Segmented regression of age-standardised mortality rates - Scotland all-ages Q1 1990 to Q2 2018

# Introduction

To undertake segmented regression (one and two-break models) for Scotland, all-ages, age-standardised mortality rates(ASMR). Employs full data range available (Q1 1990-Q2 2018). Quarterly annual ASMR employ the 2013 European Standard Popualtion, and were provided by National Records for Scotland.

Contents:

* Load packages, load data, tidy data labels, and convert dates to identifiable quarters
* Plot observed data
* Generate, view and plot linear model
* Run Davies test to identify and test signifcance of single break point
* Generate and view one breakpoint segmented model
* Extract breakpoints and confidence intervals
* Plot one breakpoint model
* Generate two break segmented model
* Use AIC and BIC to compare fit of one and two break models
* Plot two breakpoint model
* Error bar plot as alternative approach to presenting breakpoint and confidence intervals

# Summary of findings

This analysis provides a means of assessing whether there has been a significant change in the trend of age-standardised mortality rates for men and women in Scotland.

Both one and two-breakpoint models identify Jul 2012-Jun 2013 for men, and Jul 2013-Jun 2014 for women, as the most significant breakpoint. The two breakpoint model additionally identifies Jan-Dec 1990 as a breakpoint for both sexes. The two breakpoint model is a better fit.

A test of statistical significance (Davies test) is provided for the one-break model, and 95% confidence intervals for both models.

# Analytical steps, code, and results:

## Load packages

rm(list = ls())  
#install.packages("pacman")  
pacman::p\_load(  
 tidyverse,  
 segmented,  
 plotly,  
 dplyr,  
 readr,  
 ggplot2,  
 broom,  
 tidyr  
 )

## Load data and assign to object “data”

data <- read.csv("Data/QuarterlyASMR1990\_2018.csv")  
data

## period sex allageesprate allagestderr allagelcli allageucli  
## 1 19901 F 1500.4002 7.788046 1485.1356 1515.6648  
## 2 19901 M 2287.7414 13.950236 2260.3990 2315.0839  
## 3 19901 P 1796.2713 6.854256 1782.8370 1809.7056  
## 4 19902 F 1499.6691 7.774313 1484.4314 1514.9067  
## 5 19902 M 2271.7785 13.869048 2244.5951 2298.9618  
## 6 19902 P 1790.5826 6.830757 1777.1943 1803.9709  
## 7 19903 F 1485.5072 7.730787 1470.3549 1500.6596  
## 8 19903 M 2252.7301 13.786253 2225.7090 2279.7512  
## 9 19903 P 1774.0388 6.788831 1760.7327 1787.3450  
## 10 19904 F 1386.2319 7.495202 1371.5413 1400.9225  
## 11 19904 M 2114.4333 13.357631 2088.2523 2140.6142  
## 12 19904 P 1662.7854 6.585258 1649.8783 1675.6925  
## 13 19911 F 1370.9937 7.438755 1356.4137 1385.5736  
## 14 19911 M 2090.4911 13.295297 2064.4323 2116.5499  
## 15 19911 P 1642.7102 6.534532 1629.9025 1655.5179  
## 16 19912 F 1361.9806 7.398476 1347.4796 1376.4817  
## 17 19912 M 2081.5897 13.253416 2055.6131 2107.5664  
## 18 19912 P 1632.2207 6.497969 1619.4847 1644.9567  
## 19 19913 F 1356.4288 7.367201 1341.9891 1370.8685  
## 20 19913 M 2074.8453 13.169875 2049.0323 2100.6582  
## 21 19913 P 1627.9710 6.471122 1615.2876 1640.6544  
## 22 19914 F 1359.8080 7.358394 1345.3855 1374.2304  
## 23 19914 M 2077.0059 13.121307 2051.2881 2102.7237  
## 24 19914 P 1632.2590 6.462073 1619.5933 1644.9246  
## 25 19921 F 1358.5900 7.346454 1344.1910 1372.9891  
## 26 19921 M 2084.4016 13.078631 2058.7674 2110.0357  
## 27 19921 P 1633.0666 6.447639 1620.4292 1645.7040  
## 28 19922 F 1349.7919 7.313476 1335.4575 1364.1263  
## 29 19922 M 2067.2606 12.963311 2041.8525 2092.6686  
## 30 19922 P 1622.1381 6.413711 1609.5673 1634.7090  
## 31 19923 F 1354.0802 7.313358 1339.7460 1368.4144  
## 32 19923 M 2076.6938 12.953957 2051.3041 2102.0836  
## 33 19923 P 1626.1669 6.408399 1613.6064 1638.7273  
## 34 19924 F 1341.5783 7.270973 1327.3272 1355.8294  
## 35 19924 M 2077.7699 12.931945 2052.4233 2103.1165  
## 36 19924 P 1615.5167 6.377835 1603.0162 1628.0173  
## 37 19931 F 1345.6595 7.265753 1331.4187 1359.9004  
## 38 19931 M 2071.4982 12.845335 2046.3213 2096.6751  
## 39 19931 P 1619.6928 6.373524 1607.2007 1632.1849  
## 40 19932 F 1360.0188 7.291139 1345.7282 1374.3095  
## 41 19932 M 2096.5156 12.873813 2071.2830 2121.7483  
## 42 19932 P 1637.6889 6.395933 1625.1529 1650.2249  
## 43 19933 F 1364.8308 7.291811 1350.5388 1379.1227  
## 44 19933 M 2097.2932 12.840109 2072.1266 2122.4598  
## 45 19933 P 1642.1300 6.395382 1629.5950 1654.6649  
## 46 19934 F 1418.0949 7.405196 1403.5807 1432.6091  
## 47 19934 M 2155.2243 12.955677 2129.8312 2180.6174  
## 48 19934 P 1697.7914 6.481042 1685.0886 1710.4943  
## 49 19941 F 1405.8620 7.375433 1391.4062 1420.3179  
## 50 19941 M 2139.6174 12.896941 2114.3394 2164.8954  
## 51 19941 P 1682.9862 6.451101 1670.3421 1695.6304  
## 52 19942 F 1379.5644 7.310106 1365.2365 1393.8922  
## 53 19942 M 2106.8907 12.788730 2081.8248 2131.9566  
## 54 19942 P 1654.0631 6.396042 1641.5269 1666.5994  
## 55 19943 F 1375.9499 7.300813 1361.6403 1390.2595  
## 56 19943 M 2077.2160 12.675264 2052.3725 2102.0595  
## 57 19943 P 1641.2919 6.367119 1628.8123 1653.7714  
## 58 19944 F 1300.4151 7.119427 1286.4610 1314.3692  
## 59 19944 M 1974.0242 12.349373 1949.8195 1998.2290  
## 60 19944 P 1557.3200 6.213255 1545.1420 1569.4980  
## 61 19951 F 1297.1418 7.099794 1283.2262 1311.0574  
## 62 19951 M 1966.1240 12.276911 1942.0613 1990.1868  
## 63 19951 P 1553.4352 6.194014 1541.2949 1565.5754  
## 64 19952 F 1306.8696 7.109859 1292.9343 1320.8049  
## 65 19952 M 1955.0497 12.192508 1931.1524 1978.9470  
## 66 19952 P 1556.5743 6.184906 1544.4519 1568.6967  
## 67 19953 F 1290.6128 7.052143 1276.7906 1304.4350  
## 68 19953 M 1952.0999 12.138832 1928.3077 1975.8920  
## 69 19953 P 1546.0238 6.151473 1533.9669 1558.0807  
## 70 19954 F 1318.1378 7.102690 1304.2165 1332.0590  
## 71 19954 M 1978.8214 12.166546 1954.9750 2002.6678  
## 72 19954 P 1573.4918 6.184847 1561.3695 1585.6141  
## 73 19961 F 1331.4086 7.122295 1317.4489 1345.3683  
## 74 19961 M 1999.1481 12.177492 1975.2802 2023.0159  
## 75 19961 P 1588.7226 6.197821 1576.5749 1600.8704  
## 76 19962 F 1315.3620 7.074731 1301.4956 1329.2285  
## 77 19962 M 1999.1219 12.148724 1975.3104 2022.9334  
## 78 19962 P 1578.0485 6.169588 1565.9561 1590.1409  
## 79 19963 F 1313.5481 7.063900 1299.7028 1327.3933  
## 80 19963 M 2008.3256 12.134335 1984.5423 2032.1089  
## 81 19963 P 1579.7444 6.162493 1567.6659 1591.8229  
## 82 19964 F 1298.2784 7.020290 1284.5186 1312.0381  
## 83 19964 M 1987.5467 12.035604 1963.9569 2011.1364  
## 84 19964 P 1564.1079 6.126281 1552.1004 1576.1154  
## 85 19971 F 1298.3450 7.009413 1284.6066 1312.0835  
## 86 19971 M 1955.7523 11.925889 1932.3776 1979.1271  
## 87 19971 P 1554.2160 6.100560 1542.2589 1566.1731  
## 88 19972 F 1300.6993 7.010299 1286.9591 1314.4395  
## 89 19972 M 1946.9756 11.863816 1923.7226 1970.2287  
## 90 19972 P 1552.8521 6.089923 1540.9159 1564.7884  
## 91 19973 F 1295.1969 6.987684 1281.5011 1308.8928  
## 92 19973 M 1917.5341 11.750372 1894.5033 1940.5648  
## 93 19973 P 1540.2292 6.059776 1528.3521 1552.1064  
## 94 19974 F 1281.7783 6.945698 1268.1647 1295.3919  
## 95 19974 M 1903.7481 11.685846 1880.8439 1926.6524  
## 96 19974 P 1527.0203 6.028472 1515.2045 1538.8361  
## 97 19981 F 1257.4773 6.885696 1243.9813 1270.9733  
## 98 19981 M 1879.1620 11.589256 1856.4470 1901.8769  
## 99 19981 P 1501.0436 5.975541 1489.3316 1512.7557  
## 100 19982 F 1258.5509 6.875069 1245.0757 1272.0260  
## 101 19982 M 1873.6902 11.541221 1851.0694 1896.3110  
## 102 19982 P 1500.7500 5.964808 1489.0590 1512.4410  
## 103 19983 F 1263.7122 6.880343 1250.2267 1277.1977  
## 104 19983 M 1880.6585 11.513039 1858.0930 1903.2241  
## 105 19983 P 1507.7719 5.967981 1496.0747 1519.4691  
## 106 19984 F 1269.1613 6.886387 1255.6640 1282.6586  
## 107 19984 M 1866.5687 11.434141 1844.1578 1888.9796  
## 108 19984 P 1507.6018 5.959356 1495.9215 1519.2822  
## 109 19991 F 1311.4337 6.969265 1297.7740 1325.0935  
## 110 19991 M 1933.5279 11.583785 1910.8237 1956.2321  
## 111 19991 P 1558.8875 6.036276 1547.0564 1570.7186  
## 112 19992 F 1293.5518 6.925504 1279.9778 1307.1257  
## 113 19992 M 1898.8561 11.456244 1876.4018 1921.3103  
## 114 19992 P 1535.8232 5.991470 1524.0799 1547.5665  
## 115 19993 F 1284.3456 6.899407 1270.8228 1297.8685  
## 116 19993 M 1875.1125 11.365642 1852.8359 1897.3892  
## 117 19993 P 1520.5648 5.957314 1508.8884 1532.2411  
## 118 19994 F 1287.8906 6.902113 1274.3624 1301.4187  
## 119 19994 M 1889.8916 11.367018 1867.6122 1912.1709  
## 120 19994 P 1527.2067 5.959353 1515.5264 1538.8870  
## 121 20001 F 1271.4174 6.859829 1257.9722 1284.8627  
## 122 20001 M 1858.1596 11.233187 1836.1426 1880.1767  
## 123 20001 P 1507.1653 5.916518 1495.5690 1518.7617  
## 124 20002 F 1266.3159 6.840217 1252.9091 1279.7227  
## 125 20002 M 1852.9947 11.175306 1831.0911 1874.8983  
## 126 20002 P 1501.4978 5.895040 1489.9435 1513.0521  
## 127 20003 F 1255.7367 6.805842 1242.3973 1269.0762  
## 128 20003 M 1824.3019 11.040080 1802.6634 1845.9405  
## 129 20003 P 1486.2839 5.857386 1474.8034 1497.7644  
## 130 20004 F 1218.2774 6.706034 1205.1336 1231.4213  
## 131 20004 M 1776.4543 10.882474 1755.1246 1797.7839  
## 132 20004 P 1443.1422 5.769266 1431.8345 1454.4500  
## 133 20011 F 1184.0636 6.615371 1171.0975 1197.0297  
## 134 20011 M 1733.1274 10.731062 1712.0945 1754.1603  
## 135 20011 P 1403.6884 5.686797 1392.5422 1414.8345  
## 136 20012 F 1183.1437 6.597024 1170.2136 1196.0739  
## 137 20012 M 1725.3525 10.664236 1704.4506 1746.2544  
## 138 20012 P 1402.3477 5.671522 1391.2315 1413.4639  
## 139 20013 F 1184.4611 6.587975 1171.5486 1197.3735  
## 140 20013 M 1740.1062 10.681163 1719.1711 1761.0413  
## 141 20013 P 1407.4148 5.667992 1396.3056 1418.5241  
## 142 20014 F 1196.2046 6.605672 1183.2574 1209.1517  
## 143 20014 M 1735.9769 10.628250 1715.1455 1756.8082  
## 144 20014 P 1415.7088 5.672315 1404.5911 1426.8265  
## 145 20021 F 1184.5618 6.568416 1171.6877 1197.4359  
## 146 20021 M 1711.8563 10.537969 1691.2019 1732.5107  
## 147 20021 P 1399.8546 5.635460 1388.8091 1410.9001  
## 148 20022 F 1187.8689 6.573506 1174.9848 1200.7530  
## 149 20022 M 1720.0179 10.541374 1699.3568 1740.6790  
## 150 20022 P 1404.0595 5.636263 1393.0125 1415.1066  
## 151 20023 F 1193.4426 6.581729 1180.5424 1206.3428  
## 152 20023 M 1719.2442 10.513627 1698.6375 1739.8509  
## 153 20023 P 1408.4341 5.638048 1397.3835 1419.4846  
## 154 20024 F 1201.8232 6.594412 1188.8981 1214.7482  
## 155 20024 M 1741.0947 10.554434 1720.4080 1761.7814  
## 156 20024 P 1422.3076 5.656660 1411.2206 1433.3947  
## 157 20031 F 1208.8964 6.607315 1195.9461 1221.8467  
## 158 20031 M 1750.0442 10.564422 1729.3379 1770.7504  
## 159 20031 P 1430.0467 5.665556 1418.9423 1441.1512  
## 160 20032 F 1206.3813 6.596375 1193.4524 1219.3102  
## 161 20032 M 1755.8439 10.571636 1735.1235 1776.5643  
## 162 20032 P 1429.9267 5.661350 1418.8304 1441.0229  
## 163 20033 F 1200.5565 6.581697 1187.6564 1213.4567  
## 164 20033 M 1751.5067 10.556345 1730.8162 1772.1971  
## 165 20033 P 1422.9234 5.646099 1411.8571 1433.9898  
## 166 20034 F 1212.9987 6.611954 1200.0392 1225.9581  
## 167 20034 M 1751.8965 10.552199 1731.2142 1772.5788  
## 168 20034 P 1428.6046 5.651143 1417.5283 1439.6808  
## 169 20041 F 1208.5862 6.595837 1195.6584 1221.5141  
## 170 20041 M 1734.9259 10.498776 1714.3483 1755.5035  
## 171 20041 P 1419.4438 5.630223 1408.4086 1430.4790  
## 172 20042 F 1198.9439 6.571156 1186.0645 1211.8234  
## 173 20042 M 1704.1133 10.397005 1683.7352 1724.4914  
## 174 20042 P 1403.1378 5.597599 1392.1665 1414.1091  
## 175 20043 F 1193.3301 6.555050 1180.4822 1206.1780  
## 176 20043 M 1684.8586 10.322965 1664.6255 1705.0916  
## 177 20043 P 1393.0870 5.574287 1382.1614 1404.0126  
## 178 20044 F 1157.2493 6.456802 1144.5940 1169.9046  
## 179 20044 M 1645.9699 10.184245 1626.0088 1665.9310  
## 180 20044 P 1357.6417 5.502950 1346.8559 1368.4275  
## 181 20051 F 1158.8288 6.450615 1146.1856 1171.4720  
## 182 20051 M 1648.6899 10.156366 1628.7835 1668.5964  
## 183 20051 P 1360.1868 5.496818 1349.4130 1370.9605  
## 184 20052 F 1161.1501 6.446570 1148.5148 1173.7853  
## 185 20052 M 1643.5641 10.108514 1623.7514 1663.3768  
## 186 20052 P 1359.2380 5.482706 1348.4919 1369.9841  
## 187 20053 F 1153.4810 6.415625 1140.9064 1166.0556  
## 188 20053 M 1623.2456 10.008639 1603.6286 1642.8625  
## 189 20053 P 1348.1141 5.450263 1337.4316 1358.7967  
## 190 20054 F 1139.0776 6.377244 1126.5782 1151.5770  
## 191 20054 M 1600.9223 9.916047 1581.4869 1620.3578  
## 192 20054 P 1329.4413 5.406915 1318.8438 1340.0389  
## 193 20061 F 1115.7765 6.318862 1103.3916 1128.1615  
## 194 20061 M 1578.2453 9.818446 1559.0012 1597.4895  
## 195 20061 P 1305.5004 5.354286 1295.0060 1315.9948  
## 196 20062 F 1119.0732 6.318414 1106.6891 1131.4573  
## 197 20062 M 1574.8997 9.777824 1555.7351 1594.0642  
## 198 20062 P 1306.7298 5.346061 1296.2515 1317.2081  
## 199 20063 F 1116.6279 6.303830 1104.2723 1128.9834  
## 200 20063 M 1560.9849 9.716700 1541.9401 1580.0296  
## 201 20063 P 1299.2885 5.321546 1288.8582 1309.7187  
## 202 20064 F 1112.5995 6.281683 1100.2874 1124.9116  
## 203 20064 M 1549.6572 9.656710 1530.7300 1568.5843  
## 204 20064 P 1293.8656 5.301384 1283.4749 1304.2564  
## 205 20071 F 1137.7195 6.329171 1125.3144 1150.1247  
## 206 20071 M 1560.8716 9.671372 1541.9157 1579.8275  
## 207 20071 P 1314.4557 5.328291 1304.0123 1324.8992  
## 208 20072 F 1114.5282 6.264688 1102.2494 1126.8070  
## 209 20072 M 1556.7835 9.644463 1537.8803 1575.6866  
## 210 20072 P 1297.6640 5.290560 1287.2945 1308.0335  
## 211 20073 F 1105.6755 6.237829 1093.4493 1117.9016  
## 212 20073 M 1556.3819 9.623885 1537.5191 1575.2447  
## 213 20073 P 1292.5286 5.275820 1282.1880 1302.8692  
## 214 20074 F 1114.6443 6.255267 1102.3840 1126.9047  
## 215 20074 M 1568.3305 9.641170 1549.4338 1587.2272  
## 216 20074 P 1302.5357 5.287879 1292.1714 1312.8999  
## 217 20081 F 1092.5233 6.198271 1080.3746 1104.6719  
## 218 20081 M 1544.6720 9.559575 1525.9352 1563.4088  
## 219 20081 P 1280.2620 5.243761 1269.9842 1290.5398  
## 220 20082 F 1100.2690 6.214012 1088.0895 1112.4484  
## 221 20082 M 1529.1838 9.504347 1510.5553 1547.8123  
## 222 20082 P 1279.4314 5.236623 1269.1676 1289.6952  
## 223 20083 F 1103.1500 6.217915 1090.9629 1115.3371  
## 224 20083 M 1515.1621 9.453055 1496.6341 1533.6901  
## 225 20083 P 1275.6985 5.224315 1265.4588 1285.9381  
## 226 20084 F 1111.2940 6.228590 1099.0859 1123.5020  
## 227 20084 M 1517.6631 9.445356 1499.1502 1536.1760  
## 228 20084 P 1282.0033 5.228414 1271.7556 1292.2510  
## 229 20091 F 1102.7386 6.199430 1090.5877 1114.8895  
## 230 20091 M 1508.1118 9.401085 1489.6856 1526.5379  
## 231 20091 P 1272.5258 5.203051 1262.3278 1282.7237  
## 232 20092 F 1083.6370 6.145608 1071.5917 1095.6824  
## 233 20092 M 1483.4906 9.307778 1465.2473 1501.7338  
## 234 20092 P 1251.7180 5.157937 1241.6085 1261.8276  
## 235 20093 F 1072.0579 6.106374 1060.0894 1084.0264  
## 236 20093 M 1478.2422 9.260140 1460.0924 1496.3921  
## 237 20093 P 1242.8494 5.131446 1232.7918 1252.9071  
## 238 20094 F 1056.1941 6.060743 1044.3151 1068.0732  
## 239 20094 M 1444.0035 9.115947 1426.1362 1461.8707  
## 240 20094 P 1219.9563 5.076813 1210.0057 1229.9068  
## 241 20101 F 1047.4957 6.028074 1035.6807 1059.3108  
## 242 20101 M 1435.0434 9.043649 1417.3179 1452.7690  
## 243 20101 P 1211.1109 5.045867 1201.2210 1221.0008  
## 244 20102 F 1044.9811 6.007067 1033.2072 1056.7549  
## 245 20102 M 1426.8991 8.969416 1409.3191 1444.4792  
## 246 20102 P 1205.8461 5.018330 1196.0102 1215.6820  
## 247 20103 F 1045.5545 5.991628 1033.8109 1057.2981  
## 248 20103 M 1413.6407 8.875425 1396.2449 1431.0365  
## 249 20103 P 1201.0305 4.989845 1191.2504 1210.8106  
## 250 20104 F 1036.2268 5.949484 1024.5658 1047.8877  
## 251 20104 M 1422.4929 8.847120 1405.1525 1439.8332  
## 252 20104 P 1198.3176 4.965877 1188.5845 1208.0508  
## 253 20111 F 1025.3450 5.908553 1013.7642 1036.9258  
## 254 20111 M 1408.4984 8.749362 1391.3496 1425.6471  
## 255 20111 P 1186.9200 4.928196 1177.2607 1196.5793  
## 256 20112 F 1022.5737 5.886143 1011.0369 1034.1106  
## 257 20112 M 1402.1113 8.675408 1385.1075 1419.1151  
## 258 20112 P 1183.5068 4.904842 1173.8933 1193.1203  
## 259 20113 F 1013.3507 5.850393 1001.8839 1024.8175  
## 260 20113 M 1406.9538 8.639061 1390.0212 1423.8863  
## 261 20113 P 1179.6857 4.882611 1170.1158 1189.2556  
## 262 20114 F 1006.8648 5.818177 995.4611 1018.2684  
## 263 20114 M 1377.9585 8.516405 1361.2663 1394.6506  
## 264 20114 P 1164.5485 4.838957 1155.0642 1174.0329  
## 265 20121 F 1001.1900 5.785233 989.8510 1012.5291  
## 266 20121 M 1357.0982 8.419730 1340.5956 1373.6009  
## 267 20121 P 1153.3400 4.802258 1143.9276 1162.7524  
## 268 20122 F 1013.4333 5.802119 1002.0611 1024.8055  
## 269 20122 M 1366.8424 8.409204 1350.3603 1383.3244  
## 270 20122 P 1165.1323 4.810264 1155.7042 1174.5605  
## 271 20123 F 1019.3835 5.805566 1008.0046 1030.7624  
## 272 20123 M 1353.0283 8.336878 1336.6880 1369.3686  
## 273 20123 P 1163.5416 4.795000 1154.1434 1172.9398  
## 274 20124 F 1034.0236 5.833506 1022.5900 1045.4573  
## 275 20124 M 1356.8340 8.313661 1340.5393 1373.1288  
## 276 20124 P 1174.1447 4.803423 1164.7300 1183.5595  
## 277 20131 F 1047.2367 5.854494 1035.7619 1058.7115  
## 278 20131 M 1375.5554 8.335746 1359.2173 1391.8934  
## 279 20131 P 1189.2227 4.818895 1179.7777 1198.6678  
## 280 20132 F 1042.9404 5.839561 1031.4949 1054.3860  
## 281 20132 M 1369.2158 8.286537 1352.9742 1385.4574  
## 282 20132 P 1184.6234 4.802627 1175.2103 1194.0366  
## 283 20133 F 1026.8583 5.791984 1015.5060 1038.2106  
## 284 20133 M 1354.2704 8.218164 1338.1628 1370.3780  
## 285 20133 P 1168.6580 4.763858 1159.3208 1177.9952  
## 286 20134 F 1004.2657 5.727811 993.0392 1015.4923  
## 287 20134 M 1344.8635 8.161921 1328.8661 1360.8609  
## 288 20134 P 1150.9365 4.721254 1141.6829 1160.1902  
## 289 20141 F 976.4886 5.651298 965.4121 987.5651  
## 290 20141 M 1312.9867 8.045527 1297.2175 1328.7560  
## 291 20141 P 1120.7865 4.655869 1111.6610 1129.9120  
## 292 20142 F 952.9044 5.577405 941.9727 963.8361  
## 293 20142 M 1290.4061 7.955956 1274.8124 1305.9998  
## 294 20142 P 1096.7635 4.598415 1087.7506 1105.7764  
## 295 20143 F 960.3534 5.583404 949.4099 971.2969  
## 296 20143 M 1300.2353 7.946754 1284.6596 1315.8109  
## 297 20143 P 1105.9584 4.602598 1096.9373 1114.9795  
## 298 20144 F 972.3775 5.600251 961.4010 983.3540  
## 299 20144 M 1310.9825 7.943615 1295.4130 1326.5520  
## 300 20144 P 1118.4652 4.613532 1109.4227 1127.5077  
## 301 20151 F 1021.1782 5.704504 1009.9973 1032.3590  
## 302 20151 M 1362.1791 8.052756 1346.3957 1377.9625  
## 303 20151 P 1169.7788 4.693668 1160.5792 1178.9784  
## 304 20152 F 1038.9698 5.738346 1027.7226 1050.2169  
## 305 20152 M 1381.3043 8.076673 1365.4740 1397.1345  
## 306 20152 P 1188.8987 4.718133 1179.6512 1198.1463  
## 307 20153 F 1038.4427 5.731829 1027.2083 1049.6770  
## 308 20153 M 1382.2152 8.057059 1366.4234 1398.0071  
## 309 20153 P 1188.8931 4.711221 1179.6591 1198.1271  
## 310 20154 F 1024.3997 5.691830 1013.2438 1035.5557  
## 311 20154 M 1371.2413 8.005924 1355.5497 1386.9329  
## 312 20154 P 1176.1470 4.681691 1166.9709 1185.3231  
## 313 20161 F 996.8737 5.629051 985.8408 1007.9067  
## 314 20161 M 1341.7542 7.902014 1326.2662 1357.2421  
## 315 20161 P 1148.2907 4.629096 1139.2176 1157.3637  
## 316 20162 F 984.0351 5.592026 973.0748 994.9955  
## 317 20162 M 1325.4592 7.832422 1310.1076 1340.8107  
## 318 20162 P 1133.6794 4.594019 1124.6751 1142.6837  
## 319 20163 F 981.1454 5.574846 970.2187 992.0721  
## 320 20163 M 1322.5719 7.797007 1307.2897 1337.8540  
## 321 20163 P 1131.1683 4.578997 1122.1935 1140.1431  
## 322 20164 F 988.3911 5.587239 977.4401 999.3421  
## 323 20164 M 1326.3755 7.779044 1311.1286 1341.6224  
## 324 20164 P 1136.3389 4.577712 1127.3666 1145.3112  
## 325 20171 F 993.3512 5.583058 982.4084 1004.2940  
## 326 20171 M 1324.8449 7.752792 1309.6495 1340.0404  
## 327 20171 P 1137.7484 4.566362 1128.7984 1146.6985  
## 328 20172 F 996.1639 5.577996 985.2311 1007.0968  
## 329 20172 M 1324.8598 7.728819 1309.7113 1340.0083  
## 330 20172 P 1139.8314 4.559409 1130.8949 1148.7678  
## 331 20173 F 992.5277 5.563545 981.6231 1003.4322  
## 332 20173 M 1318.6081 7.689910 1303.5359 1333.6803  
## 333 20173 P 1134.6061 4.541377 1125.7050 1143.5072  
## 334 20174 F 997.5625 5.562902 986.6592 1008.4658  
## 335 20174 M 1329.0268 7.695007 1313.9445 1344.1090  
## 336 20174 P 1143.0130 4.547210 1134.1005 1151.9256  
## 337 20181 F 1033.7135 5.641288 1022.6566 1044.7705  
## 338 20181 M 1364.0444 7.758272 1348.8382 1379.2506  
## 339 20181 P 1179.3760 4.600157 1170.3597 1188.3923  
## 340 20182 F 1024.6352 5.615129 1013.6295 1035.6409  
## 341 20182 M 1354.7984 7.713807 1339.6793 1369.9175  
## 342 20182 P 1170.6852 4.578881 1161.7106 1179.6598  
## under75esprate under75stderr under75lcli under75ucli totdeaths  
## 1 589.2652 4.994766 579.4755 599.0550 34163  
## 2 1010.2307 7.222368 996.0749 1024.3866 31360  
## 3 777.9763 4.242511 769.6609 786.2916 65523  
## 4 590.4938 4.998890 580.6960 600.2917 34216  
## 5 1002.3490 7.183408 988.2696 1016.4285 31247  
## 6 775.1230 4.230873 766.8305 783.4155 65463  
## 7 588.0220 4.985508 578.2504 597.7936 33997  
## 8 993.3030 7.136414 979.3157 1007.2904 31069  
## 9 770.2041 4.212956 761.9467 778.4615 65066  
## 10 563.1330 4.878688 553.5707 572.6952 31910  
## 11 956.6519 6.995124 942.9415 970.3623 29617  
## 12 740.2788 4.128148 732.1876 748.3700 61527  
## 13 555.4841 4.840917 545.9959 564.9723 31664  
## 14 941.4973 6.929547 927.9154 955.0793 29208  
## 15 729.6407 4.094823 721.6148 737.6666 60872  
## 16 549.5080 4.813271 540.0740 558.9420 31586  
## 17 934.8245 6.897882 921.3047 948.3444 29072  
## 18 723.1296 4.073493 715.1456 731.1137 60658  
## 19 547.9595 4.802851 538.5459 557.3731 31568  
## 20 932.6121 6.877034 919.1331 946.0911 29167  
## 21 721.5066 4.064258 713.5406 729.4725 60735  
## 22 546.4500 4.791896 537.0579 555.8421 31729  
## 23 940.0322 6.890620 926.5266 953.5378 29312  
## 24 724.0880 4.066052 716.1185 732.0574 61041  
## 25 548.9494 4.799107 539.5431 558.3556 31778  
## 26 937.5931 6.867713 924.1324 951.0538 29496  
## 27 724.3674 4.061136 716.4076 732.3273 61274  
## 28 548.5090 4.790205 539.1202 557.8978 31655  
## 29 932.6521 6.832138 919.2611 946.0431 29396  
## 30 722.6616 4.050106 714.7234 730.5998 61051  
## 31 547.3855 4.781513 538.0137 556.7572 31813  
## 32 928.6915 6.802658 915.3583 942.0247 29448  
## 33 720.3504 4.037711 712.4365 728.2643 61261  
## 34 540.4431 4.744338 531.1442 549.7420 31603  
## 35 914.3240 6.737445 901.1186 927.5294 29334  
## 36 710.3634 4.004000 702.5156 718.2112 60937  
## 37 536.1959 4.719480 526.9458 545.4461 31768  
## 38 916.5478 6.733429 903.3502 929.7453 29417  
## 39 709.1012 3.994526 701.2719 716.9305 61185  
## 40 536.1983 4.713564 526.9597 545.4369 32138  
## 41 920.0684 6.734040 906.8697 933.2671 29737  
## 42 710.6491 3.992774 702.8233 718.4749 61875  
## 43 533.8050 4.695402 524.6020 543.0080 32297  
## 44 921.9072 6.731083 908.7143 935.1002 29768  
## 45 710.2473 3.986380 702.4340 718.0606 62065  
## 46 546.7425 4.745409 537.4415 556.0435 33545  
## 47 938.9586 6.780140 925.6695 952.2476 30504  
## 48 725.0369 4.021333 717.1551 732.9188 64049  
## 49 544.1989 4.731515 534.9251 553.4727 33276  
## 50 930.3834 6.737965 917.1770 943.5898 30261  
## 51 719.9878 4.003204 712.1415 727.8341 63537  
## 52 538.9417 4.703137 529.7235 548.1598 32702  
## 53 920.8877 6.692814 907.7698 934.0057 29864  
## 54 712.8230 3.978042 705.0260 720.6200 62566  
## 55 544.8969 4.725287 535.6354 554.1585 32658  
## 56 910.3242 6.642916 897.3041 923.3443 29578  
## 57 711.3439 3.968729 703.5652 719.1226 62236  
## 58 525.4818 4.644118 516.3794 534.5843 30912  
## 59 881.8196 6.532589 869.0158 894.6235 28416  
## 60 687.9739 3.902628 680.3248 695.6231 59328  
## 61 523.2478 4.633353 514.1664 532.3292 30917  
## 62 881.1147 6.527763 868.3202 893.9091 28428  
## 63 686.7475 3.898988 679.1055 694.3895 59345  
## 64 523.4807 4.639458 514.3874 532.5741 31233  
## 65 875.1320 6.507997 862.3763 887.8876 28363  
## 66 684.3379 3.895148 676.7034 691.9724 59596  
## 67 511.1164 4.590943 502.1181 520.1146 30931  
## 68 873.6062 6.506189 860.8541 886.3584 28386  
## 69 677.1221 3.878861 669.5196 684.7247 59317  
## 70 514.4259 4.609486 505.3913 523.4605 31709  
## 71 879.9233 6.532862 867.1189 892.7278 28791  
## 72 681.8686 3.895197 674.2340 689.5032 60500  
## 73 517.6255 4.627715 508.5552 526.6958 32095  
## 74 881.6302 6.542013 868.8079 894.4526 29100  
## 75 684.2530 3.904114 676.6009 691.9050 61195  
## 76 510.4151 4.601614 501.3959 519.4342 31759  
## 77 878.6407 6.532753 865.8365 891.4449 29131  
## 78 678.9675 3.891870 671.3394 686.5956 60890  
## 79 511.1630 4.608769 502.1298 520.1962 31779  
## 80 880.7067 6.541798 867.8847 893.5286 29333  
## 81 680.2047 3.897010 672.5665 687.8428 61112  
## 82 508.4486 4.600125 499.4324 517.4649 31445  
## 83 875.8383 6.522176 863.0549 888.6218 29207  
## 84 677.0324 3.889732 669.4085 684.6563 60652  
## 85 504.6133 4.587306 495.6222 513.6045 31474  
## 86 860.2718 6.465683 847.5991 872.9446 28808  
## 87 667.8576 3.865403 660.2814 675.4338 60282  
## 88 508.3427 4.604062 499.3188 517.3667 31586  
## 89 856.9735 6.454813 844.3221 869.6249 28782  
## 90 668.4764 3.867953 660.8952 676.0576 60368  
## 91 502.0798 4.577683 493.1076 511.0521 31471  
## 92 842.3538 6.399558 829.8107 854.8970 28448  
## 93 658.5949 3.840353 651.0678 666.1220 59919  
## 94 492.7550 4.533636 483.8691 501.6410 31189  
## 95 838.0275 6.381487 825.5198 850.5352 28304  
## 96 651.5480 3.818795 644.0631 659.0328 59493  
## 97 489.0798 4.515675 480.2290 497.9305 30633  
## 98 827.0981 6.338013 814.6756 839.5206 28002  
## 99 644.5553 3.797298 637.1126 651.9980 58635  
## 100 482.1169 4.482966 473.3303 490.9035 30682  
## 101 820.3801 6.304241 808.0238 832.7364 27975  
## 102 638.0027 3.775625 630.6025 645.4029 58657  
## 103 484.9340 4.492963 476.1278 493.7402 30868  
## 104 830.2018 6.334550 817.7861 842.6175 28223  
## 105 644.3068 3.791419 636.8756 651.7380 59091  
## 106 486.9379 4.502758 478.1125 495.7634 31032  
## 107 825.3447 6.311880 812.9734 837.7159 28131  
## 108 643.2843 3.787412 635.8610 650.7076 59163  
## 109 489.6006 4.514622 480.7519 498.4493 32123  
## 110 839.0978 6.357872 826.6364 851.5593 29023  
## 111 651.2656 3.809118 643.7997 658.7314 61146  
## 112 484.9108 4.492562 476.1053 493.7162 31715  
## 113 828.5612 6.314949 816.1839 840.9385 28665  
## 114 643.9690 3.786777 636.5469 651.3910 60380  
## 115 480.0671 4.470474 471.3050 488.8293 31533  
## 116 811.0340 6.244163 798.7954 823.2725 28359  
## 117 633.3500 3.754396 625.9914 640.7086 59892  
## 118 480.7927 4.472905 472.0258 489.5596 31676  
## 119 807.9581 6.229267 795.7487 820.1675 28605  
## 120 632.3993 3.750415 625.0485 639.7501 60281  
## 121 478.3569 4.459741 469.6158 487.0980 31328  
## 122 808.6444 6.224862 796.4437 820.8452 28394  
## 123 631.7333 3.746152 624.3909 639.0758 59722  
## 124 475.7089 4.446394 466.9939 484.4238 31298  
## 125 808.5067 6.219674 796.3161 820.6972 28410  
## 126 630.2215 3.739702 622.8917 637.5513 59708  
## 127 472.6178 4.430513 463.9340 481.3016 31129  
## 128 801.0334 6.188688 788.9036 813.1633 28194  
## 129 625.1810 3.723721 617.8825 632.4795 59323  
## 130 459.3657 4.367026 450.8064 467.9251 30287  
## 131 777.7768 6.095518 765.8296 789.7240 27511  
## 132 607.1837 3.668248 599.9939 614.3735 57798  
## 133 451.1472 4.328097 442.6642 459.6303 29517  
## 134 754.3660 5.998906 742.6081 766.1238 26919  
## 135 591.9820 3.620698 584.8854 599.0786 56436  
## 136 447.5070 4.309101 439.0611 455.9528 29576  
## 137 752.9899 5.987553 741.2543 764.7255 26958  
## 138 589.4957 3.610822 582.4184 596.5729 56534  
## 139 445.0650 4.297341 436.6422 453.4878 29675  
## 140 756.2504 5.992174 744.5057 767.9950 27180  
## 141 589.8164 3.609125 582.7425 596.8903 56855  
## 142 446.4347 4.300546 438.0056 454.8638 30058  
## 143 760.5730 6.000248 748.8125 772.3334 27324  
## 144 592.6795 3.613865 585.5964 599.7627 57382  
## 145 438.4166 4.258760 430.0694 446.7638 29829  
## 146 751.1106 5.954461 739.4398 762.7813 27057  
## 147 584.1621 3.584247 577.1370 591.1873 56886  
## 148 442.4425 4.274762 434.0640 450.8211 29945  
## 149 750.8407 5.946423 739.1857 762.4957 27227  
## 150 586.1246 3.586476 579.0951 593.1541 57172  
## 151 443.3342 4.273054 434.9590 451.7094 30129  
## 152 750.4955 5.936105 738.8608 762.1303 27357  
## 153 586.5837 3.583120 579.5608 593.6066 57486  
## 154 442.7198 4.267573 434.3553 451.0842 30359  
## 155 755.4483 5.946411 743.7934 767.1033 27743  
## 156 588.8459 3.586655 581.8160 595.8757 58102  
## 157 444.7862 4.273707 436.4097 453.1626 30548  
## 158 755.0115 5.938792 743.3715 766.6516 27922  
## 159 589.5947 3.585263 582.5676 596.6219 58470  
## 160 438.0293 4.237392 429.7240 446.3346 30496  
## 161 749.0528 5.906629 737.4758 760.6298 28001  
## 162 583.4768 3.563036 576.4932 590.4603 58497  
## 163 434.5252 4.217594 426.2587 442.7916 30342  
## 164 737.8092 5.856278 726.3309 749.2875 27889  
## 165 576.3377 3.538101 569.4030 583.2723 58231  
## 166 439.6473 4.238102 431.3406 447.9539 30639  
## 167 725.6516 5.800302 714.2830 737.0202 27830  
## 168 573.3545 3.524647 566.4462 580.2628 58469  
## 169 436.8744 4.220404 428.6024 445.1464 30540  
## 170 717.8273 5.761932 706.5339 729.1207 27598  
## 171 568.3680 3.505737 561.4968 575.2393 58138  
## 172 433.2532 4.199951 425.0213 441.4851 30332  
## 173 706.7633 5.710058 695.5716 717.9551 27306  
## 174 561.3468 3.480621 554.5248 568.1689 57638  
## 175 432.1083 4.190559 423.8948 440.3218 30238  
## 176 704.6651 5.692170 693.5084 715.8217 27165  
## 177 559.8198 3.471462 553.0158 566.6239 57403  
## 178 416.0478 4.109071 407.9940 424.1015 29412  
## 179 693.3930 5.637153 682.3441 704.4418 26775  
## 180 546.1915 3.425243 539.4780 552.9050 56187  
## 181 413.4030 4.093959 405.3789 421.4272 29529  
## 182 688.1600 5.606515 677.1712 699.1488 26942  
## 183 542.4025 3.409562 535.7198 549.0853 56471  
## 184 416.2280 4.104097 408.1840 424.2721 29643  
## 185 683.4319 5.579261 672.4966 694.3673 26928  
## 186 541.7704 3.403741 535.0990 548.4417 56571  
## 187 411.6632 4.078908 403.6685 419.6578 29525  
## 188 672.0888 5.524374 661.2610 682.9166 26786  
## 189 534.1733 3.376382 527.5556 540.7910 56311  
## 190 411.8587 4.077103 403.8676 419.8498 29225  
## 191 663.8950 5.485960 653.1426 674.6475 26522  
## 192 530.3758 3.361695 523.7869 536.9647 55747  
## 193 411.6743 4.073711 403.6898 419.6588 28680  
## 194 660.9544 5.464765 650.2435 671.6653 26326  
## 195 529.1313 3.354388 522.5567 535.7059 55006  
## 196 409.4537 4.061030 401.4941 417.4133 28862  
## 197 658.3212 5.444328 647.6503 668.9921 26411  
## 198 526.9596 3.344213 520.4050 533.5143 55273  
## 199 408.6935 4.054510 400.7467 416.6404 28869  
## 200 650.3689 5.401277 639.7824 660.9554 26264  
## 201 523.0168 3.327698 516.4945 529.5391 55133  
## 202 404.7294 4.031077 396.8285 412.6303 28842  
## 203 647.8839 5.378777 637.3415 658.4263 26251  
## 204 519.9535 3.312916 513.4601 526.4468 55093  
## 205 405.5770 4.031278 397.6757 413.4783 29561  
## 206 646.3213 5.363925 635.8080 656.8346 26476  
## 207 519.7034 3.307836 513.2201 526.1868 56037  
## 208 400.9551 4.002695 393.1098 408.8004 29010  
## 209 644.9473 5.348094 634.4650 655.4296 26487  
## 210 516.4973 3.291777 510.0455 522.9492 55497  
## 211 400.0638 3.992936 392.2377 407.8900 28819  
## 212 643.9942 5.335836 633.5360 654.4525 26621  
## 213 515.5982 3.284256 509.1610 522.0353 55440  
## 214 401.0305 3.992650 393.2049 408.8561 29091  
## 215 644.9325 5.330366 634.4850 655.3800 26895  
## 216 516.6640 3.282951 510.2295 523.0986 55986  
## 217 393.1224 3.947431 385.3855 400.8594 28564  
## 218 637.3240 5.288936 626.9577 647.6904 26675  
## 219 508.9234 3.252945 502.5477 515.2992 55239  
## 220 391.8108 3.935313 384.0975 399.5240 28804  
## 221 631.3588 5.252427 621.0640 641.6535 26528  
## 222 505.6298 3.236979 499.2854 511.9743 55332  
## 223 389.6794 3.917943 382.0003 397.3586 28942  
## 224 629.5425 5.233863 619.2841 639.8009 26402  
## 225 503.6620 3.224604 497.3417 509.9822 55344  
## 226 387.7681 3.902244 380.1197 395.4165 29196  
## 227 626.7597 5.214031 616.5402 636.9792 26504  
## 228 501.3423 3.212304 495.0461 507.6384 55700  
## 229 384.1561 3.877352 376.5565 391.7558 29037  
## 230 620.0800 5.175561 609.9359 630.2241 26420  
## 231 496.2873 3.190100 490.0347 502.5399 55457  
## 232 379.6509 3.849688 372.1055 387.1963 28584  
## 233 606.2219 5.108044 596.2102 616.2337 26150  
## 234 487.4429 3.156898 481.2554 493.6305 54734  
## 235 373.3581 3.813325 365.8840 380.8322 28347  
## 236 600.8136 5.076617 590.8634 610.7638 26188  
## 237 481.5983 3.133473 475.4566 487.7399 54535  
## 238 374.3882 3.813649 366.9135 381.8630 28028  
## 239 590.3224 5.022963 580.4774 600.1674 25828  
## 240 477.1869 3.114224 471.0830 483.2907 53856  
## 241 374.6221 3.811471 367.1516 382.0925 27891  
## 242 587.2131 5.000670 577.4118 597.0144 25825  
## 243 475.9536 3.106191 469.8655 482.0417 53716  
## 244 373.1289 3.800480 365.6800 380.5778 27966  
## 245 582.7919 4.976508 573.0379 592.5458 25792  
## 246 473.0933 3.093927 467.0292 479.1574 53758  
## 247 375.0197 3.805937 367.5601 382.4794 28128  
## 248 574.8124 4.935196 565.1394 584.4854 25709  
## 249 470.3687 3.081286 464.3293 476.4080 53837  
## 250 370.3460 3.778972 362.9392 377.7527 28004  
## 251 573.5011 4.921449 563.8551 583.1471 25963  
## 252 467.3815 3.067750 461.3687 473.3942 53967  
## 253 368.4699 3.764941 361.0906 375.8492 27855  
## 254 572.8861 4.913272 563.2561 582.5161 25957  
## 255 466.0494 3.059733 460.0523 472.0465 53812  
## 256 366.2595 3.749448 358.9106 373.6084 27915  
## 257 572.1242 4.904122 562.5121 581.7363 26056  
## 258 464.4518 3.050703 458.4724 470.4311 53971  
## 259 365.3631 3.741894 358.0290 372.6972 27782  
## 260 573.2561 4.902038 563.6481 582.8641 26301  
## 261 464.5965 3.047915 458.6226 470.5704 54083  
## 262 360.5075 3.711221 353.2335 367.7815 27748  
## 263 560.2504 4.841422 550.7612 569.7396 25913  
## 264 455.7781 3.015017 449.8687 461.6876 53661  
## 265 352.5282 3.666826 345.3412 359.7152 27708  
## 266 547.3470 4.775479 537.9871 556.7069 25638  
## 267 445.6947 2.977583 439.8587 451.5308 53346  
## 268 354.5750 3.672420 347.3770 361.7729 28141  
## 269 549.6492 4.774822 540.2905 559.0078 25934  
## 270 447.9725 2.979982 442.1317 453.8132 54075  
## 271 352.8307 3.657623 345.6618 359.9997 28413  
## 272 541.8354 4.733518 532.5577 551.1131 25805  
## 273 443.3078 2.959835 437.5065 449.1091 54218  
## 274 356.1223 3.669263 348.9305 363.3140 28922  
## 275 542.0360 4.724524 532.7760 551.2961 26015  
## 276 445.2668 2.961491 439.4622 451.0713 54937  
## 277 359.5514 3.681041 352.3366 366.7662 29377  
## 278 540.8204 4.712626 531.5836 550.0571 26431  
## 279 446.4331 2.960921 440.6297 452.2365 55808  
## 280 358.0809 3.668368 350.8909 365.2709 29329  
## 281 541.5888 4.707021 532.3630 550.8146 26514  
## 282 446.0549 2.954797 440.2635 451.8463 55843  
## 283 352.9945 3.637119 345.8657 360.1232 28946  
## 284 536.6187 4.675582 527.4545 545.7828 26360  
## 285 441.0401 2.932949 435.2915 446.7887 55306  
## 286 349.1551 3.612967 342.0736 356.2365 28375  
## 287 533.0471 4.651250 523.9306 542.1635 26325  
## 288 437.3693 2.916250 431.6534 443.0851 54700  
## 289 341.3567 3.566242 334.3669 348.3466 27696  
## 290 524.7562 4.607983 515.7246 533.7879 25872  
## 291 429.2771 2.884449 423.6236 434.9306 53568  
## 292 335.0977 3.527661 328.1835 342.0120 27154  
## 293 513.0798 4.551545 504.1587 522.0008 25525  
## 294 420.3371 2.850364 414.7504 425.9238 52679  
## 295 335.8663 3.525147 328.9570 342.7756 27488  
## 296 515.3508 4.552414 506.4280 524.2735 25905  
## 297 421.8842 2.850369 416.2975 427.4710 53393  
## 298 334.8183 3.513907 327.9311 341.7056 27950  
## 299 519.2360 4.559053 510.3003 528.1718 26289  
## 300 423.2372 2.849391 417.6524 428.8220 54239  
## 301 343.7407 3.556073 336.7708 350.7106 29431  
## 302 535.0266 4.620563 525.9703 544.0830 27374  
## 303 435.4668 2.886283 429.8097 441.1239 56805  
## 304 346.8734 3.568364 339.8794 353.8674 29989  
## 305 542.6378 4.642378 533.5387 551.7368 27873  
## 306 440.9131 2.899553 435.2299 446.5962 57862  
## 307 346.9427 3.565049 339.9552 353.9302 30022  
## 308 544.8386 4.644617 535.7351 553.9420 27988  
## 309 442.0291 2.899499 436.3461 447.7121 58010  
## 310 347.0565 3.560535 340.0779 354.0351 29674  
## 311 540.9592 4.620745 531.9025 550.0158 27905  
## 312 440.2223 2.889240 434.5594 445.8852 57579  
## 313 348.1597 3.560045 341.1821 355.1374 28930  
## 314 541.1112 4.607455 532.0805 550.1418 27612  
## 315 440.9702 2.884891 435.3158 446.6246 56542  
## 316 346.6154 3.545814 339.6656 353.5652 28655  
## 317 535.7167 4.573591 526.7525 544.6809 27450  
## 318 437.6005 2.867913 431.9794 443.2217 56105  
## 319 347.0069 3.541736 340.0651 353.9487 28665  
## 320 537.2314 4.567742 528.2786 546.1841 27556  
## 321 438.6752 2.865418 433.0590 444.2914 56221  
## 322 346.7401 3.533362 339.8148 353.6655 28968  
## 323 538.7257 4.560839 529.7864 547.6649 27760  
## 324 439.2790 2.860350 433.6728 444.8853 56728  
## 325 341.6247 3.499808 334.7651 348.4843 29226  
## 326 526.0515 4.496705 517.2379 534.8650 27725  
## 327 430.5683 2.825894 425.0295 436.1070 56951  
## 328 341.7009 3.490648 334.8592 348.5426 29407  
## 329 523.0952 4.472267 514.3296 531.8609 27867  
## 330 429.2246 2.814185 423.7087 434.7404 57274  
## 331 339.7323 3.471941 332.9273 346.5373 29387  
## 332 514.6490 4.423470 505.9790 523.3190 27870  
## 333 424.1087 2.789872 418.6406 429.5769 57257  
## 334 338.7803 3.459186 332.0003 345.5603 29633  
## 335 518.4523 4.428869 509.7717 527.1329 28250  
## 336 425.4801 2.787948 420.0157 430.9445 57883  
## 337 351.4466 3.515957 344.5553 358.3379 30792  
## 338 529.8106 4.466724 521.0558 538.5654 29151  
## 339 437.5576 2.821137 432.0282 443.0870 59943  
## 340 351.0592 3.507894 344.1837 357.9347 30603  
## 341 531.7191 4.465858 522.9660 540.4722 29172  
## 342 438.2989 2.818340 432.7750 443.8229 59775

# Tidy periods into quarters, select all age rate, filter to M&F only

Quarters assigned as follows: .125 = quarter 1, .375 = quarter 2, .625 = quarter 3, .875 = quarter 4. Quarter indicates last quarter in annual period i.e. ASMR for the year that includes that quarter and three preceding quarters.

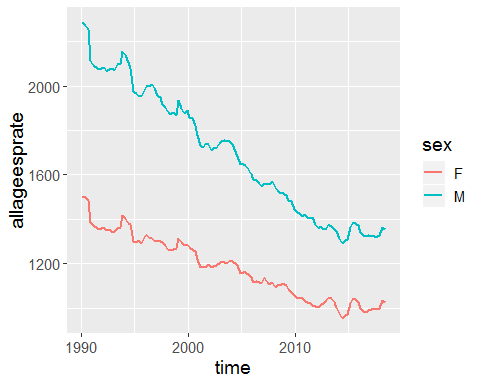
tidied\_allagerates\_2018 <-  
 data %>%  
 separate(period, into = c("year","quarter"), sep = 4) %>%   
 mutate(  
 year = as.double(year),  
 quarter = as.double(quarter)  
 ) %>%   
 mutate(  
 time = year + (quarter / 4) - 0.125  
 ) %>%   
 select(time, sex, allageesprate) %>%  
 filter(sex!="P")  
   
  
tidied\_allagerates\_2018

## time sex allageesprate  
## 1 1990.125 F 1500.4002  
## 2 1990.125 M 2287.7414  
## 3 1990.375 F 1499.6691  
## 4 1990.375 M 2271.7785  
## 5 1990.625 F 1485.5072  
## 6 1990.625 M 2252.7301  
## 7 1990.875 F 1386.2319  
## 8 1990.875 M 2114.4333  
## 9 1991.125 F 1370.9937  
## 10 1991.125 M 2090.4911  
## 11 1991.375 F 1361.9806  
## 12 1991.375 M 2081.5897  
## 13 1991.625 F 1356.4288  
## 14 1991.625 M 2074.8453  
## 15 1991.875 F 1359.8080  
## 16 1991.875 M 2077.0059  
## 17 1992.125 F 1358.5900  
## 18 1992.125 M 2084.4016  
## 19 1992.375 F 1349.7919  
## 20 1992.375 M 2067.2606  
## 21 1992.625 F 1354.0802  
## 22 1992.625 M 2076.6938  
## 23 1992.875 F 1341.5783  
## 24 1992.875 M 2077.7699  
## 25 1993.125 F 1345.6595  
## 26 1993.125 M 2071.4982  
## 27 1993.375 F 1360.0188  
## 28 1993.375 M 2096.5156  
## 29 1993.625 F 1364.8308  
## 30 1993.625 M 2097.2932  
## 31 1993.875 F 1418.0949  
## 32 1993.875 M 2155.2243  
## 33 1994.125 F 1405.8620  
## 34 1994.125 M 2139.6174  
## 35 1994.375 F 1379.5644  
## 36 1994.375 M 2106.8907  
## 37 1994.625 F 1375.9499  
## 38 1994.625 M 2077.2160  
## 39 1994.875 F 1300.4151  
## 40 1994.875 M 1974.0242  
## 41 1995.125 F 1297.1418  
## 42 1995.125 M 1966.1240  
## 43 1995.375 F 1306.8696  
## 44 1995.375 M 1955.0497  
## 45 1995.625 F 1290.6128  
## 46 1995.625 M 1952.0999  
## 47 1995.875 F 1318.1378  
## 48 1995.875 M 1978.8214  
## 49 1996.125 F 1331.4086  
## 50 1996.125 M 1999.1481  
## 51 1996.375 F 1315.3620  
## 52 1996.375 M 1999.1219  
## 53 1996.625 F 1313.5481  
## 54 1996.625 M 2008.3256  
## 55 1996.875 F 1298.2784  
## 56 1996.875 M 1987.5467  
## 57 1997.125 F 1298.3450  
## 58 1997.125 M 1955.7523  
## 59 1997.375 F 1300.6993  
## 60 1997.375 M 1946.9756  
## 61 1997.625 F 1295.1969  
## 62 1997.625 M 1917.5341  
## 63 1997.875 F 1281.7783  
## 64 1997.875 M 1903.7481  
## 65 1998.125 F 1257.4773  
## 66 1998.125 M 1879.1620  
## 67 1998.375 F 1258.5509  
## 68 1998.375 M 1873.6902  
## 69 1998.625 F 1263.7122  
## 70 1998.625 M 1880.6585  
## 71 1998.875 F 1269.1613  
## 72 1998.875 M 1866.5687  
## 73 1999.125 F 1311.4337  
## 74 1999.125 M 1933.5279  
## 75 1999.375 F 1293.5518  
## 76 1999.375 M 1898.8561  
## 77 1999.625 F 1284.3456  
## 78 1999.625 M 1875.1125  
## 79 1999.875 F 1287.8906  
## 80 1999.875 M 1889.8916  
## 81 2000.125 F 1271.4174  
## 82 2000.125 M 1858.1596  
## 83 2000.375 F 1266.3159  
## 84 2000.375 M 1852.9947  
## 85 2000.625 F 1255.7367  
## 86 2000.625 M 1824.3019  
## 87 2000.875 F 1218.2774  
## 88 2000.875 M 1776.4543  
## 89 2001.125 F 1184.0636  
## 90 2001.125 M 1733.1274  
## 91 2001.375 F 1183.1437  
## 92 2001.375 M 1725.3525  
## 93 2001.625 F 1184.4611  
## 94 2001.625 M 1740.1062  
## 95 2001.875 F 1196.2046  
## 96 2001.875 M 1735.9769  
## 97 2002.125 F 1184.5618  
## 98 2002.125 M 1711.8563  
## 99 2002.375 F 1187.8689  
## 100 2002.375 M 1720.0179  
## 101 2002.625 F 1193.4426  
## 102 2002.625 M 1719.2442  
## 103 2002.875 F 1201.8232  
## 104 2002.875 M 1741.0947  
## 105 2003.125 F 1208.8964  
## 106 2003.125 M 1750.0442  
## 107 2003.375 F 1206.3813  
## 108 2003.375 M 1755.8439  
## 109 2003.625 F 1200.5565  
## 110 2003.625 M 1751.5067  
## 111 2003.875 F 1212.9987  
## 112 2003.875 M 1751.8965  
## 113 2004.125 F 1208.5862  
## 114 2004.125 M 1734.9259  
## 115 2004.375 F 1198.9439  
## 116 2004.375 M 1704.1133  
## 117 2004.625 F 1193.3301  
## 118 2004.625 M 1684.8586  
## 119 2004.875 F 1157.2493  
## 120 2004.875 M 1645.9699  
## 121 2005.125 F 1158.8288  
## 122 2005.125 M 1648.6899  
## 123 2005.375 F 1161.1501  
## 124 2005.375 M 1643.5641  
## 125 2005.625 F 1153.4810  
## 126 2005.625 M 1623.2456  
## 127 2005.875 F 1139.0776  
## 128 2005.875 M 1600.9223  
## 129 2006.125 F 1115.7765  
## 130 2006.125 M 1578.2453  
## 131 2006.375 F 1119.0732  
## 132 2006.375 M 1574.8997  
## 133 2006.625 F 1116.6279  
## 134 2006.625 M 1560.9849  
## 135 2006.875 F 1112.5995  
## 136 2006.875 M 1549.6572  
## 137 2007.125 F 1137.7195  
## 138 2007.125 M 1560.8716  
## 139 2007.375 F 1114.5282  
## 140 2007.375 M 1556.7835  
## 141 2007.625 F 1105.6755  
## 142 2007.625 M 1556.3819  
## 143 2007.875 F 1114.6443  
## 144 2007.875 M 1568.3305  
## 145 2008.125 F 1092.5233  
## 146 2008.125 M 1544.6720  
## 147 2008.375 F 1100.2690  
## 148 2008.375 M 1529.1838  
## 149 2008.625 F 1103.1500  
## 150 2008.625 M 1515.1621  
## 151 2008.875 F 1111.2940  
## 152 2008.875 M 1517.6631  
## 153 2009.125 F 1102.7386  
## 154 2009.125 M 1508.1118  
## 155 2009.375 F 1083.6370  
## 156 2009.375 M 1483.4906  
## 157 2009.625 F 1072.0579  
## 158 2009.625 M 1478.2422  
## 159 2009.875 F 1056.1941  
## 160 2009.875 M 1444.0035  
## 161 2010.125 F 1047.4957  
## 162 2010.125 M 1435.0434  
## 163 2010.375 F 1044.9811  
## 164 2010.375 M 1426.8991  
## 165 2010.625 F 1045.5545  
## 166 2010.625 M 1413.6407  
## 167 2010.875 F 1036.2268  
## 168 2010.875 M 1422.4929  
## 169 2011.125 F 1025.3450  
## 170 2011.125 M 1408.4984  
## 171 2011.375 F 1022.5737  
## 172 2011.375 M 1402.1113  
## 173 2011.625 F 1013.3507  
## 174 2011.625 M 1406.9538  
## 175 2011.875 F 1006.8648  
## 176 2011.875 M 1377.9585  
## 177 2012.125 F 1001.1900  
## 178 2012.125 M 1357.0982  
## 179 2012.375 F 1013.4333  
## 180 2012.375 M 1366.8424  
## 181 2012.625 F 1019.3835  
## 182 2012.625 M 1353.0283  
## 183 2012.875 F 1034.0236  
## 184 2012.875 M 1356.8340  
## 185 2013.125 F 1047.2367  
## 186 2013.125 M 1375.5554  
## 187 2013.375 F 1042.9404  
## 188 2013.375 M 1369.2158  
## 189 2013.625 F 1026.8583  
## 190 2013.625 M 1354.2704  
## 191 2013.875 F 1004.2657  
## 192 2013.875 M 1344.8635  
## 193 2014.125 F 976.4886  
## 194 2014.125 M 1312.9867  
## 195 2014.375 F 952.9044  
## 196 2014.375 M 1290.4061  
## 197 2014.625 F 960.3534  
## 198 2014.625 M 1300.2353  
## 199 2014.875 F 972.3775  
## 200 2014.875 M 1310.9825  
## 201 2015.125 F 1021.1782  
## 202 2015.125 M 1362.1791  
## 203 2015.375 F 1038.9698  
## 204 2015.375 M 1381.3043  
## 205 2015.625 F 1038.4427  
## 206 2015.625 M 1382.2152  
## 207 2015.875 F 1024.3997  
## 208 2015.875 M 1371.2413  
## 209 2016.125 F 996.8737  
## 210 2016.125 M 1341.7542  
## 211 2016.375 F 984.0351  
## 212 2016.375 M 1325.4592  
## 213 2016.625 F 981.1454  
## 214 2016.625 M 1322.5719  
## 215 2016.875 F 988.3911  
## 216 2016.875 M 1326.3755  
## 217 2017.125 F 993.3512  
## 218 2017.125 M 1324.8449  
## 219 2017.375 F 996.1639  
## 220 2017.375 M 1324.8598  
## 221 2017.625 F 992.5277  
## 222 2017.625 M 1318.6081  
## 223 2017.875 F 997.5625  
## 224 2017.875 M 1329.0268  
## 225 2018.125 F 1033.7135  
## 226 2018.125 M 1364.0444  
## 227 2018.375 F 1024.6352  
## 228 2018.375 M 1354.7984

# Plot quarterly-rolling annual age-standardised mortality rates by time

Demonstrates overall reduction in mortality rates over the period, more steeply among men than women. There is variability in the trend, particularly before 2003, and after 2011.

plot<-ggplot(tidied\_allagerates\_2018,aes(x=time,y=allageesprate, color=sex))+geom\_line(size=1.0001, show.legend = TRUE)+theme(text=element\_text(size=14))  
plot



## Generate linear model for both sexes

tidied\_allagerates\_2018 %>%   
 rename(rate = allageesprate) %>%  
 filter(sex == "M") -> allagemale  
 lm(rate ~ time, data = allagemale) -> lmod\_male\_2018  
  
tidied\_allagerates\_2018 %>%  
 rename(rate = allageesprate) %>%  
 filter(sex == "F") -> allagefemale  
 lm(rate ~ time, data = allagefemale) -> lmod\_female\_2018

## View linear model

summary (lmod\_male\_2018)

##   
## Call:  
## lm(formula = rate ~ time, data = allagemale)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -68.73 -38.87 -16.80 36.84 142.55   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 69951.244 1164.509 60.07 <2e-16 \*\*\*  
## time -34.056 0.581 -58.62 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 51.04 on 112 degrees of freedom  
## Multiple R-squared: 0.9684, Adjusted R-squared: 0.9681   
## F-statistic: 3436 on 1 and 112 DF, p-value: < 2.2e-16

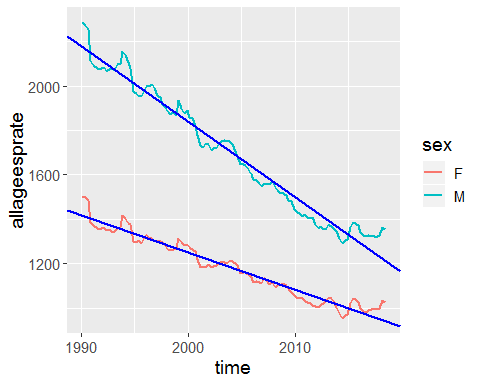
summary (lmod\_female\_2018)

##   
## Call:  
## lm(formula = rate ~ time, data = allagefemale)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -56.519 -24.836 -3.137 17.272 89.669   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 34630.7949 734.8493 47.13 <2e-16 \*\*\*  
## time -16.6907 0.3666 -45.52 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 32.21 on 112 degrees of freedom  
## Multiple R-squared: 0.9487, Adjusted R-squared: 0.9483   
## F-statistic: 2072 on 1 and 112 DF, p-value: < 2.2e-16

## Get trend line of linear model fit to whole timeseries

A linear trend line fitted to the whole data series demonstrates the overall decline in mortality rates, and the steeper decline in men than women. For both sexes the recent observed data lie above the linear trend line.

my.coeftrendlinemale\_2018 <- coef(lmod\_male\_2018)  
my.coeftrendlinefemale\_2018 <- coef(lmod\_female\_2018)  
addtrendline <- plot + geom\_abline(intercept = my.coeftrendlinemale\_2018[1], col="Blue", size=1.0001,  
 slope = my.coeftrendlinemale\_2018[2],   
 aes(colour = "Overall"))+  
 geom\_abline(intercept = my.coeftrendlinefemale\_2018[1], col="Blue", size=1.0001,  
 slope = my.coeftrendlinefemale\_2018[2],   
 aes(colour = "Overall"))  
addtrendline



# Segmented regression

## Davies test to test for the significance of breakpoint at each of the 114 possible data points

This identifies 2013.5 as the most significant breakpoint for men, hence within quarter 2 2013, indicating the year July 2012-June 2013. For women the result is 2014.4, hence within quarter 2 2014, indicating the year July 2013-June 2014.

davies\_allmale\_2018 = davies.test(lmod\_male\_2018, ~time, k=114)  
davies\_allfemale\_2018 = davies.test(lmod\_female\_2018, ~time, k=114)  
davies\_allmale\_2018

##   
## Davies' test for a change in the slope  
##   
## data: formula = rate ~ time , method = lm   
## model = gaussian , link = identity   
## segmented variable = time  
## 'best' at = 2013.5, n.points = 112, p-value = 4.652e-16  
## alternative hypothesis: two.sided

davies\_allfemale\_2018

##   
## Davies' test for a change in the slope  
##   
## data: formula = rate ~ time , method = lm   
## model = gaussian , link = identity   
## segmented variable = time  
## 'best' at = 2014.4, n.points = 112, p-value = 2.565e-08  
## alternative hypothesis: two.sided

## Segmented regression - one breakpoint model

The same breakpoint is identifed for men and women as with the Davies test.

my.seg\_male\_2018<-segmented( lmod\_male\_2018, seg\_rate.Z = ~time, psi = NA, control = seg.control(K=1))  
 my.seg\_female\_2018<-segmented( lmod\_female\_2018, seg\_rate.Z = ~time, psi = NA, control = seg.control(K=1))  
   
summary(my.seg\_male\_2018)

##   
## \*\*\*Regression Model with Segmented Relationship(s)\*\*\*  
##   
## Call:   
## segmented.lm(obj = lmod\_male\_2018, psi = NA, control = seg.control(K = 1),   
## seg\_rate.Z = ~time)  
##   
## Estimated Break-Point(s):  
## Est. St.Err   
## 2013.493 0.464   
##   
## Meaningful coefficients of the linear terms:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 76337.103 1118.968 68.22 <2e-16 \*\*\*  
## time -37.251 0.559 -66.64 <2e-16 \*\*\*  
## U1.time 39.081 5.730 6.82 NA   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 36.76 on 110 degrees of freedom  
## Multiple R-Squared: 0.9839, Adjusted R-squared: 0.9835   
##   
## Convergence attained in 2 iterations with relative change 1.957553e-16

summary(my.seg\_female\_2018)

##   
## \*\*\*Regression Model with Segmented Relationship(s)\*\*\*  
##   
## Call:   
## segmented.lm(obj = lmod\_female\_2018, psi = NA, control = seg.control(K = 1),   
## seg\_rate.Z = ~time)  
##   
## Estimated Break-Point(s):  
## Est. St.Err   
## 2014.369 0.578   
##   
## Meaningful coefficients of the linear terms:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 37364.8419 793.9866 47.060 <2e-16 \*\*\*  
## time -18.0584 0.3966 -45.537 <2e-16 \*\*\*  
## U1.time 24.0419 5.4287 4.429 NA   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 27.34 on 110 degrees of freedom  
## Multiple R-Squared: 0.9637, Adjusted R-squared: 0.9627   
##   
## Convergence attained in 5 iterations with relative change -1.770497e-16

## Extract breakpoint and 95% confidence intervals for one break model

The standard error is used to calcuate an upper and lower 95% confidence intervals. These are presented below.

breakpointmale\_2018 <- my.seg\_male\_2018$psi[, 2]  
breakpointfemale\_2018 <- my.seg\_female\_2018$psi[, 2]  
breakpoint\_SEmale\_2018 <- my.seg\_male\_2018$psi[, 3]  
breakpoint\_SEfemale\_2018 <- my.seg\_female\_2018$psi[, 3]  
breakpoint\_low\_CImale\_2018 <- breakpointmale\_2018 - (breakpoint\_SEmale\_2018\*1.96)  
breakpoint\_up\_CImale\_2018 <- breakpointmale\_2018 + (breakpoint\_SEmale\_2018\*1.96)  
breakpoint\_low\_CIfemale\_2018 <- breakpointfemale\_2018 - (breakpoint\_SEfemale\_2018\*1.96)  
breakpoint\_up\_CIfemale\_2018 <- breakpointfemale\_2018 + (breakpoint\_SEfemale\_2018\*1.96)  
  
breakpointmale\_2018

## [1] 2013.493

breakpoint\_low\_CImale\_2018

## [1] 2012.583

breakpoint\_up\_CImale\_2018

## [1] 2014.403

breakpointfemale\_2018

## [1] 2014.369

breakpoint\_low\_CIfemale\_2018

## [1] 2013.236

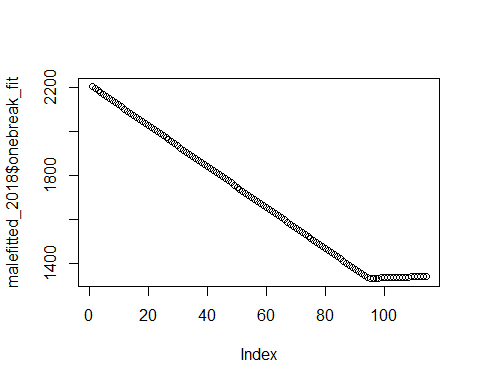
breakpoint\_up\_CIfemale\_2018

## [1] 2015.502

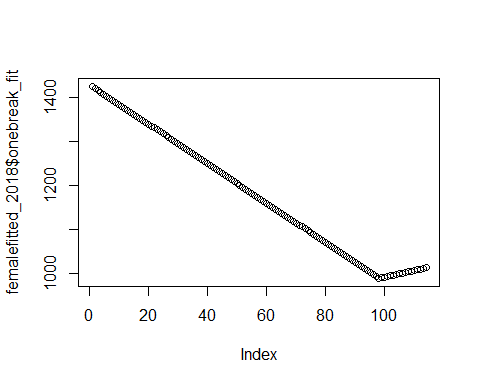
## Generate and plot predicted values from one break model

The ‘fitted’ function is used to predict values for ASMR based on the one break segmented regression model. These predicted values are plotted below.

tidied\_allagerates\_2018 %>%  
 filter(sex == "M") %>%   
 mutate(  
 onebreak\_fit = fitted(  
 my.seg\_male\_2018   
   
 )  
 ) -> malefitted\_2018  
  
tidied\_allagerates\_2018 %>%  
 filter(sex == "F") %>%   
 mutate(  
 onebreak\_fit = fitted(  
 my.seg\_female\_2018   
  
 )  
 ) -> femalefitted\_2018  
  
plot(malefitted\_2018$onebreak\_fit)



plot(femalefitted\_2018$onebreak\_fit)



## Combine male and female observed and predicted values in single data frame

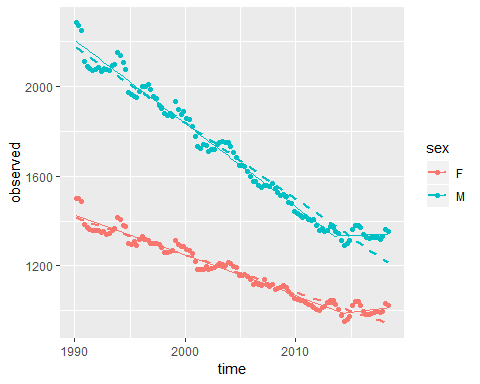
femalefitted\_2018 %>%   
 select(  
 time, sex, observed = allageesprate,  
 predicted = onebreak\_fit  
 ) %>%   
 bind\_rows(  
 malefitted\_2018 %>%   
 select(  
 time, sex, observed = allageesprate,  
 predicted = onebreak\_fit  
 )   
 ) -> obs\_fit\_both\_2018  
  
age <- "all"  
obs\_fit\_both\_2018$agegroup = age  
  
obs\_fit\_both\_2018

## time sex observed predicted agegroup  
## 1 1990.125 F 1500.4002 1426.3009 all  
## 2 1990.375 F 1499.6691 1421.7863 all  
## 3 1990.625 F 1485.5072 1417.2717 all  
## 4 1990.875 F 1386.2319 1412.7571 all  
## 5 1991.125 F 1370.9937 1408.2425 all  
## 6 1991.375 F 1361.9806 1403.7279 all  
## 7 1991.625 F 1356.4288 1399.2133 all  
## 8 1991.875 F 1359.8080 1394.6987 all  
## 9 1992.125 F 1358.5900 1390.1841 all  
## 10 1992.375 F 1349.7919 1385.6695 all  
## 11 1992.625 F 1354.0802 1381.1549 all  
## 12 1992.875 F 1341.5783 1376.6403 all  
## 13 1993.125 F 1345.6595 1372.1256 all  
## 14 1993.375 F 1360.0188 1367.6110 all  
## 15 1993.625 F 1364.8308 1363.0964 all  
## 16 1993.875 F 1418.0949 1358.5818 all  
## 17 1994.125 F 1405.8620 1354.0672 all  
## 18 1994.375 F 1379.5644 1349.5526 all  
## 19 1994.625 F 1375.9499 1345.0380 all  
## 20 1994.875 F 1300.4151 1340.5234 all  
## 21 1995.125 F 1297.1418 1336.0088 all  
## 22 1995.375 F 1306.8696 1331.4942 all  
## 23 1995.625 F 1290.6128 1326.9796 all  
## 24 1995.875 F 1318.1378 1322.4649 all  
## 25 1996.125 F 1331.4086 1317.9503 all  
## 26 1996.375 F 1315.3620 1313.4357 all  
## 27 1996.625 F 1313.5481 1308.9211 all  
## 28 1996.875 F 1298.2784 1304.4065 all  
## 29 1997.125 F 1298.3450 1299.8919 all  
## 30 1997.375 F 1300.6993 1295.3773 all  
## 31 1997.625 F 1295.1969 1290.8627 all  
## 32 1997.875 F 1281.7783 1286.3481 all  
## 33 1998.125 F 1257.4773 1281.8335 all  
## 34 1998.375 F 1258.5509 1277.3189 all  
## 35 1998.625 F 1263.7122 1272.8043 all  
## 36 1998.875 F 1269.1613 1268.2896 all  
## 37 1999.125 F 1311.4337 1263.7750 all  
## 38 1999.375 F 1293.5518 1259.2604 all  
## 39 1999.625 F 1284.3456 1254.7458 all  
## 40 1999.875 F 1287.8906 1250.2312 all  
## 41 2000.125 F 1271.4174 1245.7166 all  
## 42 2000.375 F 1266.3159 1241.2020 all  
## 43 2000.625 F 1255.7367 1236.6874 all  
## 44 2000.875 F 1218.2774 1232.1728 all  
## 45 2001.125 F 1184.0636 1227.6582 all  
## 46 2001.375 F 1183.1437 1223.1436 all  
## 47 2001.625 F 1184.4611 1218.6290 all  
## 48 2001.875 F 1196.2046 1214.1143 all  
## 49 2002.125 F 1184.5618 1209.5997 all  
## 50 2002.375 F 1187.8689 1205.0851 all  
## 51 2002.625 F 1193.4426 1200.5705 all  
## 52 2002.875 F 1201.8232 1196.0559 all  
## 53 2003.125 F 1208.8964 1191.5413 all  
## 54 2003.375 F 1206.3813 1187.0267 all  
## 55 2003.625 F 1200.5565 1182.5121 all  
## 56 2003.875 F 1212.9987 1177.9975 all  
## 57 2004.125 F 1208.5862 1173.4829 all  
## 58 2004.375 F 1198.9439 1168.9683 all  
## 59 2004.625 F 1193.3301 1164.4537 all  
## 60 2004.875 F 1157.2493 1159.9390 all  
## 61 2005.125 F 1158.8288 1155.4244 all  
## 62 2005.375 F 1161.1501 1150.9098 all  
## 63 2005.625 F 1153.4810 1146.3952 all  
## 64 2005.875 F 1139.0776 1141.8806 all  
## 65 2006.125 F 1115.7765 1137.3660 all  
## 66 2006.375 F 1119.0732 1132.8514 all  
## 67 2006.625 F 1116.6279 1128.3368 all  
## 68 2006.875 F 1112.5995 1123.8222 all  
## 69 2007.125 F 1137.7195 1119.3076 all  
## 70 2007.375 F 1114.5282 1114.7930 all  
## 71 2007.625 F 1105.6755 1110.2783 all  
## 72 2007.875 F 1114.6443 1105.7637 all  
## 73 2008.125 F 1092.5233 1101.2491 all  
## 74 2008.375 F 1100.2690 1096.7345 all  
## 75 2008.625 F 1103.1500 1092.2199 all  
## 76 2008.875 F 1111.2940 1087.7053 all  
## 77 2009.125 F 1102.7386 1083.1907 all  
## 78 2009.375 F 1083.6370 1078.6761 all  
## 79 2009.625 F 1072.0579 1074.1615 all  
## 80 2009.875 F 1056.1941 1069.6469 all  
## 81 2010.125 F 1047.4957 1065.1323 all  
## 82 2010.375 F 1044.9811 1060.6177 all  
## 83 2010.625 F 1045.5545 1056.1030 all  
## 84 2010.875 F 1036.2268 1051.5884 all  
## 85 2011.125 F 1025.3450 1047.0738 all  
## 86 2011.375 F 1022.5737 1042.5592 all  
## 87 2011.625 F 1013.3507 1038.0446 all  
## 88 2011.875 F 1006.8648 1033.5300 all  
## 89 2012.125 F 1001.1900 1029.0154 all  
## 90 2012.375 F 1013.4333 1024.5008 all  
## 91 2012.625 F 1019.3835 1019.9862 all  
## 92 2012.875 F 1034.0236 1015.4716 all  
## 93 2013.125 F 1047.2367 1010.9570 all  
## 94 2013.375 F 1042.9404 1006.4424 all  
## 95 2013.625 F 1026.8583 1001.9277 all  
## 96 2013.875 F 1004.2657 997.4131 all  
## 97 2014.125 F 976.4886 992.8985 all  
## 98 2014.375 F 952.9044 988.5228 all  
## 99 2014.625 F 960.3534 990.0186 all  
## 100 2014.875 F 972.3775 991.5145 all  
## 101 2015.125 F 1021.1782 993.0104 all  
## 102 2015.375 F 1038.9698 994.5063 all  
## 103 2015.625 F 1038.4427 996.0021 all  
## 104 2015.875 F 1024.3997 997.4980 all  
## 105 2016.125 F 996.8737 998.9939 all  
## 106 2016.375 F 984.0351 1000.4897 all  
## 107 2016.625 F 981.1454 1001.9856 all  
## 108 2016.875 F 988.3911 1003.4815 all  
## 109 2017.125 F 993.3512 1004.9774 all  
## 110 2017.375 F 996.1639 1006.4732 all  
## 111 2017.625 F 992.5277 1007.9691 all  
## 112 2017.875 F 997.5625 1009.4650 all  
## 113 2018.125 F 1033.7135 1010.9609 all  
## 114 2018.375 F 1024.6352 1012.4567 all  
## 115 1990.125 M 2287.7414 2203.0057 all  
## 116 1990.375 M 2271.7785 2193.6929 all  
## 117 1990.625 M 2252.7301 2184.3802 all  
## 118 1990.875 M 2114.4333 2175.0674 all  
## 119 1991.125 M 2090.4911 2165.7547 all  
## 120 1991.375 M 2081.5897 2156.4419 all  
## 121 1991.625 M 2074.8453 2147.1292 all  
## 122 1991.875 M 2077.0059 2137.8164 all  
## 123 1992.125 M 2084.4016 2128.5037 all  
## 124 1992.375 M 2067.2606 2119.1910 all  
## 125 1992.625 M 2076.6938 2109.8782 all  
## 126 1992.875 M 2077.7699 2100.5655 all  
## 127 1993.125 M 2071.4982 2091.2527 all  
## 128 1993.375 M 2096.5156 2081.9400 all  
## 129 1993.625 M 2097.2932 2072.6272 all  
## 130 1993.875 M 2155.2243 2063.3145 all  
## 131 1994.125 M 2139.6174 2054.0018 all  
## 132 1994.375 M 2106.8907 2044.6890 all  
## 133 1994.625 M 2077.2160 2035.3763 all  
## 134 1994.875 M 1974.0242 2026.0635 all  
## 135 1995.125 M 1966.1240 2016.7508 all  
## 136 1995.375 M 1955.0497 2007.4380 all  
## 137 1995.625 M 1952.0999 1998.1253 all  
## 138 1995.875 M 1978.8214 1988.8125 all  
## 139 1996.125 M 1999.1481 1979.4998 all  
## 140 1996.375 M 1999.1219 1970.1871 all  
## 141 1996.625 M 2008.3256 1960.8743 all  
## 142 1996.875 M 1987.5467 1951.5616 all  
## 143 1997.125 M 1955.7523 1942.2488 all  
## 144 1997.375 M 1946.9756 1932.9361 all  
## 145 1997.625 M 1917.5341 1923.6233 all  
## 146 1997.875 M 1903.7481 1914.3106 all  
## 147 1998.125 M 1879.1620 1904.9979 all  
## 148 1998.375 M 1873.6902 1895.6851 all  
## 149 1998.625 M 1880.6585 1886.3724 all  
## 150 1998.875 M 1866.5687 1877.0596 all  
## 151 1999.125 M 1933.5279 1867.7469 all  
## 152 1999.375 M 1898.8561 1858.4341 all  
## 153 1999.625 M 1875.1125 1849.1214 all  
## 154 1999.875 M 1889.8916 1839.8086 all  
## 155 2000.125 M 1858.1596 1830.4959 all  
## 156 2000.375 M 1852.9947 1821.1832 all  
## 157 2000.625 M 1824.3019 1811.8704 all  
## 158 2000.875 M 1776.4543 1802.5577 all  
## 159 2001.125 M 1733.1274 1793.2449 all  
## 160 2001.375 M 1725.3525 1783.9322 all  
## 161 2001.625 M 1740.1062 1774.6194 all  
## 162 2001.875 M 1735.9769 1765.3067 all  
## 163 2002.125 M 1711.8563 1755.9939 all  
## 164 2002.375 M 1720.0179 1746.6812 all  
## 165 2002.625 M 1719.2442 1737.3685 all  
## 166 2002.875 M 1741.0947 1728.0557 all  
## 167 2003.125 M 1750.0442 1718.7430 all  
## 168 2003.375 M 1755.8439 1709.4302 all  
## 169 2003.625 M 1751.5067 1700.1175 all  
## 170 2003.875 M 1751.8965 1690.8047 all  
## 171 2004.125 M 1734.9259 1681.4920 all  
## 172 2004.375 M 1704.1133 1672.1793 all  
## 173 2004.625 M 1684.8586 1662.8665 all  
## 174 2004.875 M 1645.9699 1653.5538 all  
## 175 2005.125 M 1648.6899 1644.2410 all  
## 176 2005.375 M 1643.5641 1634.9283 all  
## 177 2005.625 M 1623.2456 1625.6155 all  
## 178 2005.875 M 1600.9223 1616.3028 all  
## 179 2006.125 M 1578.2453 1606.9900 all  
## 180 2006.375 M 1574.8997 1597.6773 all  
## 181 2006.625 M 1560.9849 1588.3646 all  
## 182 2006.875 M 1549.6572 1579.0518 all  
## 183 2007.125 M 1560.8716 1569.7391 all  
## 184 2007.375 M 1556.7835 1560.4263 all  
## 185 2007.625 M 1556.3819 1551.1136 all  
## 186 2007.875 M 1568.3305 1541.8008 all  
## 187 2008.125 M 1544.6720 1532.4881 all  
## 188 2008.375 M 1529.1838 1523.1754 all  
## 189 2008.625 M 1515.1621 1513.8626 all  
## 190 2008.875 M 1517.6631 1504.5499 all  
## 191 2009.125 M 1508.1118 1495.2371 all  
## 192 2009.375 M 1483.4906 1485.9244 all  
## 193 2009.625 M 1478.2422 1476.6116 all  
## 194 2009.875 M 1444.0035 1467.2989 all  
## 195 2010.125 M 1435.0434 1457.9861 all  
## 196 2010.375 M 1426.8991 1448.6734 all  
## 197 2010.625 M 1413.6407 1439.3607 all  
## 198 2010.875 M 1422.4929 1430.0479 all  
## 199 2011.125 M 1408.4984 1420.7352 all  
## 200 2011.375 M 1402.1113 1411.4224 all  
## 201 2011.625 M 1406.9538 1402.1097 all  
## 202 2011.875 M 1377.9585 1392.7969 all  
## 203 2012.125 M 1357.0982 1383.4842 all  
## 204 2012.375 M 1366.8424 1374.1714 all  
## 205 2012.625 M 1353.0283 1364.8587 all  
## 206 2012.875 M 1356.8340 1355.5460 all  
## 207 2013.125 M 1375.5554 1346.2332 all  
## 208 2013.375 M 1369.2158 1336.9205 all  
## 209 2013.625 M 1354.2704 1332.7726 all  
## 210 2013.875 M 1344.8635 1333.2300 all  
## 211 2014.125 M 1312.9867 1333.6874 all  
## 212 2014.375 M 1290.4061 1334.1448 all  
## 213 2014.625 M 1300.2353 1334.6022 all  
## 214 2014.875 M 1310.9825 1335.0596 all  
## 215 2015.125 M 1362.1791 1335.5170 all  
## 216 2015.375 M 1381.3043 1335.9744 all  
## 217 2015.625 M 1382.2152 1336.4318 all  
## 218 2015.875 M 1371.2413 1336.8892 all  
## 219 2016.125 M 1341.7542 1337.3466 all  
## 220 2016.375 M 1325.4592 1337.8040 all  
## 221 2016.625 M 1322.5719 1338.2614 all  
## 222 2016.875 M 1326.3755 1338.7188 all  
## 223 2017.125 M 1324.8449 1339.1762 all  
## 224 2017.375 M 1324.8598 1339.6336 all  
## 225 2017.625 M 1318.6081 1340.0910 all  
## 226 2017.875 M 1329.0268 1340.5484 all  
## 227 2018.125 M 1364.0444 1341.0058 all  
## 228 2018.375 M 1354.7984 1341.4632 all

## Plot observed values with linear and segmented models

The observed data are presented as data points, and the lines indicate the predicted values, according to the one break segmented model.

obs\_fit\_both\_2018 %>%   
 ggplot(  
 aes (x=time, color=sex)  
 ) +  
 geom\_point(  
 aes (y=observed)) +  
 geom\_line (   
 aes (y=predicted)) +  
 stat\_smooth(method="lm",se=F,linetype="dashed",  
 aes (y=observed)  
 )



## Get segmented regression coefficients

Coefficients are used in order to be able to plot a continuation of the pre-break point trend. This differs slightly from the overall linear model, as it does not include the post-breakpoint data.

coef(my.seg\_male\_2018)

## (Intercept) time U1.time psi1.time   
## 76337.10325 -37.25098 39.08059 0.00000

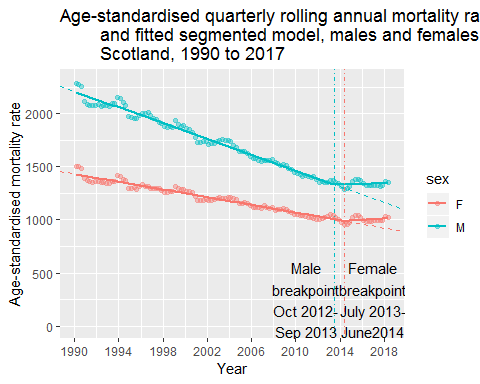
coef(my.seg\_female\_2018)

## (Intercept) time U1.time psi1.time   
## 37364.84189 -18.05843 24.04193 0.00000

# Get coeffiencents male  
 b0\_aspec\_m\_2018 <- coef(my.seg\_male\_2018)[[1]]  
 b1\_aspec\_m\_2018 <- coef(my.seg\_male\_2018)[[2]]  
 c1\_aspec\_m\_2018 <- coef(my.seg\_male\_2018)[[2]] + coef(my.seg\_male\_2018)[[3]]  
   
 break1\_aspec\_m\_2018 <- my.seg\_male\_2018$psi[[2]]  
   
# Get coefficients female  
 b0\_aspec\_f\_2018 <- coef(my.seg\_female\_2018)[[1]]  
 b1\_aspec\_f\_2018 <- coef(my.seg\_female\_2018)[[2]]  
 c1\_aspec\_f\_2018 <- coef(my.seg\_female\_2018)[[2]] + coef(my.seg\_female\_2018)[[3]]  
   
 break1\_aspec\_f <- my.seg\_female\_2018$psi[[2]]

## Annotated plot of observed data, segmented model, and continutation of pre-breakpoint trend

p <- obs\_fit\_both\_2018 %>%   
 ggplot(  
 aes (x=time, color=sex)  
 ) +  
 geom\_point(  
 aes (y=observed), alpha=0.4) +  
 geom\_line (  
 aes (y=predicted), size=1) +  
 geom\_abline(intercept = b0\_aspec\_m\_2018, slope = b1\_aspec\_m\_2018, color="#00BFC4", linetype="dashed") +  
 geom\_abline(intercept = b0\_aspec\_f\_2018, slope = b1\_aspec\_f\_2018, color="#F8766D", linetype= "dashed") +  
 ylim(0,2300)+  
 labs(x="Year", y="Age-standardised mortality rate", title =   
 "Age-standardised quarterly rolling annual mortality rates   
 and fitted segmented model, males and females, all ages,   
 Scotland, 1990 to 2017") +  
 scale\_x\_continuous (breaks=c(1990, 1994, 1998, 2002, 2006, 2010, 2014, 2018))+  
 geom\_vline(xintercept = my.seg\_male\_2018[["psi"]][[2]], color = "#00BFC4", linetype="dotdash")+  
 geom\_vline(xintercept = my.seg\_female\_2018[["psi"]][[2]], color = "#F8766D", linetype="dotdash") +  
 annotate(geom="text", x=2011, y=250, label="Male\nbreakpoint\nOct 2012-\n Sep 2013 ")+  
 annotate(geom="text", x=2017, y=250, label="Female\nbreakpoint\nJuly 2013-\nJune2014")  
   
   
plot(p)



ggsave (  
 "Figures/Segmentedplot\_Scotland\_Allagesto2018.png", height=15, width=20, units="cm")

## Segmented regression with two breakpoints

Allowing the model to break at two points identifies a breakpoint in quarter 4 of 1990 for both men and women, indicating the year Jan-Dec 1990. The time period identified for the later breakpoint is not altered from the one breakpoint model. It should be noted that the 1990 breakpoint identified indicates the change between a steep decline in the early data points, to a steadier decline in the middle period of the data.

my.seg\_male2\_2018 <-segmented( lmod\_male\_2018, seg\_rate.Z = ~timepoint, psi = NA, control = seg.control(K=2))  
my.seg\_female2\_2018<- segmented(lmod\_female\_2018, seg\_rate.Z = ~timepoint, psi = NA, control = seg.control(K=2))  
  
summary(my.seg\_male2\_2018)

##   
## \*\*\*Regression Model with Segmented Relationship(s)\*\*\*  
##   
## Call:   
## segmented.lm(obj = lmod\_male\_2018, psi = NA, control = seg.control(K = 2),   
## seg\_rate.Z = ~timepoint)  
##   
## Estimated Break-Point(s):  
## Est. St.Err  
## psi1.time 1991.098 0.399  
## psi2.time 2013.808 0.433  
##   
## Meaningful coefficients of the linear terms:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 284414.492 124536.618 2.284 0.0243 \*  
## time -141.760 62.565 -2.266 0.0255 \*  
## U1.time 105.244 62.568 1.682 NA   
## U2.time 40.240 5.886 6.836 NA   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 34.98 on 108 degrees of freedom  
## Multiple R-Squared: 0.9857, Adjusted R-squared: 0.985   
##   
## Convergence attained in 2 iterations with relative change -3.484298e-16

summary(my.seg\_female2\_2018)

##   
## \*\*\*Regression Model with Segmented Relationship(s)\*\*\*  
##   
## Call:   
## segmented.lm(obj = lmod\_female\_2018, psi = NA, control = seg.control(K = 2),   
## seg\_rate.Z = ~timepoint)  
##   
## Estimated Break-Point(s):  
## Est. St.Err  
## psi1.time 1990.982 0.210  
## psi2.time 2014.326 0.588  
##   
## Meaningful coefficients of the linear terms:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 275435.656 88275.965 3.120 0.00232 \*\*  
## time -137.637 44.349 -3.104 0.00244 \*\*  
## U1.time 120.099 44.350 2.708 NA   
## U2.time 21.799 4.924 4.427 NA   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 24.79 on 108 degrees of freedom  
## Multiple R-Squared: 0.9707, Adjusted R-squared: 0.9693   
##   
## Convergence attained in 12 iterations with relative change 1.756785e-15

## AIC and BIC to compare one and two break models

The lower AIC and BIC indicate that the two break models are a better fit than the one break model for both males and females.

AIC(my.seg\_male\_2018, my.seg\_male2\_2018)

## df AIC  
## my.seg\_male\_2018 5 1151.276  
## my.seg\_male2\_2018 7 1141.812

AIC(my.seg\_female\_2018, my.seg\_female2\_2018)

## df AIC  
## my.seg\_female\_2018 5 1083.753  
## my.seg\_female2\_2018 7 1063.350

BIC(my.seg\_male\_2018, my.seg\_male2\_2018)

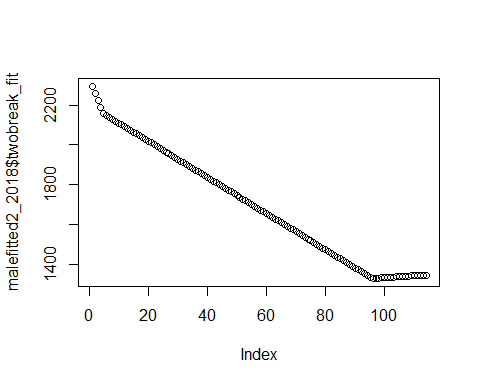
## df BIC  
## my.seg\_male\_2018 5 1164.957  
## my.seg\_male2\_2018 7 1160.965

BIC(my.seg\_female\_2018, my.seg\_female2\_2018)

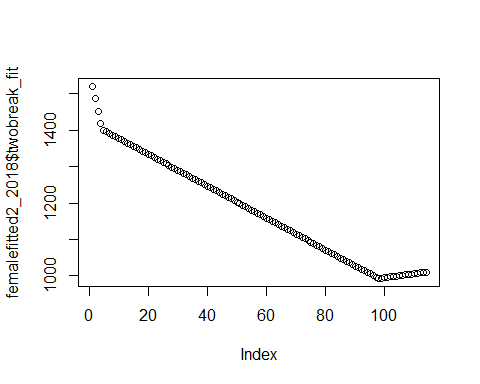
## df BIC  
## my.seg\_female\_2018 5 1097.434  
## my.seg\_female2\_2018 7 1082.503

## Generate and plot predicted values for two break model

tidied\_allagerates\_2018 %>%  
 filter(sex == "M") %>%   
 mutate(  
 twobreak\_fit = fitted(  
 my.seg\_male2\_2018   
   
 )  
 ) -> malefitted2\_2018  
  
tidied\_allagerates\_2018 %>%  
 filter(sex == "F") %>%   
 mutate(  
 twobreak\_fit = fitted(  
 my.seg\_female2\_2018   
  
 )  
 ) -> femalefitted2\_2018  
plot(malefitted2\_2018$twobreak\_fit)



plot(femalefitted2\_2018$twobreak\_fit)



## Combine male and female observed and predicted values for two break model

femalefitted2\_2018 %>%   
 select(  
 time, sex, observed = allageesprate,  
 predicted = twobreak\_fit  
 ) %>%   
 bind\_rows(  
 malefitted2\_2018 %>%   
 select(  
 time, sex, observed = allageesprate,  
 predicted = twobreak\_fit  
 )   
 ) -> obs\_fit\_both\_2018\_2break  
  
age <- "all"  
obs\_fit\_both\_2018\_2break$agegroup = age  
  
obs\_fit\_both\_2018\_2break

## time sex observed predicted agegroup  
## 1 1990.125 F 1500.4002 1520.3813 all  
## 2 1990.375 F 1499.6691 1485.9720 all  
## 3 1990.625 F 1485.5072 1451.5627 all  
## 4 1990.875 F 1386.2319 1417.1534 all  
## 5 1991.125 F 1370.9937 1399.9179 all  
## 6 1991.375 F 1361.9806 1395.5333 all  
## 7 1991.625 F 1356.4288 1391.1487 all  
## 8 1991.875 F 1359.8080 1386.7640 all  
## 9 1992.125 F 1358.5900 1382.3794 all  
## 10 1992.375 F 1349.7919 1377.9947 all  
## 11 1992.625 F 1354.0802 1373.6101 all  
## 12 1992.875 F 1341.5783 1369.2255 all  
## 13 1993.125 F 1345.6595 1364.8408 all  
## 14 1993.375 F 1360.0188 1360.4562 all  
## 15 1993.625 F 1364.8308 1356.0716 all  
## 16 1993.875 F 1418.0949 1351.6869 all  
## 17 1994.125 F 1405.8620 1347.3023 all  
## 18 1994.375 F 1379.5644 1342.9177 all  
## 19 1994.625 F 1375.9499 1338.5330 all  
## 20 1994.875 F 1300.4151 1334.1484 all  
## 21 1995.125 F 1297.1418 1329.7638 all  
## 22 1995.375 F 1306.8696 1325.3791 all  
## 23 1995.625 F 1290.6128 1320.9945 all  
## 24 1995.875 F 1318.1378 1316.6099 all  
## 25 1996.125 F 1331.4086 1312.2252 all  
## 26 1996.375 F 1315.3620 1307.8406 all  
## 27 1996.625 F 1313.5481 1303.4560 all  
## 28 1996.875 F 1298.2784 1299.0713 all  
## 29 1997.125 F 1298.3450 1294.6867 all  
## 30 1997.375 F 1300.6993 1290.3020 all  
## 31 1997.625 F 1295.1969 1285.9174 all  
## 32 1997.875 F 1281.7783 1281.5328 all  
## 33 1998.125 F 1257.4773 1277.1481 all  
## 34 1998.375 F 1258.5509 1272.7635 all  
## 35 1998.625 F 1263.7122 1268.3789 all  
## 36 1998.875 F 1269.1613 1263.9942 all  
## 37 1999.125 F 1311.4337 1259.6096 all  
## 38 1999.375 F 1293.5518 1255.2250 all  
## 39 1999.625 F 1284.3456 1250.8403 all  
## 40 1999.875 F 1287.8906 1246.4557 all  
## 41 2000.125 F 1271.4174 1242.0711 all  
## 42 2000.375 F 1266.3159 1237.6864 all  
## 43 2000.625 F 1255.7367 1233.3018 all  
## 44 2000.875 F 1218.2774 1228.9172 all  
## 45 2001.125 F 1184.0636 1224.5325 all  
## 46 2001.375 F 1183.1437 1220.1479 all  
## 47 2001.625 F 1184.4611 1215.7632 all  
## 48 2001.875 F 1196.2046 1211.3786 all  
## 49 2002.125 F 1184.5618 1206.9940 all  
## 50 2002.375 F 1187.8689 1202.6093 all  
## 51 2002.625 F 1193.4426 1198.2247 all  
## 52 2002.875 F 1201.8232 1193.8401 all  
## 53 2003.125 F 1208.8964 1189.4554 all  
## 54 2003.375 F 1206.3813 1185.0708 all  
## 55 2003.625 F 1200.5565 1180.6862 all  
## 56 2003.875 F 1212.9987 1176.3015 all  
## 57 2004.125 F 1208.5862 1171.9169 all  
## 58 2004.375 F 1198.9439 1167.5323 all  
## 59 2004.625 F 1193.3301 1163.1476 all  
## 60 2004.875 F 1157.2493 1158.7630 all  
## 61 2005.125 F 1158.8288 1154.3784 all  
## 62 2005.375 F 1161.1501 1149.9937 all  
## 63 2005.625 F 1153.4810 1145.6091 all  
## 64 2005.875 F 1139.0776 1141.2245 all  
## 65 2006.125 F 1115.7765 1136.8398 all  
## 66 2006.375 F 1119.0732 1132.4552 all  
## 67 2006.625 F 1116.6279 1128.0705 all  
## 68 2006.875 F 1112.5995 1123.6859 all  
## 69 2007.125 F 1137.7195 1119.3013 all  
## 70 2007.375 F 1114.5282 1114.9166 all  
## 71 2007.625 F 1105.6755 1110.5320 all  
## 72 2007.875 F 1114.6443 1106.1474 all  
## 73 2008.125 F 1092.5233 1101.7627 all  
## 74 2008.375 F 1100.2690 1097.3781 all  
## 75 2008.625 F 1103.1500 1092.9935 all  
## 76 2008.875 F 1111.2940 1088.6088 all  
## 77 2009.125 F 1102.7386 1084.2242 all  
## 78 2009.375 F 1083.6370 1079.8396 all  
## 79 2009.625 F 1072.0579 1075.4549 all  
## 80 2009.875 F 1056.1941 1071.0703 all  
## 81 2010.125 F 1047.4957 1066.6857 all  
## 82 2010.375 F 1044.9811 1062.3010 all  
## 83 2010.625 F 1045.5545 1057.9164 all  
## 84 2010.875 F 1036.2268 1053.5318 all  
## 85 2011.125 F 1025.3450 1049.1471 all  
## 86 2011.375 F 1022.5737 1044.7625 all  
## 87 2011.625 F 1013.3507 1040.3778 all  
## 88 2011.875 F 1006.8648 1035.9932 all  
## 89 2012.125 F 1001.1900 1031.6086 all  
## 90 2012.375 F 1013.4333 1027.2239 all  
## 91 2012.625 F 1019.3835 1022.8393 all  
## 92 2012.875 F 1034.0236 1018.4547 all  
## 93 2013.125 F 1047.2367 1014.0700 all  
## 94 2013.375 F 1042.9404 1009.6854 all  
## 95 2013.625 F 1026.8583 1005.3008 all  
## 96 2013.875 F 1004.2657 1000.9161 all  
## 97 2014.125 F 976.4886 996.5315 all  
## 98 2014.375 F 952.9044 993.2169 all  
## 99 2014.625 F 960.3534 994.2819 all  
## 100 2014.875 F 972.3775 995.3470 all  
## 101 2015.125 F 1021.1782 996.4120 all  
## 102 2015.375 F 1038.9698 997.4771 all  
## 103 2015.625 F 1038.4427 998.5421 all  
## 104 2015.875 F 1024.3997 999.6071 all  
## 105 2016.125 F 996.8737 1000.6722 all  
## 106 2016.375 F 984.0351 1001.7372 all  
## 107 2016.625 F 981.1454 1002.8023 all  
## 108 2016.875 F 988.3911 1003.8673 all  
## 109 2017.125 F 993.3512 1004.9323 all  
## 110 2017.375 F 996.1639 1005.9974 all  
## 111 2017.625 F 992.5277 1007.0624 all  
## 112 2017.875 F 997.5625 1008.1275 all  
## 113 2018.125 F 1033.7135 1009.1925 all  
## 114 2018.375 F 1024.6352 1010.2575 all  
## 115 1990.125 M 2287.7414 2294.4746 all  
## 116 1990.375 M 2271.7785 2259.0346 all  
## 117 1990.625 M 2252.7301 2223.5946 all  
## 118 1990.875 M 2114.4333 2188.1546 all  
## 119 1991.125 M 2090.4911 2155.5459 all  
## 120 1991.375 M 2081.5897 2146.4170 all  
## 121 1991.625 M 2074.8453 2137.2880 all  
## 122 1991.875 M 2077.0059 2128.1590 all  
## 123 1992.125 M 2084.4016 2119.0301 all  
## 124 1992.375 M 2067.2606 2109.9011 all  
## 125 1992.625 M 2076.6938 2100.7721 all  
## 126 1992.875 M 2077.7699 2091.6432 all  
## 127 1993.125 M 2071.4982 2082.5142 all  
## 128 1993.375 M 2096.5156 2073.3852 all  
## 129 1993.625 M 2097.2932 2064.2563 all  
## 130 1993.875 M 2155.2243 2055.1273 all  
## 131 1994.125 M 2139.6174 2045.9983 all  
## 132 1994.375 M 2106.8907 2036.8694 all  
## 133 1994.625 M 2077.2160 2027.7404 all  
## 134 1994.875 M 1974.0242 2018.6114 all  
## 135 1995.125 M 1966.1240 2009.4825 all  
## 136 1995.375 M 1955.0497 2000.3535 all  
## 137 1995.625 M 1952.0999 1991.2245 all  
## 138 1995.875 M 1978.8214 1982.0956 all  
## 139 1996.125 M 1999.1481 1972.9666 all  
## 140 1996.375 M 1999.1219 1963.8376 all  
## 141 1996.625 M 2008.3256 1954.7086 all  
## 142 1996.875 M 1987.5467 1945.5797 all  
## 143 1997.125 M 1955.7523 1936.4507 all  
## 144 1997.375 M 1946.9756 1927.3217 all  
## 145 1997.625 M 1917.5341 1918.1928 all  
## 146 1997.875 M 1903.7481 1909.0638 all  
## 147 1998.125 M 1879.1620 1899.9348 all  
## 148 1998.375 M 1873.6902 1890.8059 all  
## 149 1998.625 M 1880.6585 1881.6769 all  
## 150 1998.875 M 1866.5687 1872.5479 all  
## 151 1999.125 M 1933.5279 1863.4190 all  
## 152 1999.375 M 1898.8561 1854.2900 all  
## 153 1999.625 M 1875.1125 1845.1610 all  
## 154 1999.875 M 1889.8916 1836.0321 all  
## 155 2000.125 M 1858.1596 1826.9031 all  
## 156 2000.375 M 1852.9947 1817.7741 all  
## 157 2000.625 M 1824.3019 1808.6452 all  
## 158 2000.875 M 1776.4543 1799.5162 all  
## 159 2001.125 M 1733.1274 1790.3872 all  
## 160 2001.375 M 1725.3525 1781.2583 all  
## 161 2001.625 M 1740.1062 1772.1293 all  
## 162 2001.875 M 1735.9769 1763.0003 all  
## 163 2002.125 M 1711.8563 1753.8714 all  
## 164 2002.375 M 1720.0179 1744.7424 all  
## 165 2002.625 M 1719.2442 1735.6134 all  
## 166 2002.875 M 1741.0947 1726.4845 all  
## 167 2003.125 M 1750.0442 1717.3555 all  
## 168 2003.375 M 1755.8439 1708.2265 all  
## 169 2003.625 M 1751.5067 1699.0976 all  
## 170 2003.875 M 1751.8965 1689.9686 all  
## 171 2004.125 M 1734.9259 1680.8396 all  
## 172 2004.375 M 1704.1133 1671.7106 all  
## 173 2004.625 M 1684.8586 1662.5817 all  
## 174 2004.875 M 1645.9699 1653.4527 all  
## 175 2005.125 M 1648.6899 1644.3237 all  
## 176 2005.375 M 1643.5641 1635.1948 all  
## 177 2005.625 M 1623.2456 1626.0658 all  
## 178 2005.875 M 1600.9223 1616.9368 all  
## 179 2006.125 M 1578.2453 1607.8079 all  
## 180 2006.375 M 1574.8997 1598.6789 all  
## 181 2006.625 M 1560.9849 1589.5499 all  
## 182 2006.875 M 1549.6572 1580.4210 all  
## 183 2007.125 M 1560.8716 1571.2920 all  
## 184 2007.375 M 1556.7835 1562.1630 all  
## 185 2007.625 M 1556.3819 1553.0341 all  
## 186 2007.875 M 1568.3305 1543.9051 all  
## 187 2008.125 M 1544.6720 1534.7761 all  
## 188 2008.375 M 1529.1838 1525.6472 all  
## 189 2008.625 M 1515.1621 1516.5182 all  
## 190 2008.875 M 1517.6631 1507.3892 all  
## 191 2009.125 M 1508.1118 1498.2603 all  
## 192 2009.375 M 1483.4906 1489.1313 all  
## 193 2009.625 M 1478.2422 1480.0023 all  
## 194 2009.875 M 1444.0035 1470.8734 all  
## 195 2010.125 M 1435.0434 1461.7444 all  
## 196 2010.375 M 1426.8991 1452.6154 all  
## 197 2010.625 M 1413.6407 1443.4865 all  
## 198 2010.875 M 1422.4929 1434.3575 all  
## 199 2011.125 M 1408.4984 1425.2285 all  
## 200 2011.375 M 1402.1113 1416.0995 all  
## 201 2011.625 M 1406.9538 1406.9706 all  
## 202 2011.875 M 1377.9585 1397.8416 all  
## 203 2012.125 M 1357.0982 1388.7126 all  
## 204 2012.375 M 1366.8424 1379.5837 all  
## 205 2012.625 M 1353.0283 1370.4547 all  
## 206 2012.875 M 1356.8340 1361.3257 all  
## 207 2013.125 M 1375.5554 1352.1968 all  
## 208 2013.375 M 1369.2158 1343.0678 all  
## 209 2013.625 M 1354.2704 1333.9388 all  
## 210 2013.875 M 1344.8635 1327.5201 all  
## 211 2014.125 M 1312.9867 1328.4510 all  
## 212 2014.375 M 1290.4061 1329.3819 all  
## 213 2014.625 M 1300.2353 1330.3129 all  
## 214 2014.875 M 1310.9825 1331.2438 all  
## 215 2015.125 M 1362.1791 1332.1747 all  
## 216 2015.375 M 1381.3043 1333.1057 all  
## 217 2015.625 M 1382.2152 1334.0366 all  
## 218 2015.875 M 1371.2413 1334.9675 all  
## 219 2016.125 M 1341.7542 1335.8985 all  
## 220 2016.375 M 1325.4592 1336.8294 all  
## 221 2016.625 M 1322.5719 1337.7603 all  
## 222 2016.875 M 1326.3755 1338.6913 all  
## 223 2017.125 M 1324.8449 1339.6222 all  
## 224 2017.375 M 1324.8598 1340.5531 all  
## 225 2017.625 M 1318.6081 1341.4841 all  
## 226 2017.875 M 1329.0268 1342.4150 all  
## 227 2018.125 M 1364.0444 1343.3459 all  
## 228 2018.375 M 1354.7984 1344.2769 all

# Extract breakpoint and calcuate 95% confidence intervals for two break model

#CI for first male breakpoint  
breakpoint1male\_2018\_2break <- my.seg\_male2\_2018$psi[3]  
breakpoint1\_SEmale\_2018\_2break <- my.seg\_male2\_2018$psi[5]  
breakpoint1male\_lowCI\_2018\_2break <- breakpoint1male\_2018\_2break - (breakpoint1\_SEmale\_2018\_2break\*1.96)  
breakpoint1male\_upCI\_2018\_2break <- breakpoint1male\_2018\_2break + (breakpoint1\_SEmale\_2018\_2break\*1.96)  
  
breakpoint1male\_2018\_2break

## [1] 1991.098

breakpoint1male\_lowCI\_2018\_2break

## [1] 1990.317

breakpoint1male\_upCI\_2018\_2break

## [1] 1991.879

#CI for second male breakpoint  
breakpoint2male\_2018\_2break <- my.seg\_male2\_2018$psi[4]  
breakpoint2\_SEmale\_2018\_2break <- my.seg\_male2\_2018$psi[6]  
breakpoint2male\_lowCI\_2018\_2break <- breakpoint2male\_2018\_2break - (breakpoint2\_SEmale\_2018\_2break\*1.96)  
breakpoint2male\_upCI\_2018\_2break <- breakpoint2male\_2018\_2break + (breakpoint2\_SEmale\_2018\_2break\*1.96)  
  
breakpoint2male\_2018\_2break

## [1] 2013.808

breakpoint2male\_lowCI\_2018\_2break

## [1] 2012.96

breakpoint2male\_upCI\_2018\_2break

## [1] 2014.655

#CI for first female breakpoint  
breakpoint1female\_2018\_2break <- my.seg\_female2\_2018$psi[3]  
breakpoint1\_SEfemale\_2018\_2break <- my.seg\_female2\_2018$psi[5]  
breakpoint1female\_lowCI\_2018\_2break <- breakpoint1female\_2018\_2break - (breakpoint1\_SEfemale\_2018\_2break\*1.96)  
breakpoint1female\_upCI\_2018\_2break <- breakpoint1female\_2018\_2break + (breakpoint1\_SEfemale\_2018\_2break\*1.96)  
  
breakpoint1female\_2018\_2break

## [1] 1990.982

breakpoint1female\_lowCI\_2018\_2break

## [1] 1990.57

breakpoint1female\_upCI\_2018\_2break

## [1] 1991.394

breakpoint2female\_2018\_2break <- my.seg\_female2\_2018$psi[4]  
breakpoint2\_SEfemale\_2018\_2break <- my.seg\_female2\_2018$psi[6]  
breakpoint2female\_lowCI\_2018\_2break <- breakpoint2female\_2018\_2break - (breakpoint2\_SEfemale\_2018\_2break\*1.96)  
breakpoint2female\_upCI\_2018\_2break <- breakpoint2female\_2018\_2break + (breakpoint2\_SEfemale\_2018\_2break\*1.96)  
  
breakpoint2female\_2018\_2break

## [1] 2014.326

breakpoint2female\_lowCI\_2018\_2break

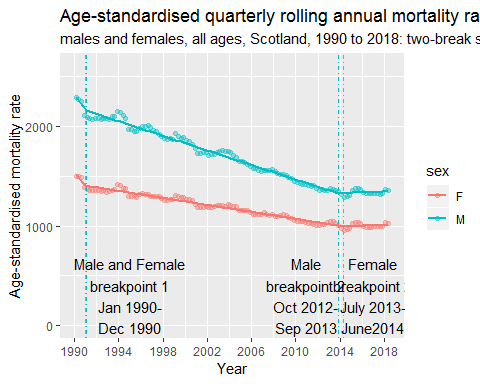
## [1] 2013.174

breakpoint2female\_upCI\_2018\_2break

## [1] 2015.478

## 2 break segmented plot

segmentedplot\_allage2break <- obs\_fit\_both\_2018\_2break %>%   
 ggplot(  
 aes (x=time, color=sex)  
 ) +  
 geom\_point(  
 aes (y=observed), alpha=0.4)+  
 geom\_line (  
 aes (y=predicted), size=1) +  
 ylim(0,2600)+  
 labs(x="Year", y="Age-standardised mortality rate", title = "Age-standardised quarterly rolling annual mortality rates", subtitles="males and females, all ages, Scotland, 1990 to 2018: two-break segmented model fitted")+  
 scale\_x\_continuous (breaks=c(1990, 1994, 1998, 2002, 2006, 2010, 2014, 2018))+   
 geom\_vline(xintercept = my.seg\_male2\_2018[["psi"]][[4]], color = "#00BFC4", linetype="dotdash")+  
 geom\_vline(xintercept = my.seg\_female2\_2018[["psi"]][[4]], color = "#F8766D", linetype="dotdash") +  
 geom\_vline(xintercept = my.seg\_male2\_2018[["psi"]][[3]], color = "#00BFC4", linetype="dotdash")+  
 geom\_vline(xintercept = my.seg\_female2\_2018[["psi"]][[3]], color = "#F8766D", linetype="dotdash") +  
 annotate(geom="text", x=2011, y=300, label="Male\nbreakpoint 2\nOct 2012-\n Sep 2013 ")+  
 annotate(geom="text", x=2017, y=300, label="Female\nbreakpoint 2\nJuly 2013-\nJune2014")+  
 annotate(geom="text", x=1995, y=300, label="Male and Female\nbreakpoint 1\nJan 1990-\nDec 1990")  
  
segmentedplot\_allage2break

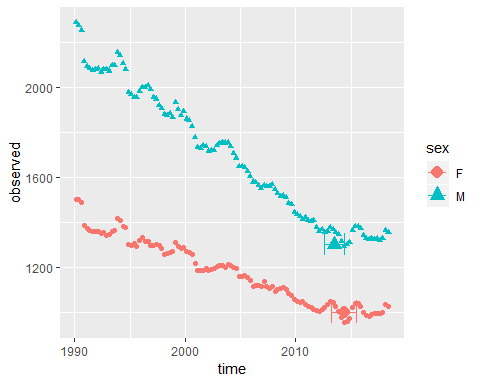


ggsave (  
 "Figures/segmentedplotonly\_Scotland\_Allages\_2break.png", height=15, width=20, units="cm")

## Errorbar plot

Alternative way to indicate breakpoint, employing a point with error bars to indicate 95% confidence interval.

obs\_fit\_both\_2018 <- as\_tibble(obs\_fit\_both\_2018) # convert to 'nice' tibble format (better display)  
  
temp\_data <- tribble(  
 ~ sex, ~time\_min, ~time\_max, ~y\_pos,   
 "M", breakpointmale\_2018 - 2 \* breakpoint\_SEmale\_2018, breakpointmale\_2018 + 2 \* breakpoint\_SEmale\_2018, 1300,  
 "F", breakpointfemale\_2018 - 2 \* breakpoint\_SEfemale\_2018, breakpointfemale\_2018 + 2 \* breakpoint\_SEfemale\_2018, 1000   
)  
  
  
obs\_fit\_both\_2018 %>%   
 ggplot(  
 aes(x = time, y = observed, color = sex, shape = sex)  
 ) +   
 geom\_point(aes(y=observed)) +  
 geom\_errorbarh(  
 aes(xmin = time\_min, xmax = time\_max, y = y\_pos, colour = sex),  
 inherit.aes = F,   
 height = 100,  
 data = temp\_data  
 ) +  
 geom\_point(  
 aes(x = brkpoint, y = y\_pos, shape = sex, color = sex),  
 inherit.aes = F,  
 data = tribble(  
 ~ sex, ~brkpoint, ~y\_pos,  
 "M", breakpointmale\_2018, 1300,  
 "F", breakpointfemale\_2018, 1000  
 ),  
 size = 4  
 )



# Summary of breakpoints as box-and-whisker charts

load("summary\_stats\_75andover.rdata") # for 75 and over  
load("summary\_stats\_under75.rdata")  
  
breakpoint\_summaries\_allage <- tribble(  
 ~gender, ~num\_breaks, ~break\_num, ~lower, ~upper, ~point,  
 "Female", "One", 1, breakpoint\_low\_CIfemale\_2018, breakpoint\_up\_CIfemale\_2018, breakpointfemale\_2018,  
 "Male", "One", 1, breakpoint\_low\_CImale\_2018, breakpoint\_up\_CImale\_2018, breakpointmale\_2018,  
 "Female", "Two", 1, breakpoint1female\_lowCI\_2018\_2break[1], breakpoint1female\_upCI\_2018\_2break[1], breakpoint1female\_2018\_2break[1],  
 "Female", "Two", 2, breakpoint2female\_lowCI\_2018\_2break[1], breakpoint2female\_upCI\_2018\_2break[1], breakpoint2female\_2018\_2break[1],  
 "Male", "Two", 1, breakpoint1male\_lowCI\_2018\_2break[1], breakpoint1male\_upCI\_2018\_2break[1], breakpoint1male\_2018\_2break[1],  
 "Male", "Two", 2, breakpoint2male\_lowCI\_2018\_2break[1], breakpoint2male\_upCI\_2018\_2break[1], breakpoint2male\_2018\_2break[1]  
)  
  
breakpoint\_summaries\_over75 <- tribble(  
 ~gender, ~num\_breaks, ~break\_num, ~lower, ~upper, ~point,  
 "Female", "One", 1, breakpoint\_low\_CIfemale\_O75, breakpoint\_up\_CIfemale\_O75, breakpointfemale\_O75,  
 "Male", "One", 1, breakpoint\_low\_CImale\_O75, breakpoint\_up\_CImale\_O75, breakpointmale\_O75,  
 "Female", "Two", 1, breakpoint\_low\_CIfemale\_O75\_2break[1], breakpoint\_up\_CIfemale\_O75\_2break[1], breakpointfemale\_O75\_2break[1],  
 "Female", "Two", 2, breakpoint\_low\_CIfemale\_O75\_2break[2], breakpoint\_up\_CIfemale\_O75\_2break[2], breakpointfemale\_O75\_2break[2],  
 "Male", "Two", 1, breakpoint\_low\_CImale\_O75\_2break[1], breakpoint\_up\_CImale\_O75\_2break[1], breakpointmale\_O75\_2break[1],  
 "Male", "Two", 2, breakpoint\_low\_CImale\_O75\_2break[2], breakpoint\_up\_CImale\_O75\_2break[2], breakpointmale\_O75\_2break[2]  
)  
  
breakpoint\_summaries\_upto75 <- tribble(  
 ~gender, ~num\_breaks, ~break\_num, ~lower, ~upper, ~point,  
 "Female", "One", 1, breakpoint\_low\_CIfemale\_U75, breakpoint\_up\_CIfemale\_U75, breakpointfemale\_U75,  
 "Male", "One", 1, breakpoint\_low\_CImale\_U75, breakpoint\_up\_CImale\_U75, breakpointmale\_U75,  
 "Female", "Two", 1, breakpoint\_low\_CIfemale\_U75\_2break[1], breakpoint\_up\_CIfemale\_U75\_2break[1], breakpointfemale\_U75\_2break[1],  
 "Female", "Two", 2, breakpoint\_low\_CIfemale\_U75\_2break[2], breakpoint\_up\_CIfemale\_U75\_2break[2], breakpointfemale\_U75\_2break[2],  
 "Male", "Two", 1, breakpoint\_low\_CImale\_U75\_2break[1], breakpoint\_up\_CImale\_U75\_2break[1], breakpointmale\_U75\_2break[1],  
 "Male", "Two", 2, breakpoint\_low\_CImale\_U75\_2break[2], breakpoint\_up\_CImale\_U75\_2break[2], breakpointmale\_U75\_2break[2]  
)  
  
  
breakpoint\_summaries\_allage

## # A tibble: 6 x 6  
## gender num\_breaks break\_num lower upper point  
## <chr> <chr> <dbl> <dbl> <dbl> <dbl>  
## 1 Female One 1 2013. 2016. 2014.  
## 2 Male One 1 2013. 2014. 2013.  
## 3 Female Two 1 1991. 1991. 1991.  
## 4 Female Two 2 2013. 2015. 2014.  
## 5 Male Two 1 1990. 1992. 1991.  
## 6 Male Two 2 2013. 2015. 2014.

breakpoint\_summaries\_over75

## # A tibble: 6 x 6  
## gender num\_breaks break\_num lower upper point  
## <chr> <chr> <dbl> <dbl> <dbl> <dbl>  
## 1 Female One 1 2013. 2017. 2015.  
## 2 Male One 1 2013. 2015. 2014.  
## 3 Female Two 1 1996. 2003. 1999.  
## 4 Female Two 2 2013. 2016. 2014.  
## 5 Male Two 1 1992. 1995. 1994.  
## 6 Male Two 2 2012. 2014. 2013.

breakpoint\_summaries\_upto75

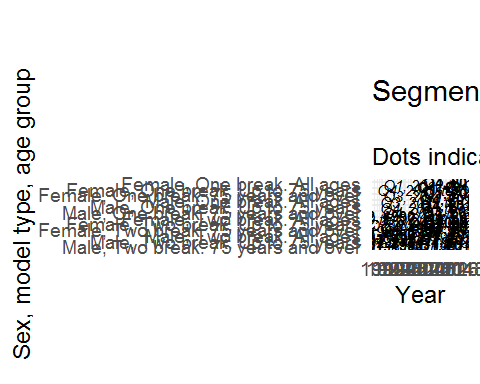
## # A tibble: 6 x 6  
## gender num\_breaks break\_num lower upper point  
## <chr> <chr> <dbl> <dbl> <dbl> <dbl>  
## 1 Female One 1 2012. 2013. 2013.  
## 2 Male One 1 2013. 2014. 2013.  
## 3 Female Two 1 2007. 2012. 2009.  
## 4 Female Two 2 2014. 2016. 2015.  
## 5 Male Two 1 1993. 1995. 1994.  
## 6 Male Two 2 2012. 2013. 2013.

breakpoint\_summaries\_all <- breakpoint\_summaries\_allage %>%   
 mutate(age\_group = "All ages") %>%   
 bind\_rows(  
 breakpoint\_summaries\_over75 %>% mutate(age\_group = "75 years and over")  
 ) %>%   
 bind\_rows(  
 breakpoint\_summaries\_upto75 %>% mutate(age\_group = "Up to 75 years")  
 )  
  
breakpoint\_summaries\_all <- breakpoint\_summaries\_all %>%   
 mutate(age\_group = factor(age\_group, levels = c("All ages", "Up to 75 years", "75 years and over")))

Now let’s visualise this

Now let’s think about labelling/describing to take into account the use of quarterly rolling values

write\_yearquarter <- function(x){  
 df <- data\_frame(  
 x = x, floor = floor(x)  
 ) %>%   
 mutate(remainder = x - floor) %>%   
 mutate(quarter = 1 + floor(4 \* remainder)) %>%   
 mutate(label = paste0("Q", quarter, ", ", floor))   
   
 pull(df, label)  
}  
  
breakpoint\_summaries\_all %>%   
 arrange(num\_breaks, gender, age\_group) %>%   
 mutate(model\_name = paste0(gender, ", ", num\_breaks, " break. ", age\_group)) %>%   
 mutate(rownum = row\_number()) %>%   
 mutate(model\_name = fct\_reorder(model\_name, rownum, .desc = TRUE)) %>%   
 mutate(  
 lower\_label = write\_yearquarter(lower - 1),  
 upper\_label = write\_yearquarter(upper),  
 point\_label = write\_yearquarter(point - 0.5),  
 both\_label = paste0(lower\_label, " to ", upper\_label)  
 ) %>%   
 ggplot(aes(y = model\_name)) +   
 geom\_point(aes(x = point)) +   
 geom\_segment(aes(yend = model\_name, x = lower, xend = upper)) +   
 theme\_minimal(base\_size = 18) +   
 labs(  
 x = "Year", y = "Sex, model type, age group",  
 title = "Segmented regression of age-standardised mortality rates for Scotland:  
 breakpoint estimates for males and females, one and two break models",  
 subtitle = "Dots indicate point estimates; lines indicate 95% confidence interval"  
 ) +  
 coord\_fixed(ratio = 2) +   
 geom\_text(aes(x = point, label = point\_label), nudge\_y = 0.3, fontface = "bold") +   
 geom\_text(aes(x = point, label = both\_label), nudge\_y = -0.2, fontface = "italic") +  
 scale\_x\_continuous(limits = c(1988, 2018), breaks = seq(1990, 2018, by = 2), minor\_breaks = seq(1984, 2018, by = 1))



ggsave("figures/breakpoint\_timeline.png", width = 50, height = 30, dpi = 300, units = "cm")

This might be a bit of a Phyrric victory, but seems to do the job.