencia a normalidad asintótica en menor medida, teniendo problemas mas tempranos con los valores de d en contratarte con el caso IID, también al aumentar de 100 a 500 y a 1000 series se pudo observar aun mas el aumento de esta tendencia. Durante las pruebas con 500 series para el caso d=5 algunas casos obtenían correlaciones integrales 0, por lo que valores indefinidos para $X_N(r,d)$, esto no se dio en la prueba con 1000 series $AR(1)$.

```
library(MASS)
```

test por aplicar:

```
# Función Shapiro-Wilk test
shapiro_test <- function(series) {
  # Shapiro-Wilk test
  shapiro.test(series)
}

# Aplicar el Shapiro-Wilk test a cada columna
shapiro_results <- apply(sqrt_N_ln_X_N_ar, 2, function(column) {
  # Quitar valores NA
  column <- na.omit(column)
  shapiro_test(column)
})

# p-values
shapiro_p_values <- sapply(shapiro_results, function(x) x$p.value)
```

```r
shapiro_p_values
```

```
##       d = 1       d = 2       d = 3       d = 4       d = 5
## 0.043424692 0.157500112 0.008344508 0.024657969 0.301237807
```

```r
# Función del Kolmogorov-Smirnov test
ks_test <- function(series) {
  # K-S test comparando la serie a una distribución normal
  ks.test(series, "pnorm", mean = mean(series), sd = sd(series))
}

# Aplicar el K-S test a cada columna
ks_results <- apply(sqrt_N_ln_X_N_ar, 2, function(column) {
  # Remove NA values if they exist
  column <- na.omit(column)
  ks_test(column)
})

# p-values
ks_p_values <- sapply(ks_results, function(x) x$p.value)


ks_p_values
```

```
##     d = 1     d = 2     d = 3     d = 4     d = 5
## 0.4708963 0.2835113 0.2613561 0.4574208 0.8759034
```