

# Homework #5: Customer Retention

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## Grading Note

This HW is worth 16 points in total. I've made notes in this document where those points were earned.

## Objectives & setup

- Homework tasks:
  - Estimate a model of customer churn from a cell phone carrier – Data for the homework is contained in `cellphone_churn.csv`, 1 observation (row) per customer – Customers in the dataset are subscribers to the carrier's unlimited talk plan – Unlimited plan subscribers have a 1 year contract – We observe some customer demographics, service usage metrics, and whether the customer cancelled the contract at the end of the term (`churn=1`) or renewed the service for another year (`churn = 0`) – For an active customer, the carrier makes \$40 per month in profit (\$480 per year)
  - Evaluate the profitability of various retention efforts

The variables in the `cellphone_churn.csv` are:

Variable	Description
id	Identifier for customer
male	(=1 if customer is male)
age	Customer age (years)
usage	Average number of minutes of call time per month
dropped_calls	Total number of dropped calls (year)
callcenter_waittime	Total number of minutes spent on hold for customer service (year)

## Read in the data

To begin, load the customer data into a dataframe named `DF`. Use `head()` and `summary()` to visualize the first few rows and to summarize the variables. **(2 points)**

```
DF<-read.csv("/Users/raveena/Desktop/Classroom - R/Marketing Analytics/data/cellphone_churn.csv")
head(DF)
```

```
##   id male age usage dropped_calls callcenter_waittime churn
## 1  1    1  49 643.0           0             0           0
## 2  2    0  61 733.8           0             0           0
## 3  3    0  52 786.0           0             0           0
## 4  4    0  58 666.5           0             5           0
## 5  5    1  46 778.6           1             0           0
## 6  6    1  39 976.2           0             0           0
```

```
summary(DF)
```

```
##           id           male           age           usage
## Min.      : 1.0    Min.      :0.000    Min.      : 9.00    Min.      : 17.5
## 1st Qu.: 250.8    1st Qu.:0.000    1st Qu.:35.00    1st Qu.: 563.4
## Median : 500.5    Median :0.000    Median :43.00    Median : 707.5
## Mean      : 500.5    Mean      :0.436    Mean      :43.17    Mean      : 702.5
## 3rd Qu.: 750.2    3rd Qu.:1.000    3rd Qu.:51.00    3rd Qu.: 849.0
## Max.      :1000.0    Max.      :1.000    Max.      :78.00    Max.      :1377.8
## dropped_calls  callcenter_waittime    churn
## Min.      :0.000    Min.      : 0.000    Min.      :0.000
## 1st Qu.:0.000    1st Qu.: 0.000    1st Qu.:0.000
## Median :0.000    Median : 0.000    Median :0.000
## Mean      :0.354    Mean      : 3.228    Mean      :0.111
## 3rd Qu.:1.000    3rd Qu.: 0.000    3rd Qu.:0.000
## Max.      :4.000    Max.      :47.000    Max.      :1.000
```

```
mean(DF$churn)
```

```
## [1] 0.111
```

What is the churn rate among the sampled customers? (1 point)

Ans : 11%

## Question 2

Estimate a model of churn (DV = churn) with male, age, usage, dropped\_calls and callcenter\_waittime as predictor variables. (1 point)

What is the coefficient of age, and how do you interpret it? (1 point)

```
churn_model <- glm(churn ~ male + age + usage + dropped_calls + callcenter_waittime, data=DF, family='binomial')
summary(churn_model)
```

```
##
## Call:
## glm(formula = churn ~ male + age + usage + dropped_calls + callcenter_waittime,
##      family = "binomial", data = DF)
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    3.0988705  0.6930385   4.471 7.77e-06 ***
## male           0.6346920  0.2405113   2.639 0.00832 **
## age          -0.1010797  0.0128768  -7.850 4.17e-15 ***
## usage         -0.0034430  0.0006174  -5.576 2.45e-08 ***
## dropped_calls   0.4451409  0.1801266   2.471 0.01346 *
## callcenter_waittime 0.1012823  0.0119499   8.476 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
```

```
##
## Null deviance: 697.20 on 999 degrees of freedom
## Residual deviance: 511.08 on 994 degrees of freedom
## AIC: 523.08
##
## Number of Fisher Scoring iterations: 6
```

Answer here - Coefficient of age is -0.1011 which means in general, as age increases fewer people churn. In logistic regression it means with one year increase in age the log odds of churning decreases by 0.1011.

### Question 3

Which of the explanatory variables is the biggest driver of churn (i.e., which variable is responsible for the most variation in predicted churn rates)? **(3 points)**

*Hint: create table of coefficients, delta X, delta prob*

```
stddev = rep(0,5)
stddev[1] = 1
stddev[2] = sd(DF$age)
stddev[3] = sd(DF$usage)
stddev[4] = sd(DF$dropped_calls)
stddev[5] = sd(DF$callcenter_waittime)

summary_coefs <- coef(summary(churn_model))
coef_values <- summary_coefs[, 1]

table <- data.frame(Coefficients = coef_values[-1], Delta_X = stddev)
table$delta_prob <- table$Coefficients * table$Delta_X

print(table)
```

```
##                Coefficients      Delta_X delta_prob
## male                0.6346920      1.0000000  0.6346920
## age               -0.1010797     11.2873604 -1.1409234
## usage             -0.0034430    206.3294914 -0.7103925
## dropped_calls       0.4451409      0.6124207  0.2726135
## callcenter_waittime 0.1012823      7.6477777  0.7745849
```

Answer here : Age is responsible for highest variation.

### Question 4

Which of the following statements from our analysis of the drivers of churn is TRUE? **Multiple can be TRUE (1 point)**

1. In the future, acquiring a higher proportion of older, female customers will lead to lower churn rates
2. In the future, acquiring a higher proportion of younger, female customers will lead to lower churn rates
3. Reducing call center wait times is the most effective actionable method to reduce churn rates for existing customers.

Answer here - 1 & 3

## Question 5

Calculate the expected CLV of each customer in the sample. For the calculation, assume the following: (2 points)

- annual discount rate =  $r = 0.1$
- CLV horizon = `horizon` = 5 years (0,1,. . . ,4)
- annual per-customer profit, if retained = `profit` = \$480
- each customer's retention rate =  $RR = 1 - \text{predicted churn rate}$
- retention rates remain constant over time, so use the `CLV_simple()` function we've developed

```
predicted_churn_rate <- predict(churn_model, newdata = DF, type = "response")
profit<-480
horizon<- 5
r<-0.1
RR<- 1- predicted_churn_rate

CLV_simple <- function(profit, retention, r, horizon) {
  clv = 0
  for (t in 0:(horizon-1)) {
    clv = clv + profit * (retention/(1+r))^t
  }
  return(clv)
}

CLV_simple(profit = profit,
            retention = RR,
            r = r,
            horizon = horizon)
```

##	1	2	3	4	5	6	7	8
##	1891.5479	1988.1474	1973.9687	1964.1025	1858.5854	1904.8330	588.7898	635.5231
##	9	10	11	12	13	14	15	16
##	1989.7538	1995.2586	1829.6095	1727.0520	1682.5368	1985.4946	1965.8007	1915.8482
##	17	18	19	20	21	22	23	24
##	1273.5647	1975.8226	1677.8303	974.6632	1940.2392	808.1407	1795.2072	1873.7603
##	25	26	27	28	29	30	31	32
##	1367.9643	1844.9979	1835.9699	1637.7036	1854.5198	1826.8999	1957.6353	1839.3043
##	33	34	35	36	37	38	39	40
##	1963.7921	1812.1688	1269.7794	1962.5124	1823.0528	1668.5030	1721.6706	1219.3103
##	41	42	43	44	45	46	47	48
##	1803.8993	1719.2735	1582.8041	1754.2044	1923.9866	1989.4482	1944.5459	1722.6953
##	49	50	51	52	53	54	55	56
##	1981.4474	1886.9003	1994.9012	1730.7647	1977.1666	1930.4104	1974.2194	1609.5929
##	57	58	59	60	61	62	63	64
##	1240.8597	1982.0913	1769.2247	1994.4281	1960.9724	1463.8972	1821.4783	1893.1866
##	65	66	67	68	69	70	71	72
##	1835.4938	1836.6487	1938.5063	1993.4042	1913.5986	1962.1488	1857.9510	1937.6807
##	73	74	75	76	77	78	79	80
##	1970.6494	1970.0631	1037.6636	1706.3584	1931.8607	1835.0694	1572.7580	1957.9694
##	81	82	83	84	85	86	87	88
##	1308.0131	1828.3852	1261.7786	1884.8909	1595.4140	1628.2422	1695.9979	1968.9438

##	89	90	91	92	93	94	95	96
##	1034.6016	1847.7488	1322.1573	1674.1020	1406.2995	1086.5672	1948.1743	1960.3449
##	97	98	99	100	101	102	103	104
##	1773.5958	1864.9513	1216.4521	1425.6846	1590.4738	1834.9518	1817.1190	1458.8123
##	105	106	107	108	109	110	111	112
##	1191.0074	1964.0511	1692.0912	1127.6400	1699.0283	1976.9764	1985.4626	1958.8131
##	113	114	115	116	117	118	119	120
##	1492.6219	1879.9294	1855.5432	1967.0987	1746.4736	1837.7277	1570.9739	1816.4222
##	121	122	123	124	125	126	127	128
##	1948.4978	1894.5022	1993.1007	1957.2874	1707.5330	1971.0498	1935.2986	1167.3972
##	129	130	131	132	133	134	135	136
##	1990.1097	1694.6203	1981.5741	1837.1054	1993.7693	1925.1577	1717.1520	1966.2008
##	137	138	139	140	141	142	143	144
##	884.4482	1894.1214	1926.4091	1695.9887	1685.8392	1986.3693	1772.4665	1897.1496
##	145	146	147	148	149	150	151	152
##	1830.2310	1954.2833	1343.3137	1904.8571	1919.5526	1962.9050	1956.0009	1837.5467
##	153	154	155	156	157	158	159	160
##	1992.3918	1827.6930	1986.6049	1842.9542	538.3579	1591.5586	742.4581	1934.9288
##	161	162	163	164	165	166	167	168
##	1953.0430	1821.2250	1640.8515	1909.1850	772.8249	1962.9223	1091.9282	1076.9913
##	169	170	171	172	173	174	175	176
##	1400.1349	1956.9697	1926.1053	1704.0790	1612.1993	1758.6601	1917.7538	1807.4833
##	177	178	179	180	181	182	183	184
##	1596.8044	1893.9197	1902.7519	1874.6583	1970.3669	1981.6278	1951.6885	1898.0789
##	185	186	187	188	189	190	191	192
##	839.1141	1980.7271	1969.6610	1813.4588	1819.1517	985.4485	898.7619	1942.8049
##	193	194	195	196	197	198	199	200
##	1956.2410	1940.0943	1472.9794	1954.7839	1894.4523	488.3430	1975.7185	1900.7781
##	201	202	203	204	205	206	207	208
##	1918.1166	1902.9689	663.1309	1502.2767	958.5294	1601.9156	1952.3034	1991.7533
##	209	210	211	212	213	214	215	216
##	1987.4627	1904.7075	1877.4091	1014.1471	1874.3846	1960.1731	1674.2545	1912.9275
##	217	218	219	220	221	222	223	224
##	1918.7879	1442.7828	1549.2997	1506.4906	656.8453	1965.8253	1858.8405	1098.8625
##	225	226	227	228	229	230	231	232
##	1887.5944	1200.1172	1850.6892	1974.4787	1382.2702	1286.4073	1826.9223	1318.2844
##	233	234	235	236	237	238	239	240
##	1610.5403	1882.2042	1933.1786	1015.1344	1932.9382	1401.2062	1986.7614	1892.4251
##	241	242	243	244	245	246	247	248
##	1729.1013	1736.3246	1871.6577	1390.3370	1942.8835	1294.9435	1742.0837	1034.2202
##	249	250	251	252	253	254	255	256
##	1871.0433	1060.9814	1983.9085	1855.8497	1870.3014	1974.3140	842.2385	1263.5778
##	257	258	259	260	261	262	263	264
##	1705.3716	1994.5944	1905.0938	1330.2907	1613.2546	523.6587	1905.9573	755.2775
##	265	266	267	268	269	270	271	272
##	742.4637	1995.1623	1505.3309	1295.4658	1961.7763	1414.3509	1982.5638	1929.0958
##	273	274	275	276	277	278	279	280
##	1881.5392	1807.1927	1749.7280	1986.6764	1996.8921	1220.9528	1923.3556	1756.1759
##	281	282	283	284	285	286	287	288
##	1556.9048	1972.2850	1943.9637	1654.3680	1425.2891	1970.0045	918.1762	585.2594
##	289	290	291	292	293	294	295	296
##	1430.3700	1820.6508	1859.0735	1356.7232	1963.9772	1963.9364	1812.6823	1762.6197
##	297	298	299	300	301	302	303	304
##	1973.2978	1975.8676	1954.4350	1972.5229	1624.7544	1416.5311	1691.3404	1834.4403

##	305	306	307	308	309	310	311	312
##	1651.5648	1727.4195	1884.8910	1853.6240	1667.0847	1965.3351	1687.7972	1880.1209
##	313	314	315	316	317	318	319	320
##	1709.0122	1652.2259	1970.3719	1951.3274	1911.9372	1128.5656	1797.3674	1911.9644
##	321	322	323	324	325	326	327	328
##	1923.0843	1961.5211	1977.1635	1830.9052	1814.0380	1810.4180	1421.2271	1947.0850
##	329	330	331	332	333	334	335	336
##	1768.9308	1718.3932	1938.6319	1907.0984	862.8767	1953.7756	1909.3706	1400.4187
##	337	338	339	340	341	342	343	344
##	1640.5788	1282.5294	1658.1231	1925.5193	1789.3682	937.3529	1988.5897	1847.3596
##	345	346	347	348	349	350	351	352
##	1975.0070	1988.1502	1399.3073	1776.9380	1963.3093	1579.3121	1647.2478	1789.8262
##	353	354	355	356	357	358	359	360
##	1692.2075	1724.2285	1982.2348	1861.1536	1502.1750	1615.3913	1970.9817	1955.9221
##	361	362	363	364	365	366	367	368
##	1953.2690	1691.1189	1914.3049	1681.9937	1992.8467	1937.0389	997.9310	769.3835
##	369	370	371	372	373	374	375	376
##	1531.3113	1997.5959	1730.3299	1976.5645	1969.8073	1768.0294	1928.1174	1912.6812
##	377	378	379	380	381	382	383	384
##	1835.7049	1877.8749	536.4845	1419.3921	1791.1934	1768.5579	1885.6208	1923.7877
##	385	386	387	388	389	390	391	392
##	1951.3189	1968.5477	1944.4937	1805.3244	1500.4871	944.1575	1887.3529	1191.4695
##	393	394	395	396	397	398	399	400
##	1418.7783	1858.1640	1993.9842	838.9451	1548.0605	1344.8303	1962.0299	1381.2573
##	401	402	403	404	405	406	407	408
##	1984.1235	1479.1033	1804.5835	1853.1869	1675.3156	1818.1476	1638.5744	797.0947
##	409	410	411	412	413	414	415	416
##	1862.3092	1799.4794	1818.3772	1365.9255	1959.4722	1938.1931	1592.2405	1960.7300
##	417	418	419	420	421	422	423	424
##	1698.6471	1769.0821	1113.9622	1586.4306	1705.4697	1646.3978	1914.5093	1307.4502
##	425	426	427	428	429	430	431	432
##	1745.5350	1927.9342	1929.3343	1932.0373	1989.4475	1868.3895	1944.1531	1649.7049
##	433	434	435	436	437	438	439	440
##	1845.4196	1828.5626	1958.4234	1987.6445	1745.7664	1985.9902	1353.5285	1970.5402
##	441	442	443	444	445	446	447	448
##	1603.6625	1445.6463	1779.5407	1819.1995	884.2781	1638.3348	1969.2760	1967.8916
##	449	450	451	452	453	454	455	456
##	1181.6702	1994.0699	1880.6727	1924.5686	1813.6872	1875.1013	1807.7797	1260.9216
##	457	458	459	460	461	462	463	464
##	1957.0747	1988.4918	1997.3070	1955.6011	1467.7070	1998.3173	1674.1593	1993.8437
##	465	466	467	468	469	470	471	472
##	1941.8856	1503.0905	1932.4506	1945.2924	1951.0110	886.6632	1833.6620	1403.1711
##	473	474	475	476	477	478	479	480
##	1378.2797	1835.2255	1881.3565	1926.1873	810.0101	1844.5204	1829.7017	1908.2636
##	481	482	483	484	485	486	487	488
##	1985.8668	629.6284	1095.7999	1995.2193	1761.7118	1732.1019	1937.4190	1930.9374
##	489	490	491	492	493	494	495	496
##	1186.4423	1288.4318	1991.1194	1297.6306	1959.0673	1962.2797	1853.2316	1950.2970
##	497	498	499	500	501	502	503	504
##	1905.3234	1409.5674	677.0672	1897.1313	1934.6151	1954.4574	1722.1877	1953.6383
##	505	506	507	508	509	510	511	512
##	1814.2270	1456.0099	1803.3723	1990.0497	1900.6278	1287.6417	1094.4741	1606.6291
##	513	514	515	516	517	518	519	520
##	1473.6598	1965.1232	1805.9789	1868.8095	1779.5315	1969.8884	1800.5681	1166.1745

##	521	522	523	524	525	526	527	528
##	1346.8788	1876.0972	1846.0621	1622.1881	1947.3573	1844.3522	1511.8015	1522.0282
##	529	530	531	532	533	534	535	536
##	1434.8283	1264.4866	1096.0878	1566.0264	932.1216	1270.6705	1885.3672	1606.1763
##	537	538	539	540	541	542	543	544
##	1936.7427	1662.2450	724.0767	1794.5899	1848.7884	1953.1797	1580.6681	1965.9681
##	545	546	547	548	549	550	551	552
##	1978.1240	1902.7625	1977.2127	1876.8609	1810.4496	1779.2790	1605.3000	1859.4183
##	553	554	555	556	557	558	559	560
##	1771.1710	1975.5093	1996.8512	1954.4084	1651.4949	1663.2438	1660.4168	1950.5114
##	561	562	563	564	565	566	567	568
##	1746.7171	1822.1235	1736.8879	1824.2558	1120.0058	1877.0758	1827.7106	1662.0818
##	569	570	571	572	573	574	575	576
##	717.2447	1931.3198	1975.7908	1990.2467	1964.0329	1544.2401	640.2381	1471.1589
##	577	578	579	580	581	582	583	584
##	1363.7614	1937.7413	1855.0577	1513.1583	1993.9640	1903.2481	1177.4537	1963.1122
##	585	586	587	588	589	590	591	592
##	1923.4804	1647.2203	1953.4889	1982.2167	1111.9260	1850.1146	1863.8378	1115.1080
##	593	594	595	596	597	598	599	600
##	1720.7017	1872.3433	1961.2978	1593.2874	1962.1513	1869.3091	1778.8978	1670.7686
##	601	602	603	604	605	606	607	608
##	970.0871	1711.0322	1975.6672	1917.8106	1948.0301	1996.2343	1937.4739	1720.0354
##	609	610	611	612	613	614	615	616
##	1509.0465	1675.2872	1945.0925	1960.0766	1974.5888	1921.8486	601.3676	1677.1651
##	617	618	619	620	621	622	623	624
##	1967.8215	1942.8042	1672.3952	1268.1642	1895.9465	1392.9442	1347.1872	1794.2061
##	625	626	627	628	629	630	631	632
##	1965.3529	1860.8614	1959.3983	1946.6771	1784.8204	1376.7518	1781.2009	1668.3704
##	633	634	635	636	637	638	639	640
##	1970.7783	1828.8423	1969.7110	1921.2614	642.3266	1527.9442	1933.6718	1633.2025
##	641	642	643	644	645	646	647	648
##	1896.4029	1891.3192	1252.7837	1958.3279	1416.5295	1935.5749	997.6741	1928.3370
##	649	650	651	652	653	654	655	656
##	1368.5546	1897.0669	1507.0692	956.8903	1804.4470	1733.9131	1743.7837	1213.1234
##	657	658	659	660	661	662	663	664
##	1821.5840	1994.2011	1994.1741	1870.0998	1697.1079	1573.8499	1986.2184	1795.5475
##	665	666	667	668	669	670	671	672
##	1921.4666	1864.0070	1798.5465	1480.6460	1564.0535	1579.4974	864.5292	1379.9836
##	673	674	675	676	677	678	679	680
##	1761.1547	1931.3650	1545.7742	946.6283	1684.5866	1978.2776	1673.0318	1915.1318
##	681	682	683	684	685	686	687	688
##	1789.4019	1566.0250	1395.0946	1241.2100	1958.9958	1339.0769	1980.2679	1356.8631
##	689	690	691	692	693	694	695	696
##	1276.0372	1360.0859	1937.0171	1583.4419	718.1765	1980.9469	1964.5456	1996.1551
##	697	698	699	700	701	702	703	704
##	1991.5188	1186.0751	1911.4797	1967.3779	1756.6558	1839.4297	1528.2209	1801.4353
##	705	706	707	708	709	710	711	712
##	1018.6380	1530.1162	1103.3823	1964.9820	1824.9651	746.8477	1883.3291	1959.4260
##	713	714	715	716	717	718	719	720
##	1968.3725	1810.1283	1996.0872	1408.6071	1533.1516	1812.5710	1845.5864	1407.4092
##	721	722	723	724	725	726	727	728
##	1199.4548	1978.1044	1981.3376	1898.2519	993.6671	1590.2751	1832.6192	1945.8477
##	729	730	731	732	733	734	735	736
##	1954.1716	1800.9051	1930.9041	1801.3478	1186.0574	1849.9527	1538.4424	1892.6920

##	737	738	739	740	741	742	743	744
##	1853.4266	1976.7681	1818.8765	1769.3564	1922.2044	1659.7932	1893.1968	1676.0936
##	745	746	747	748	749	750	751	752
##	1853.5371	1889.4878	1766.8540	1841.1397	1161.0767	1941.9897	1816.9712	1670.4438
##	753	754	755	756	757	758	759	760
##	1159.0633	1993.3730	1312.2609	1812.9169	1938.7368	1711.9391	1992.4061	1947.6134
##	761	762	763	764	765	766	767	768
##	1623.1818	1996.6677	1520.0538	1411.4836	1301.4644	1914.1074	1935.4916	1819.2405
##	769	770	771	772	773	774	775	776
##	1309.2619	1920.1755	1912.2439	1887.6941	1930.1683	1434.0424	1581.7297	1873.9286
##	777	778	779	780	781	782	783	784
##	1951.9059	939.0784	1222.4807	1707.3194	1863.4779	1070.9502	1491.6266	1831.4282
##	785	786	787	788	789	790	791	792
##	1903.7940	1342.2006	1816.6210	1709.8575	1707.2970	1745.3923	1990.1036	1860.0864
##	793	794	795	796	797	798	799	800
##	1977.2326	1680.9564	1994.9945	1945.3212	1690.0044	1894.4746	1923.1018	1844.2521
##	801	802	803	804	805	806	807	808
##	1332.2675	1962.9939	1770.6505	1708.9451	765.1936	1743.5168	1422.7236	1817.1166
##	809	810	811	812	813	814	815	816
##	1951.6181	1958.7481	1412.7174	1959.6172	1954.2281	1951.7974	1593.0400	1968.2899
##	817	818	819	820	821	822	823	824
##	1927.2054	1985.3355	1794.8439	1882.3982	1980.0586	1959.5072	1908.6399	1939.5299
##	825	826	827	828	829	830	831	832
##	1260.1225	1321.5510	1383.7831	1918.7442	1911.0734	1496.8594	1470.9040	1908.6722
##	833	834	835	836	837	838	839	840
##	1964.3399	1949.8620	1695.2906	1935.4891	1218.6420	1073.5851	1581.7543	1772.3917
##	841	842	843	844	845	846	847	848
##	1825.1673	1813.3573	1812.6656	1889.9335	1912.1505	514.0693	1968.0668	1899.4446
##	849	850	851	852	853	854	855	856
##	1952.4898	1790.5864	1906.1149	1648.7482	1475.5196	1975.7490	1991.0746	1089.9426
##	857	858	859	860	861	862	863	864
##	1890.4089	1363.1603	1972.3883	1796.2322	1682.5569	1912.9446	1924.3270	1262.2446
##	865	866	867	868	869	870	871	872
##	1868.1551	1219.2431	1141.8344	1847.4791	1978.8214	1995.6720	1256.9941	1984.3208
##	873	874	875	876	877	878	879	880
##	1496.1279	1290.9330	1896.7391	1606.1002	1895.1952	1585.3605	1908.9196	1790.5461
##	881	882	883	884	885	886	887	888
##	1174.5191	1404.0650	1686.3769	1774.8686	1990.1729	1902.9253	1984.4305	1965.6755
##	889	890	891	892	893	894	895	896
##	1709.3265	1994.7377	1954.0436	1404.3621	1823.6438	1478.7978	1889.2208	1924.2906
##	897	898	899	900	901	902	903	904
##	1955.0389	572.5227	628.1280	1939.7245	1939.7975	1724.0282	1505.5814	1207.2970
##	905	906	907	908	909	910	911	912
##	1620.0106	1921.8329	1398.7634	1986.4756	1925.9717	1992.1760	1762.9281	1935.4770
##	913	914	915	916	917	918	919	920
##	487.6738	1894.0020	1797.2867	1713.6586	1380.3926	1393.8671	1809.4480	1940.4241
##	921	922	923	924	925	926	927	928
##	1984.1650	1707.6713	1877.4475	1690.2154	1526.3872	1714.7476	1088.4713	1984.9105
##	929	930	931	932	933	934	935	936
##	1835.6017	1592.7520	1990.9732	1936.7744	1902.8955	1828.6910	1835.8052	1946.4867
##	937	938	939	940	941	942	943	944
##	1631.9799	1432.6526	1997.5458	1196.1983	1256.3594	1281.9568	1971.5716	953.2202
##	945	946	947	948	949	950	951	952
##	1607.1002	1952.1087	1590.4645	1861.8468	1746.6244	1932.7319	1398.2688	1945.0268



```
##      953      954      955      956      957      958      959      960
## 1988.2414 1933.7184 1007.8553 1944.8320 1942.2656 1946.8539 1443.3023 1761.3427
##      961      962      963      964      965      966      967      968
## 710.6631 1969.9605 822.6688 1790.9897 1233.2565 1982.8097 1979.9662 1537.2369
##      969      970      971      972      973      974      975      976
## 1809.2899 1827.6724 1499.3854 1579.3229 1914.9959 1760.8221 1729.6875 1326.4339
##      977      978      979      980      981      982      983      984
## 1956.2262 1345.4434 1918.9867 1813.4877 1850.2978 1773.5293 1984.6849 1963.5448
##      985      986      987      988      989      990      991      992
## 1986.8949 1973.9608 1731.7657 1921.6938 832.1524 1914.9573 1965.4049 1993.8352
##      993      994      995      996      997      998      999     1000
## 1886.7406 1170.8030 1851.8534 1823.7197 1937.0129 1488.3385 1467.6866 1978.1640
```

```
CLVs <- numeric(length(RR))
for(i in 1:length(RR)) {
  CLVs[i] <- CLV_simple(retention = RR[i], profit = profit, r = r, horizon = horizon)
}
print(CLVs)
```

```
## [1] 1891.5479 1988.1474 1973.9687 1964.1025 1858.5854 1904.8330 588.7898
## [8] 635.5231 1989.7538 1995.2586 1829.6095 1727.0520 1682.5368 1985.4946
## [15] 1965.8007 1915.8482 1273.5647 1975.8226 1677.8303 974.6632 1940.2392
## [22] 808.1407 1795.2072 1873.7603 1367.9643 1844.9979 1835.9699 1637.7036
## [29] 1854.5198 1826.8999 1957.6353 1839.3043 1963.7921 1812.1688 1269.7794
## [36] 1962.5124 1823.0528 1668.5030 1721.6706 1219.3103 1803.8993 1719.2735
## [43] 1582.8041 1754.2044 1923.9866 1989.4482 1944.5459 1722.6953 1981.4474
## [50] 1886.9003 1994.9012 1730.7647 1977.1666 1930.4104 1974.2194 1609.5929
## [57] 1240.8597 1982.0913 1769.2247 1994.4281 1960.9724 1463.8972 1821.4783
## [64] 1893.1866 1835.4938 1836.6487 1938.5063 1993.4042 1913.5986 1962.1488
## [71] 1857.9510 1937.6807 1970.6494 1970.0631 1037.6636 1706.3584 1931.8607
## [78] 1835.0694 1572.7580 1957.9694 1308.0131 1828.3852 1261.7786 1884.8909
## [85] 1595.4140 1628.2422 1695.9979 1968.9438 1034.6016 1847.7488 1322.1573
## [92] 1674.1020 1406.2995 1086.5672 1948.1743 1960.3449 1773.5958 1864.9513
## [99] 1216.4521 1425.6846 1590.4738 1834.9518 1817.1190 1458.8123 1191.0074
## [106] 1964.0511 1692.0912 1127.6400 1699.0283 1976.9764 1985.4626 1958.8131
## [113] 1492.6219 1879.9294 1855.5432 1967.0987 1746.4736 1837.7277 1570.9739
## [120] 1816.4222 1948.4978 1894.5022 1993.1007 1957.2874 1707.5330 1971.0498
## [127] 1935.2986 1167.3972 1990.1097 1694.6203 1981.5741 1837.1054 1993.7693
## [134] 1925.1577 1717.1520 1966.2008 884.4482 1894.1214 1926.4091 1695.9887
## [141] 1685.8392 1986.3693 1772.4665 1897.1496 1830.2310 1954.2833 1343.3137
## [148] 1904.8571 1919.5526 1962.9050 1956.0009 1837.5467 1992.3918 1827.6930
## [155] 1986.6049 1842.9542 538.3579 1591.5586 742.4581 1934.9288 1953.0430
## [162] 1821.2250 1640.8515 1909.1850 772.8249 1962.9223 1091.9282 1076.9913
## [169] 1400.1349 1956.9697 1926.1053 1704.0790 1612.1993 1758.6601 1917.7538
## [176] 1807.4833 1596.8044 1893.9197 1902.7519 1874.6583 1970.3669 1981.6278
## [183] 1951.6885 1898.0789 839.1141 1980.7271 1969.6610 1813.4588 1819.1517
## [190] 985.4485 898.7619 1942.8049 1956.2410 1940.0943 1472.9794 1954.7839
## [197] 1894.4523 488.3430 1975.7185 1900.7781 1918.1166 1902.9689 663.1309
## [204] 1502.2767 958.5294 1601.9156 1952.3034 1991.7533 1987.4627 1904.7075
## [211] 1877.4091 1014.1471 1874.3846 1960.1731 1674.2545 1912.9275 1918.7879
## [218] 1442.7828 1549.2997 1506.4906 656.8453 1965.8253 1858.8405 1098.8625
## [225] 1887.5944 1200.1172 1850.6892 1974.4787 1382.2702 1286.4073 1826.9223
## [232] 1318.2844 1610.5403 1882.2042 1933.1786 1015.1344 1932.9382 1401.2062
## [239] 1986.7614 1892.4251 1729.1013 1736.3246 1871.6577 1390.3370 1942.8835
```

##	[246]	1294.9435	1742.0837	1034.2202	1871.0433	1060.9814	1983.9085	1855.8497
##	[253]	1870.3014	1974.3140	842.2385	1263.5778	1705.3716	1994.5944	1905.0938
##	[260]	1330.2907	1613.2546	523.6587	1905.9573	755.2775	742.4637	1995.1623
##	[267]	1505.3309	1295.4658	1961.7763	1414.3509	1982.5638	1929.0958	1881.5392
##	[274]	1807.1927	1749.7280	1986.6764	1996.8921	1220.9528	1923.3556	1756.1759
##	[281]	1556.9048	1972.2850	1943.9637	1654.3680	1425.2891	1970.0045	918.1762
##	[288]	585.2594	1430.3700	1820.6508	1859.0735	1356.7232	1963.9772	1963.9364
##	[295]	1812.6823	1762.6197	1973.2978	1975.8676	1954.4350	1972.5229	1624.7544
##	[302]	1416.5311	1691.3404	1834.4403	1651.5648	1727.4195	1884.8910	1853.6240
##	[309]	1667.0847	1965.3351	1687.7972	1880.1209	1709.0122	1652.2259	1970.3719
##	[316]	1951.3274	1911.9372	1128.5656	1797.3674	1911.9644	1923.0843	1961.5211
##	[323]	1977.1635	1830.9052	1814.0380	1810.4180	1421.2271	1947.0850	1768.9308
##	[330]	1718.3932	1938.6319	1907.0984	862.8767	1953.7756	1909.3706	1400.4187
##	[337]	1640.5788	1282.5294	1658.1231	1925.5193	1789.3682	937.3529	1988.5897
##	[344]	1847.3596	1975.0070	1988.1502	1399.3073	1776.9380	1963.3093	1579.3121
##	[351]	1647.2478	1789.8262	1692.2075	1724.2285	1982.2348	1861.1536	1502.1750
##	[358]	1615.3913	1970.9817	1955.9221	1953.2690	1691.1189	1914.3049	1681.9937
##	[365]	1992.8467	1937.0389	997.9310	769.3835	1531.3113	1997.5959	1730.3299
##	[372]	1976.5645	1969.8073	1768.0294	1928.1174	1912.6812	1835.7049	1877.8749
##	[379]	536.4845	1419.3921	1791.1934	1768.5579	1885.6208	1923.7877	1951.3189
##	[386]	1968.5477	1944.4937	1805.3244	1500.4871	944.1575	1887.3529	1191.4695
##	[393]	1418.7783	1858.1640	1993.9842	838.9451	1548.0605	1344.8303	1962.0299
##	[400]	1381.2573	1984.1235	1479.1033	1804.5835	1853.1869	1675.3156	1818.1476
##	[407]	1638.5744	797.0947	1862.3092	1799.4794	1818.3772	1365.9255	1959.4722
##	[414]	1938.1931	1592.2405	1960.7300	1698.6471	1769.0821	1113.9622	1586.4306
##	[421]	1705.4697	1646.3978	1914.5093	1307.4502	1745.5350	1927.9342	1929.3343
##	[428]	1932.0373	1989.4475	1868.3895	1944.1531	1649.7049	1845.4196	1828.5626
##	[435]	1958.4234	1987.6445	1745.7664	1985.9902	1353.5285	1970.5402	1603.6625
##	[442]	1445.6463	1779.5407	1819.1995	884.2781	1638.3348	1969.2760	1967.8916
##	[449]	1181.6702	1994.0699	1880.6727	1924.5686	1813.6872	1875.1013	1807.7797
##	[456]	1260.9216	1957.0747	1988.4918	1997.3070	1955.6011	1467.7070	1998.3173
##	[463]	1674.1593	1993.8437	1941.8856	1503.0905	1932.4506	1945.2924	1951.0110
##	[470]	886.6632	1833.6620	1403.1711	1378.2797	1835.2255	1881.3565	1926.1873
##	[477]	810.0101	1844.5204	1829.7017	1908.2636	1985.8668	629.6284	1095.7999
##	[484]	1995.2193	1761.7118	1732.1019	1937.4190	1930.9374	1186.4423	1288.4318
##	[491]	1991.1194	1297.6306	1959.0673	1962.2797	1853.2316	1950.2970	1905.3234
##	[498]	1409.5674	677.0672	1897.1313	1934.6151	1954.4574	1722.1877	1953.6383
##	[505]	1814.2270	1456.0099	1803.3723	1990.0497	1900.6278	1287.6417	1094.4741
##	[512]	1606.6291	1473.6598	1965.1232	1805.9789	1868.8095	1779.5315	1969.8884
##	[519]	1800.5681	1166.1745	1346.8788	1876.0972	1846.0621	1622.1881	1947.3573
##	[526]	1844.3522	1511.8015	1522.0282	1434.8283	1264.4866	1096.0878	1566.0264
##	[533]	932.1216	1270.6705	1885.3672	1606.1763	1936.7427	1662.2450	724.0767
##	[540]	1794.5899	1848.7884	1953.1797	1580.6681	1965.9681	1978.1240	1902.7625
##	[547]	1977.2127	1876.8609	1810.4496	1779.2790	1605.3000	1859.4183	1771.1710
##	[554]	1975.5093	1996.8512	1954.4084	1651.4949	1663.2438	1660.4168	1950.5114
##	[561]	1746.7171	1822.1235	1736.8879	1824.2558	1120.0058	1877.0758	1827.7106
##	[568]	1662.0818	717.2447	1931.3198	1975.7908	1990.2467	1964.0329	1544.2401
##	[575]	640.2381	1471.1589	1363.7614	1937.7413	1855.0577	1513.1583	1993.9640
##	[582]	1903.2481	1177.4537	1963.1122	1923.4804	1647.2203	1953.4889	1982.2167
##	[589]	1111.9260	1850.1146	1863.8378	1115.1080	1720.7017	1872.3433	1961.2978
##	[596]	1593.2874	1962.1513	1869.3091	1778.8978	1670.7686	970.0871	1711.0322
##	[603]	1975.6672	1917.8106	1948.0301	1996.2343	1937.4739	1720.0354	1509.0465
##	[610]	1675.2872	1945.0925	1960.0766	1974.5888	1921.8486	601.3676	1677.1651
##	[617]	1967.8215	1942.8042	1672.3952	1268.1642	1895.9465	1392.9442	1347.1872

##	[624]	1794.2061	1965.3529	1860.8614	1959.3983	1946.6771	1784.8204	1376.7518
##	[631]	1781.2009	1668.3704	1970.7783	1828.8423	1969.7110	1921.2614	642.3266
##	[638]	1527.9442	1933.6718	1633.2025	1896.4029	1891.3192	1252.7837	1958.3279
##	[645]	1416.5295	1935.5749	997.6741	1928.3370	1368.5546	1897.0669	1507.0692
##	[652]	956.8903	1804.4470	1733.9131	1743.7837	1213.1234	1821.5840	1994.2011
##	[659]	1994.1741	1870.0998	1697.1079	1573.8499	1986.2184	1795.5475	1921.4666
##	[666]	1864.0070	1798.5465	1480.6460	1564.0535	1579.4974	864.5292	1379.9836
##	[673]	1761.1547	1931.3650	1545.7742	946.6283	1684.5866	1978.2776	1673.0318
##	[680]	1915.1318	1789.4019	1566.0250	1395.0946	1241.2100	1958.9958	1339.0769
##	[687]	1980.2679	1356.8631	1276.0372	1360.0859	1937.0171	1583.4419	718.1765
##	[694]	1980.9469	1964.5456	1996.1551	1991.5188	1186.0751	1911.4797	1967.3779
##	[701]	1756.6558	1839.4297	1528.2209	1801.4353	1018.6380	1530.1162	1103.3823
##	[708]	1964.9820	1824.9651	746.8477	1883.3291	1959.4260	1968.3725	1810.1283
##	[715]	1996.0872	1408.6071	1533.1516	1812.5710	1845.5864	1407.4092	1199.4548
##	[722]	1978.1044	1981.3376	1898.2519	993.6671	1590.2751	1832.6192	1945.8477
##	[729]	1954.1716	1800.9051	1930.9041	1801.3478	1186.0574	1849.9527	1538.4424
##	[736]	1892.6920	1853.4266	1976.7681	1818.8765	1769.3564	1922.2044	1659.7932
##	[743]	1893.1968	1676.0936	1853.5371	1889.4878	1766.8540	1841.1397	1161.0767
##	[750]	1941.9897	1816.9712	1670.4438	1159.0633	1993.3730	1312.2609	1812.9169
##	[757]	1938.7368	1711.9391	1992.4061	1947.6134	1623.1818	1996.6677	1520.0538
##	[764]	1411.4836	1301.4644	1914.1074	1935.4916	1819.2405	1309.2619	1920.1755
##	[771]	1912.2439	1887.6941	1930.1683	1434.0424	1581.7297	1873.9286	1951.9059
##	[778]	939.0784	1222.4807	1707.3194	1863.4779	1070.9502	1491.6266	1831.4282
##	[785]	1903.7940	1342.2006	1816.6210	1709.8575	1707.2970	1745.3923	1990.1036
##	[792]	1860.0864	1977.2326	1680.9564	1994.9945	1945.3212	1690.0044	1894.4746
##	[799]	1923.1018	1844.2521	1332.2675	1962.9939	1770.6505	1708.9451	765.1936
##	[806]	1743.5168	1422.7236	1817.1166	1951.6181	1958.7481	1412.7174	1959.6172
##	[813]	1954.2281	1951.7974	1593.0400	1968.2899	1927.2054	1985.3355	1794.8439
##	[820]	1882.3982	1980.0586	1959.5072	1908.6399	1939.5299	1260.1225	1321.5510
##	[827]	1383.7831	1918.7442	1911.0734	1496.8594	1470.9040	1908.6722	1964.3399
##	[834]	1949.8620	1695.2906	1935.4891	1218.6420	1073.5851	1581.7543	1772.3917
##	[841]	1825.1673	1813.3573	1812.6656	1889.9335	1912.1505	514.0693	1968.0668
##	[848]	1899.4446	1952.4898	1790.5864	1906.1149	1648.7482	1475.5196	1975.7490
##	[855]	1991.0746	1089.9426	1890.4089	1363.1603	1972.3883	1796.2322	1682.5569
##	[862]	1912.9446	1924.3270	1262.2446	1868.1551	1219.2431	1141.8344	1847.4791
##	[869]	1978.8214	1995.6720	1256.9941	1984.3208	1496.1279	1290.9330	1896.7391
##	[876]	1606.1002	1895.1952	1585.3605	1908.9196	1790.5461	1174.5191	1404.0650
##	[883]	1686.3769	1774.8686	1990.1729	1902.9253	1984.4305	1965.6755	1709.3265
##	[890]	1994.7377	1954.0436	1404.3621	1823.6438	1478.7978	1889.2208	1924.2906
##	[897]	1955.0389	572.5227	628.1280	1939.7245	1939.7975	1724.0282	1505.5814
##	[904]	1207.2970	1620.0106	1921.8329	1398.7634	1986.4756	1925.9717	1992.1760
##	[911]	1762.9281	1935.4770	487.6738	1894.0020	1797.2867	1713.6586	1380.3926
##	[918]	1393.8671	1809.4480	1940.4241	1984.1650	1707.6713	1877.4475	1690.2154
##	[925]	1526.3872	1714.7476	1088.4713	1984.9105	1835.6017	1592.7520	1990.9732
##	[932]	1936.7744	1902.8955	1828.6910	1835.8052	1946.4867	1631.9799	1432.6526
##	[939]	1997.5458	1196.1983	1256.3594	1281.9568	1971.5716	953.2202	1607.1002
##	[946]	1952.1087	1590.4645	1861.8468	1746.6244	1932.7319	1398.2688	1945.0268
##	[953]	1988.2414	1933.7184	1007.8553	1944.8320	1942.2656	1946.8539	1443.3023
##	[960]	1761.3427	710.6631	1969.9605	822.6688	1790.9897	1233.2565	1982.8097
##	[967]	1979.9662	1537.2369	1809.2899	1827.6724	1499.3854	1579.3229	1914.9959
##	[974]	1760.8221	1729.6875	1326.4339	1956.2262	1345.4434	1918.9867	1813.4877
##	[981]	1850.2978	1773.5293	1984.6849	1963.5448	1986.8949	1973.9608	1731.7657
##	[988]	1921.6938	832.1524	1914.9573	1965.4049	1993.8352	1886.7406	1170.8030
##	[995]	1851.8534	1823.7197	1937.0129	1488.3385	1467.6866	1978.1640	

What is the average CLV across customers? (1 point)

```
avg_CLV <- mean(CLVs)
print(avg_CLV)
```

```
## [1] 1696.33
```

**Answer here : \$1696.33**

## Question 6

Assume the firm implemented improvements to its network such that `dropped_calls` are reduced by 10%.

What is the average expected increase in CLV as a result of the network improvements? (2 point)

*Hint: Use `predict()` to generate churn rates assuming `dropped_calls` is 10% less than originally observed. Then re-compute CLV values by individual. Finally, compute the difference in average CLV values with network improvements and average CLV values without network improvements.*

```
DF_new <- DF
DF_new$dropped_calls <- DF_new$dropped_calls * 0.9
predicted_churn_rate_new <- predict(churn_model, newdata = DF_new, type = "response")

RR_new <- 1 - predicted_churn_rate_new

CLVs_new <- numeric(length(RR_new))
for(i in 1:length(RR_new)) {
  CLVs_new[i] <- CLV_simple(retention = RR_new[i], profit = profit, r = r, horizon = horizon)
}
print(CLVs_new)
```

```
##      [1] 1891.5479 1988.1474 1973.9687 1964.1025 1864.3410 1904.8330 588.7898
##      [8] 642.2806 1989.7538 1995.5310 1829.6095 1737.2410 1682.5368 1985.4946
##     [15] 1967.3277 1915.8482 1310.1144 1975.8226 1700.7514 991.2539 1940.2392
##     [22] 808.1407 1795.2072 1873.7603 1367.9643 1844.9979 1842.5481 1674.8126
##     [29] 1854.5198 1833.8011 1959.5031 1845.7628 1963.7921 1812.1688 1269.7794
##     [36] 1962.5124 1823.0528 1668.5030 1721.6706 1237.7735 1803.8993 1719.2735
##     [43] 1582.8041 1772.5934 1923.9866 1989.4482 1946.9536 1722.6953 1981.4474
##     [50] 1886.9003 1994.9012 1730.7647 1979.2173 1930.4104 1974.2194 1622.9973
##     [57] 1240.8597 1982.0913 1769.2247 1994.4281 1962.7013 1463.8972 1828.5707
##     [64] 1893.1866 1835.4938 1836.6487 1938.5063 1993.4042 1913.5986 1962.1488
##     [71] 1863.7301 1940.3685 1973.2400 1970.0631 1055.1455 1706.3584 1934.7842
##     [78] 1835.0694 1572.7580 1957.9694 1308.0131 1841.8384 1261.7786 1884.8909
##     [85] 1609.1571 1628.2422 1695.9979 1968.9438 1052.0469 1847.7488 1322.1573
##     [92] 1674.1020 1406.2995 1086.5672 1950.4332 1960.3449 1773.5958 1864.9513
##     [99] 1216.4521 1425.6846 1604.3323 1834.9518 1817.1190 1475.2450 1191.0074
##    [106] 1964.0511 1692.0912 1145.8958 1699.0283 1978.0320 1985.4626 1958.8131
##    [113] 1508.4876 1879.9294 1855.5432 1968.5712 1746.4736 1837.7277 1570.9739
##    [120] 1816.4222 1948.4978 1894.5022 1993.1007 1957.2874 1707.5330 1971.0498
##    [127] 1935.2986 1167.3972 1990.1097 1716.5941 1981.5741 1837.1054 1993.7693
##    [134] 1925.1577 1717.1520 1966.2008 884.4482 1894.1214 1926.4091 1695.9887
##    [141] 1685.8392 1986.3693 1789.6884 1897.1496 1830.2310 1954.2833 1343.3137
```

##	[148]	1908.8536	1922.9694	1962.9050	1956.0009	1837.5467	1992.3918	1834.5661
##	[155]	1986.6049	1849.2811	538.3579	1591.5586	742.4581	1934.9288	1953.0430
##	[162]	1821.2250	1653.4712	1909.1850	772.8249	1964.5698	1109.9458	1076.9913
##	[169]	1400.1349	1958.8652	1926.1053	1704.0790	1612.1993	1758.6601	1917.7538
##	[176]	1807.4833	1596.8044	1898.3412	1902.7519	1874.6583	1971.7021	1982.4857
##	[183]	1953.8026	1902.3394	852.7811	1980.7271	1969.6610	1813.4588	1826.3257
##	[190]	985.4485	898.7619	1945.2839	1956.2410	1940.0943	1536.0922	1954.7839
##	[197]	1894.4523	488.3430	1975.7185	1900.7781	1921.5905	1902.9689	679.1415
##	[204]	1533.3656	958.5294	1601.9156	1952.3034	1991.7533	1987.4627	1908.7099
##	[211]	1877.4091	1014.1471	1879.5510	1960.1731	1685.9783	1912.9275	1922.2352
##	[218]	1442.7828	1549.2997	1506.4906	656.8453	1965.8253	1858.8405	1135.1273
##	[225]	1896.7445	1200.1172	1850.6892	1975.6402	1399.7380	1286.4073	1826.9223
##	[232]	1318.2844	1623.9218	1882.2042	1933.1786	1015.1344	1932.9382	1401.2062
##	[239]	1986.7614	1896.9042	1729.1013	1736.3246	1871.6577	1407.7123	1947.7337
##	[246]	1313.1553	1751.8096	1069.3013	1876.3353	1060.9814	1984.6689	1855.8497
##	[253]	1870.3014	1974.3140	870.0949	1263.5778	1705.3716	1994.5944	1909.0811
##	[260]	1330.2907	1613.2546	527.6826	1905.9573	802.1364	742.4637	1995.1623
##	[267]	1520.9663	1313.6746	1961.7763	1414.3509	1983.3817	1935.0433	1886.4349
##	[274]	1807.1927	1749.7280	1987.3184	1996.8921	1220.9528	1923.3556	1774.4405
##	[281]	1556.9048	1972.2850	1948.7272	1654.3680	1425.2891	1971.3549	918.1762
##	[288]	585.2594	1430.3700	1834.6426	1864.8111	1356.7232	1963.9772	1963.9364
##	[295]	1812.6823	1762.6197	1973.2978	1975.8676	1954.4350	1972.5229	1624.7544
##	[302]	1433.5788	1691.3404	1834.4403	1663.9036	1737.5973	1894.2445	1853.6240
##	[309]	1667.0847	1965.3351	1699.1411	1880.1209	1719.7418	1652.2259	1970.3719
##	[316]	1951.3274	1911.9372	1128.5656	1797.3674	1911.9644	1923.0843	1964.8619
##	[323]	1978.2113	1830.9052	1814.0380	1810.4180	1438.2117	1947.0850	1768.9308
##	[330]	1718.3932	1938.6319	1907.0984	862.8767	1955.8035	1909.3706	1417.6728
##	[337]	1640.5788	1282.5294	1658.1231	1928.6979	1797.5633	969.4982	1988.5897
##	[344]	1853.5266	1975.0070	1988.7289	1399.3073	1776.9380	1964.9407	1579.3121
##	[351]	1659.7005	1789.8262	1692.2075	1724.2285	1983.0667	1861.1536	1502.1750
##	[358]	1615.3913	1970.9817	1955.9221	1953.2690	1713.2925	1917.9299	1693.5015
##	[365]	1992.8467	1939.7527	1014.8849	769.3835	1546.4475	1997.5959	1730.3299
##	[372]	1977.6376	1971.1660	1768.0294	1928.1174	1916.3703	1835.7049	1877.8749
##	[379]	539.0228	1419.3921	1814.7752	1777.4405	1890.3610	1923.7877	1951.3189
##	[386]	1968.5477	1946.9036	1805.3244	1516.2114	944.1575	1887.3529	1191.4695
##	[393]	1418.7783	1863.9352	1993.9842	838.9451	1562.8547	1344.8303	1963.7147
##	[400]	1381.2573	1984.1235	1479.1033	1804.5835	1853.1869	1687.0099	1825.3567
##	[407]	1638.5744	809.5744	1862.3092	1799.4794	1818.3772	1365.9255	1961.2637
##	[414]	1938.1931	1592.2405	1960.7300	1709.6797	1769.0821	1113.9622	1586.4306
##	[421]	1705.4697	1646.3978	1918.1262	1325.5848	1745.5350	1931.0159	1929.3343
##	[428]	1932.0373	1989.4475	1868.3895	1946.5769	1649.7049	1845.4196	1828.5626
##	[435]	1958.4234	1987.6445	1745.7664	1986.6616	1353.5285	1970.5402	1603.6625
##	[442]	1462.2818	1779.5407	1826.3718	884.2781	1651.0196	1969.2760	1967.8916
##	[449]	1200.1175	1994.3937	1880.6727	1924.5686	1813.6872	1875.1013	1807.7797
##	[456]	1279.2926	1957.0747	1988.4918	1997.3070	1957.5533	1467.7070	1998.3173
##	[463]	1674.1593	1994.1773	1944.4021	1503.0905	1932.4506	1947.6696	1955.2066
##	[470]	886.6632	1833.6620	1420.3910	1378.2797	1835.2255	1881.3565	1929.3390
##	[477]	810.0101	1844.5204	1829.7017	1912.1267	1985.8668	629.6284	1095.7999
##	[484]	1995.2193	1761.7118	1732.1019	1937.4190	1933.8981	1186.4423	1288.4318
##	[491]	1991.1194	1297.6306	1959.0673	1962.2797	1859.1842	1950.2970	1905.3234
##	[498]	1409.5674	677.0672	1897.1313	1934.6151	1954.4574	1722.1877	1953.6383
##	[505]	1814.2270	1456.0099	1803.3723	1990.5468	1900.6278	1287.6417	1094.4741
##	[512]	1633.2517	1473.6598	1965.1232	1805.9789	1874.1852	1788.0542	1969.8884
##	[519]	1800.5681	1184.5873	1346.8788	1886.1076	1846.0621	1635.2827	1947.3573

##	[526]	1850.6284	1511.8015	1522.0282	1434.8283	1282.8444	1096.0878	1566.0264
##	[533]	932.1216	1270.6705	1885.3672	1606.1763	1936.7427	1662.2450	724.0767
##	[540]	1802.6091	1848.7884	1953.1797	1580.6681	1967.4881	1978.1240	1902.7625
##	[547]	1977.2127	1876.8609	1810.4496	1779.2790	1605.3000	1859.4183	1771.1710
##	[554]	1975.5093	1996.8512	1954.4084	1687.5247	1663.2438	1672.5189	1950.5114
##	[561]	1746.7171	1829.1932	1736.8879	1824.2558	1138.2182	1877.0758	1827.7106
##	[568]	1674.1389	717.2447	1931.3198	1975.7908	1990.2467	1964.0329	1544.2401
##	[575]	647.1858	1471.1589	1363.7614	1943.0027	1855.0577	1528.6474	1993.9640
##	[582]	1903.2481	1195.8932	1964.7518	1923.4804	1647.2203	1957.4838	1982.2167
##	[589]	1111.9260	1850.1146	1863.8378	1133.2905	1720.7017	1872.3433	1961.2978
##	[596]	1593.2874	1962.1513	1869.3091	1778.8978	1670.7686	970.0871	1711.0322
##	[603]	1975.6672	1917.8106	1948.0301	1996.2343	1937.4739	1730.4366	1509.0465
##	[610]	1675.2872	1945.0925	1960.0766	1976.8535	1925.1739	601.3676	1677.1651
##	[617]	1967.8215	1945.2832	1672.3952	1268.1642	1900.2897	1410.2888	1382.6634
##	[624]	1794.2061	1965.3529	1860.8614	1959.3983	1948.9975	1784.8204	1376.7518
##	[631]	1781.2009	1668.3704	1970.7783	1828.8423	1969.7110	1924.6101	642.3266
##	[638]	1527.9442	1933.6718	1633.2025	1896.4029	1891.3192	1252.7837	1958.3279
##	[645]	1416.5295	1938.3482	997.6741	1928.3370	1386.1706	1897.0669	1507.0692
##	[652]	956.8903	1804.4470	1743.8922	1743.7837	1213.1234	1828.6727	1994.2011
##	[659]	1994.1741	1870.0998	1708.1850	1573.8499	1986.2184	1795.5475	1924.8072
##	[666]	1869.5618	1798.5465	1480.6460	1564.0535	1579.4974	864.5292	1379.9836
##	[673]	1761.1547	1931.3650	1560.6160	946.6283	1696.0214	1978.2776	1684.7894
##	[680]	1918.7241	1789.4019	1580.4350	1412.4135	1241.2100	1958.9958	1339.0769
##	[687]	1980.2679	1374.5963	1276.0372	1360.0859	1937.0171	1583.4419	748.9293
##	[694]	1980.9469	1964.5456	1996.1551	1991.5188	1186.0751	1911.4797	1967.3779
##	[701]	1774.8901	1839.4297	1558.3090	1801.4353	1018.6380	1545.2762	1121.4862
##	[708]	1966.5433	1824.9651	757.7371	1883.3291	1961.2193	1968.3725	1810.1283
##	[715]	1996.0872	1408.6071	1563.0411	1812.5710	1857.8222	1424.5757	1199.4548
##	[722]	1979.1122	1981.3376	1898.2519	993.6671	1617.6743	1845.7753	1945.8477
##	[729]	1954.1716	1800.9051	1930.9041	1801.3478	1186.0574	1849.9527	1553.4349
##	[736]	1892.6920	1859.3721	1976.7681	1818.8765	1769.3564	1922.2044	1659.7932
##	[743]	1901.9235	1687.7663	1853.5371	1889.4878	1775.7919	1841.1397	1161.0767
##	[750]	1941.9897	1816.9712	1682.2728	1177.4549	1993.3730	1312.2609	1820.3083
##	[757]	1941.3816	1711.9391	1992.4061	1947.6134	1623.1818	1996.6677	1520.0538
##	[764]	1411.4836	1301.4644	1914.1074	1935.4916	1819.2405	1309.2619	1920.1755
##	[771]	1919.5101	1887.6941	1933.1600	1434.0424	1581.7297	1873.9286	1951.9059
##	[778]	939.0784	1240.9409	1707.3194	1869.0524	1070.9502	1507.5098	1831.4282
##	[785]	1903.7940	1342.2006	1816.6210	1709.8575	1707.2970	1755.0148	1990.5983
##	[792]	1860.0864	1978.2774	1692.4934	1995.2783	1945.3212	1690.0044	1894.4746
##	[799]	1923.1018	1844.2521	1350.2196	1962.9939	1770.6505	1719.6766	765.1936
##	[806]	1743.5168	1422.7236	1817.1166	1951.6181	1958.7481	1412.7174	1959.6172
##	[813]	1954.2281	1951.7974	1620.3098	1968.2899	1927.2054	1985.3355	1802.8545
##	[820]	1882.3982	1980.0586	1961.2972	1908.6399	1939.5299	1260.1225	1339.5867
##	[827]	1401.2339	1922.1931	1911.0734	1496.8594	1470.9040	1908.6722	1965.9281
##	[834]	1949.8620	1695.2906	1935.4891	1237.1057	1073.5851	1581.7543	1772.3917
##	[841]	1832.1298	1813.3573	1812.6656	1894.5084	1912.1505	514.0693	1968.0668
##	[848]	1899.4446	1952.4898	1790.5864	1906.1149	1648.7482	1475.5196	1975.7490
##	[855]	1991.5276	1089.9426	1894.9656	1363.1603	1972.3883	1796.2322	1682.5569
##	[862]	1916.6234	1927.5533	1280.6108	1868.1551	1219.2431	1160.1600	1847.4791
##	[869]	1978.8214	1995.6720	1256.9941	1984.3208	1527.4431	1290.9330	1896.7391
##	[876]	1606.1002	1899.5674	1585.3605	1908.9196	1798.7017	1174.5191	1404.0650
##	[883]	1697.7610	1783.5450	1990.1729	1902.9253	1984.4305	1967.2078	1709.3265
##	[890]	1994.7377	1956.0604	1421.5672	1837.4278	1494.9033	1893.8231	1924.2906
##	[897]	1955.0389	576.6391	628.1280	1944.8276	1939.7975	1724.0282	1505.5814

```
## [904] 1225.7654 1633.1593 1921.8329 1416.0378 1986.4756 1925.9717 1992.1760
## [911] 1780.7636 1935.4770 487.6738 1894.0020 1797.2867 1724.2505 1380.3926
## [918] 1393.8671 1809.4480 1943.0003 1984.1650 1707.6713 1877.4475 1690.2154
## [925] 1541.6210 1714.7476 1088.4713 1984.9105 1842.1932 1592.7520 1991.4305
## [932] 1936.7744 1902.8955 1828.6910 1835.8052 1946.4867 1631.9799 1449.4783
## [939] 1997.7191 1196.1983 1256.3594 1300.2382 1971.5716 953.2202 1620.5650
## [946] 1952.1087 1604.3232 1861.8468 1746.6244 1932.7319 1415.5493 1945.0268
## [953] 1988.8162 1933.7184 1024.9520 1944.8320 1942.2656 1946.8539 1459.9729
## [960] 1761.3427 710.6631 1969.9605 835.8867 1790.9897 1251.7015 1982.8097
## [967] 1979.9662 1537.2369 1824.0628 1827.6724 1499.3854 1579.3229 1914.9959
## [974] 1760.8221 1729.6875 1326.4339 1961.7683 1345.4434 1918.9867 1820.8592
## [981] 1856.3577 1782.2496 1985.4121 1965.1663 1986.8949 1973.9608 1731.7657
## [988] 1921.6938 832.1524 1914.9573 1965.4049 1993.8352 1886.7406 1170.8030
## [995] 1857.8565 1823.7197 1937.0129 1504.2796 1467.6866 1980.1318
```

```
avg_CLV_new <- mean(CLVs_new)
average_increase_in_CLV <- avg_CLV_new - avg_CLV
print(average_increase_in_CLV)
```

```
## [1] 3.031439
```

Answer here :

3.031439

## Question 7

Assume the firm implemented improvements to its call center such that `callcenter_waittime` is reduced by 10%. What is the average expected increase in CLV as a result of the call center improvements? **(2 point)**

*Hint: Use `predict()` to generate churn rates assuming `callcenter_waittime` is 10% less than originally observed. Then re-compute CLV values by individual. Finally, compute the difference in average CLV values with call center improvements and average CLV values without call center improvements.*

```
DF_improved <- DF
DF_improved$callcenter_waittime <- DF_improved$callcenter_waittime * 0.9
predicted_churn_rate_improved <- predict(churn_model, newdata = DF_improved, type = "response")

RR_improved <- 1 - predicted_churn_rate_improved

CLVs_improved <- numeric(length(RR_improved))
for (i in 1:length(RR_improved)) {
  CLVs_improved[i] <- CLV_simple(retention = RR_improved[i], profit = profit, r = r, horizon = horizon)
}

avg_CLV_improved <- mean(CLVs_improved)

avg_increase_in_CLV <- avg_CLV_improved - avg_CLV

print(avg_increase_in_CLV)
```

```
## [1] 8.999507
```

**Answer here : 9**