Woodburn Module 1 Homework

Woodburn Team

9/1/2020

##Problem 1

Our first step in beginning the assignment is to set up our environment and load the library to include the necessary “College” data set.

library(ISLR)  
dim(College)

## [1] 777 18

help(College)

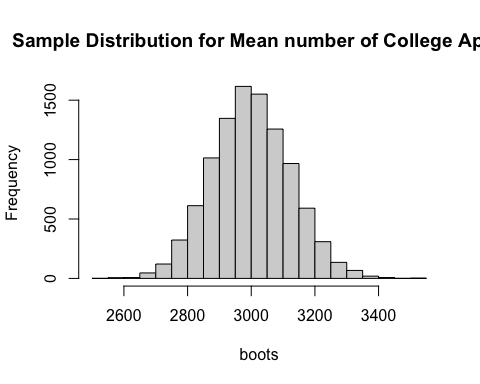
First, we need to create a name that refers to the Apps vector (column) within the College data set and find the mean.

collegeApps <- College$Apps  
mean(collegeApps)

## [1] 3001.638

Before moving forward with our analysis, it is important that we bootstrap the collegeApps vector named above. To do this, we will set a seed that can be used by later analysts to reproduce our analysis. For our first seed, that will act as a “starting point” for our random sample distribution, we use “2020.” The next chunk will include setting that seed and running code to bootstrap the sample to include 1000 observations by random sampling built off of our initial population. We will generate 10,000 observations and limit the inclusion to only 1000. We will also create a histogram to visualize the information represented in the data set. This new sample will be named “boots.”

#First Seed, 1000 observations.  
  
set.seed(2020)  
boots <- NULL  
for (i in 1:10000) {  
meanCollegeApps <- mean(sample(collegeApps,1000,replace = TRUE))  
boots<- c(boots,meanCollegeApps)  
}  
hist(boots, main = "Sample Distribution for Mean number of College Apps")



Next we will calculate the Confidence Interval (CI) of this new sample of 1000. We will calculate this with a CI of 80%.

quantile(boots,c(.1,.9))

## 10% 90%   
## 2841.396 3159.211

After calculating the CI, we can say with confidence that the mean of CollegeApps will fall between 2841 and 3159 80% of the time.

Before further analysis, we will determine how the data set is organized. Is the data set a matrix or a data.frame?

mean(boots)

## [1] 2999.567

is.matrix(College)

## [1] FALSE

is.data.frame(College)

## [1] TRUE

## College is a dataframe, which reads like a list but prints like a matrix. We will be using a list (option3)

As seen above, “College” is a data.frame, which reads like a list but prints like a matrix. We will be using a list (option3), and utilizing the sapply function. We will rename our “boots” to “mylist.”

mylist<-boots  
  
sapply(mylist, mean)

## [1] 2928.785 3168.084 3088.873 2893.745 2908.132 3003.117 3116.120 2893.129  
## [9] 3084.297 3188.113 3132.615 3141.555 2864.265 3082.916 3134.943 3091.463  
## [17] 3130.201 2925.234 3294.711 3048.556 3038.459 2756.721 3343.922 3103.977  
## [25] 3168.929 2935.231 2790.936 3234.380 2778.451 2976.181 2963.209 2873.429  
## [33] 3072.367 2829.361 3102.572 2990.211 2939.400 2656.032 3144.218 3010.803  
## [41] 3014.259 2926.599 3031.075 3212.879 3074.518 2994.294 2925.339 3203.142  
## [49] 2864.218 2926.729 3026.648 3065.174 2984.469 3073.321 3080.004 3065.906  
## [57] 3081.359 3225.191 3123.107 3122.104 2909.684 3014.411 3012.802 3116.586  
## [65] 2911.150 3111.199 3075.314 2989.962 3002.447 2887.984 2954.904 2845.915  
## [73] 3031.852 3223.864 2906.311 3098.502 3160.854 2987.723 2865.442 3040.561  
## [81] 2954.064 2920.064 2981.955 2999.247 2783.520 2946.104 2878.922 3018.149  
## [89] 2950.330 3151.449 2873.256 2881.357 3055.932 2864.048 3006.201 2930.046  
## [97] 3227.783 2888.790 3137.212 2942.377 3003.381 2926.642 2775.382 2958.979  
## [105] 3036.702 2799.224 2883.808 3158.406 2937.902 3080.288 2842.720 2708.353  
## [113] 3262.572 3078.631 3114.771 2965.761 3212.490 3020.921 2707.626 3116.358  
## [121] 3163.409 2921.230 2987.926 3104.775 2936.618 2842.404 3153.309 2833.893  
## [129] 3002.030 3134.584 3015.211 2827.600 3148.030 3030.758 3036.396 2851.661  
## [137] 3155.960 3026.149 3005.044 2931.062 3378.979 3012.411 2891.193 2995.698  
## [145] 3099.696 2790.332 3265.609 3002.259 3068.061 2875.596 2939.090 3215.268  
## [153] 2919.004 3059.033 2925.819 3005.776 2967.640 2768.910 3051.177 2805.491  
## [161] 2863.777 2750.680 3068.664 3050.017 2770.701 3008.272 3008.384 2976.111  
## [169] 3519.728 2864.736 3027.688 2785.895 2974.052 3048.475 3133.444 2683.386  
## [177] 3069.162 3299.779 2879.669 2924.165 2828.987 2841.906 3047.500 3181.701  
## [185] 3055.905 2905.853 2925.480 2859.001 3206.263 2915.265 3110.599 2982.664  
## [193] 2813.595 2988.334 2952.812 3096.893 2862.593 3046.475 3103.119 3074.564  
## [201] 2999.983 2929.169 2911.403 2613.874 3074.162 3125.747 2980.074 2885.344  
## [209] 3173.484 2939.974 2762.741 2949.461 3073.820 3100.874 3077.628 3001.085  
## [217] 2924.824 2929.274 2984.560 3388.491 2956.170 3018.118 3004.275 2934.433  
## [225] 3095.507 3159.728 3279.750 3008.408 3306.127 2924.601 2994.660 3013.622  
## [233] 2916.969 3236.678 3162.527 2963.038 3147.107 3229.669 3033.467 2949.186  
## [241] 3070.467 2803.115 3189.764 3144.090 2890.520 3090.634 2907.087 2825.178  
## [249] 2877.185 3051.327 2836.947 2945.863 2916.054 2887.336 2827.145 2891.640  
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## [265] 3079.799 3172.333 2922.130 3056.692 3070.188 3027.859 3083.096 2852.961  
## [273] 2862.993 3045.531 2823.923 3007.284 2944.967 3027.605 3052.762 3028.321  
## [281] 2759.420 3049.430 2975.989 3113.148 2999.665 2874.461 3113.878 3136.527  
## [289] 3190.995 2812.761 3056.606 3242.421 2986.556 3297.421 3193.040 2992.676  
## [297] 2790.222 2950.587 3004.647 3141.483 3037.282 3074.209 2934.312 3245.101  
## [305] 3053.252 2917.242 2974.547 3227.366 2938.915 2872.341 2858.982 3066.213  
## [313] 3020.877 3106.013 2910.105 2997.760 2954.020 2962.391 3045.725 2941.190  
## [321] 2956.246 2916.885 3244.255 3133.496 3106.332 3039.011 3025.839 2961.403  
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## [337] 2813.159 3117.371 2820.023 2971.432 3019.110 3060.493 3000.765 2939.484  
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## [353] 2950.421 3064.856 2961.222 3060.176 2777.596 2992.363 2751.636 3121.081  
## [361] 3045.509 2898.597 3221.650 3036.780 2838.385 3069.307 3063.849 3012.661  
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## [377] 2781.782 3173.076 3040.515 3126.620 2960.628 2843.873 3184.065 3184.043  
## [385] 2913.941 3163.521 3012.349 2836.401 2802.506 2945.528 3050.858 3005.556  
## [393] 3003.236 2925.466 2964.411 3136.645 2897.936 2919.555 2879.663 2919.953  
## [401] 3142.498 2948.734 3098.052 3044.199 3181.430 3196.264 3151.306 2896.856  
## [409] 2932.187 3018.149 2821.909 2928.858 3000.558 3137.665 2993.768 2906.270  
## [417] 2926.570 3023.322 2897.093 2853.296 3064.094 3027.935 3220.906 3045.024  
## [425] 2795.445 2979.728 3003.415 2836.808 2926.345 3267.969 3095.835 2914.849  
## [433] 3131.272 3136.513 2942.319 2806.307 3113.284 2795.768 2890.472 2827.019  
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## [865] 3076.455 3020.052 3010.424 2824.583 3008.868 2879.189 3125.446 3039.397  
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## [1265] 3159.068 2966.455 3002.946 2969.491 3043.630 2982.834 2911.205 3075.038  
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## [1281] 3249.306 2935.824 3087.758 3068.554 3106.720 2932.145 2817.797 3102.929  
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## [1305] 3173.490 2988.315 2855.309 3112.575 2975.082 3063.947 3145.268 2829.877  
## [1313] 3088.027 2894.396 3093.720 3262.727 2908.808 3225.569 2967.229 2973.480  
## [1321] 3041.942 3020.731 2904.722 3171.317 2717.602 3035.089 2998.002 2884.043  
## [1329] 2991.383 2918.518 3139.603 3018.201 2977.608 3081.467 2999.056 3023.054  
## [1337] 3119.354 2685.628 2962.762 3053.947 2981.798 3004.063 3041.028 2879.811  
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## [1353] 3011.111 2978.006 2868.948 3074.161 2828.425 3063.258 2946.406 3104.658  
## [1361] 2906.428 3007.228 2893.504 2879.573 2985.360 3110.846 3182.601 2730.092  
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## [1377] 2853.997 2900.041 2912.099 3175.096 2949.560 3017.979 3097.788 2923.372  
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## [1401] 3057.418 2661.772 3020.524 3051.217 2890.057 2986.218 3043.739 2916.811  
## [1409] 3054.995 2964.283 3193.616 3006.244 2920.169 3081.439 2864.875 2910.255  
## [1417] 3060.044 3095.163 3008.877 2766.703 2832.928 3010.571 2958.186 2967.266  
## [1425] 3061.345 2850.675 2850.910 2954.810 2791.099 3214.870 2970.049 2772.206  
## [1433] 2895.327 2923.066 2948.918 3049.960 3011.632 2850.603 2961.790 2906.284  
## [1441] 3014.314 2759.383 2919.632 3274.628 2818.333 3265.784 2851.753 2955.896  
## [1449] 2990.907 3221.611 3004.846 2875.482 3076.107 3083.334 2914.118 3038.662  
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## [9361] 3174.204 3019.143 2988.418 2962.606 2933.827 3225.848 3187.978 3216.882  
## [9369] 3145.507 3119.507 2903.766 3031.280 2981.413 3150.469 2891.067 2962.021  
## [9377] 2840.586 2814.258 3110.197 3012.682 2987.710 3179.552 2821.124 3116.117  
## [9385] 2958.763 3180.473 3120.716 2844.150 3027.159 3146.778 3096.179 3034.226  
## [9393] 2820.184 2872.896 3017.406 3105.343 2961.292 3193.604 3130.758 3191.809  
## [9401] 3053.995 2892.148 3168.284 3198.792 2760.379 2901.109 2941.182 3133.320  
## [9409] 3102.853 2924.843 3002.149 3128.338 3215.191 3012.647 3025.138 3047.902  
## [9417] 3053.517 3212.559 3044.436 3050.990 3036.249 2842.645 3021.244 3097.143  
## [9425] 3036.350 3019.017 2892.573 2862.857 2959.144 2952.027 3059.104 2981.120  
## [9433] 2928.333 3003.834 2794.863 2981.575 3001.230 3017.222 2959.824 2995.998  
## [9441] 3150.963 3224.380 3073.988 2970.067 3187.151 3229.360 2987.601 2791.264  
## [9449] 3087.865 3064.670 2860.600 3139.988 2982.181 3031.667 2899.141 3315.855  
## [9457] 3089.956 2942.838 3067.959 2981.973 3087.230 2890.199 3077.014 3024.668  
## [9465] 3261.653 2862.269 3094.451 3045.340 3106.073 3029.146 2957.513 3059.824  
## [9473] 3182.404 3000.909 3010.515 3133.034 3017.866 3063.816 3079.101 3043.002  
## [9481] 3092.134 3034.618 2983.007 2781.544 2962.360 3033.730 2858.099 3062.755  
## [9489] 2999.558 3123.630 2897.422 3001.831 3037.658 2935.790 3013.739 2838.354  
## [9497] 2888.799 3048.002 3276.558 2976.087 2797.535 3132.397 3013.973 2986.472  
## [9505] 3133.209 2943.387 3142.960 2910.677 3072.317 3036.194 2902.066 3036.014  
## [9513] 2998.363 2946.901 3088.955 3074.258 2973.791 2907.336 2969.325 2934.678  
## [9521] 3148.981 2982.050 3054.226 3018.976 3026.553 3079.661 3184.376 2924.444  
## [9529] 3001.600 2870.939 2967.891 2874.285 2864.149 3163.555 3158.059 2969.320  
## [9537] 2942.115 3088.379 3046.705 2959.549 3043.248 3111.347 3142.724 3062.823  
## [9545] 2877.900 2923.324 3073.931 3172.377 3025.033 2865.871 3178.417 2833.762  
## [9553] 2808.791 3084.426 3103.603 2964.914 2977.890 3038.876 3207.169 3045.568  
## [9561] 3088.269 2991.599 2911.461 3105.327 2907.564 2983.693 2649.008 2838.561  
## [9569] 3030.722 2947.574 2876.770 2926.008 2923.794 3173.613 3187.921 2961.326  
## [9577] 3086.875 3062.895 2968.619 2966.347 2801.287 2990.784 2544.173 2937.467  
## [9585] 2943.716 3079.418 3156.243 2950.841 2966.437 3038.274 3181.590 2945.978  
## [9593] 3098.510 3135.447 2917.733 2946.782 2967.815 3262.415 3057.525 3068.020  
## [9601] 2943.679 3140.158 3186.097 2970.712 2984.230 2942.791 3028.512 3040.136  
## [9609] 2911.027 3079.736 2826.606 2999.814 3047.219 2827.097 2952.418 2882.760  
## [9617] 2881.550 2767.174 2787.778 2983.670 2879.335 3045.402 2939.380 3029.000  
## [9625] 3014.619 2954.430 2901.053 3029.548 3065.407 2737.401 2924.329 3020.839  
## [9633] 2904.689 3196.562 3283.572 2972.662 3053.985 2870.724 2742.212 3012.982  
## [9641] 3186.640 3112.084 3028.940 2966.422 3018.004 3075.241 2883.004 2954.335  
## [9649] 3275.266 2867.613 2861.549 3178.536 3209.549 3227.365 2849.502 2967.696  
## [9657] 3068.139 2682.495 2848.196 3013.861 2768.978 2933.013 3162.218 3016.544  
## [9665] 3075.330 2997.516 3025.719 2851.331 2917.965 3070.136 3108.501 3215.589  
## [9673] 3117.469 3118.494 2958.158 2977.567 3175.293 3068.305 3182.741 3063.477  
## [9681] 2720.377 2975.425 3059.754 3015.093 2842.680 3151.310 2961.474 3028.562  
## [9689] 3051.454 3005.590 3077.793 2838.143 3007.351 3163.874 2999.430 2985.837  
## [9697] 3112.468 2952.572 3001.800 2990.254 3156.482 2938.222 3007.418 2939.145  
## [9705] 2894.159 2779.311 3037.563 2948.441 3139.055 2813.317 3115.543 3122.635  
## [9713] 2924.925 3075.727 2953.723 2917.141 3065.086 2936.660 3058.502 2719.505  
## [9721] 3003.974 2743.891 3042.213 3042.889 2966.761 2916.762 2886.790 3229.350  
## [9729] 2969.300 3007.668 3009.011 3164.218 3126.808 3009.618 2947.529 3007.843  
## [9737] 2761.815 3112.082 2877.194 3121.716 2961.853 3177.541 3089.836 3098.414  
## [9745] 2986.856 3126.718 3280.837 2676.062 2922.800 2974.066 2903.828 3104.638  
## [9753] 3138.506 2878.619 2820.905 3037.281 3030.627 2998.412 3087.918 2767.776  
## [9761] 2996.535 2973.093 2809.474 2981.024 2921.996 2896.756 2947.210 2983.046  
## [9769] 3069.696 3019.391 3226.097 3067.197 3081.718 3141.079 2990.596 2912.993  
## [9777] 2824.919 2895.674 3136.463 3160.859 3100.305 3272.443 3108.857 2942.894  
## [9785] 2924.769 2872.908 2929.543 2814.997 3145.127 2993.063 2805.009 3121.731  
## [9793] 2971.393 3203.170 2873.785 3060.653 2995.289 3075.545 2891.727 3065.319  
## [9801] 2813.961 3128.375 3016.485 2855.084 3207.543 2965.451 2836.534 2893.226  
## [9809] 3067.327 3056.132 2955.751 3173.630 2901.687 2993.544 3050.878 3034.551  
## [9817] 2945.266 2920.445 3115.453 3133.121 3086.703 2687.159 3040.540 3156.077  
## [9825] 3020.915 3063.569 3428.817 2989.512 3219.096 3024.253 3118.743 2875.109  
## [9833] 2918.772 3028.253 2939.334 2957.711 2890.117 2958.826 2909.687 2726.167  
## [9841] 3100.773 3212.939 3168.248 3264.586 3037.359 2865.801 2878.481 3057.463  
## [9849] 3090.186 2773.230 3012.664 3080.891 2963.467 2977.707 3126.451 3054.815  
## [9857] 2897.302 2857.277 3151.921 3063.457 2895.215 3208.553 3130.306 2987.237  
## [9865] 3030.142 2942.348 3029.390 3059.142 2745.871 2856.784 2895.793 2704.315  
## [9873] 3089.604 3107.657 3147.281 3071.128 3025.152 3148.394 3131.736 2860.495  
## [9881] 3011.753 2913.538 3113.512 2906.226 2933.674 3168.184 3013.015 3014.551  
## [9889] 3159.687 2998.313 3099.346 3181.132 3047.353 2910.864 3066.246 2876.892  
## [9897] 2866.387 2947.240 3117.295 3075.983 3121.311 3020.093 2974.779 2981.285  
## [9905] 2846.192 2931.445 3104.519 2907.404 2964.564 2975.951 2868.648 2917.682  
## [9913] 3141.377 2935.917 2964.412 3095.029 3068.816 3105.886 2890.857 2896.349  
## [9921] 3032.545 3154.259 2966.597 2845.035 2975.028 3259.036 2988.909 2939.588  
## [9929] 3092.118 3010.389 3104.003 2937.183 2798.178 3045.595 2846.258 2986.549  
## [9937] 2798.443 3131.809 2991.031 2947.756 2902.061 2943.620 2880.474 2974.646  
## [9945] 2890.491 2927.984 3178.638 3142.317 3199.512 2880.274 2991.827 2961.126  
## [9953] 2846.303 2804.911 3176.553 2907.719 3016.426 2874.578 2873.368 3020.739  
## [9961] 2943.574 3133.180 2927.894 3041.173 2791.730 3032.487 2952.963 3091.370  
## [9969] 3205.236 3014.902 3121.272 3095.568 2976.842 3187.821 3100.879 2979.844  
## [9977] 2786.260 3076.188 2959.373 3149.153 2949.168 3138.341 3173.571 2749.974  
## [9985] 2874.399 2785.643 2953.583 2784.147 3019.059 3173.890 3251.931 3041.092  
## [9993] 3000.145 2760.515 3062.145 3085.840 2970.429 3085.595 2945.985 2937.644

We will also examine a CI of 80% of the new “mylist.”

quantile(mylist,c(.1,.9))

## 10% 90%   
## 2841.396 3159.211

With the above mean of 3002, and confidence interval of 2825-3191, we are confident that the true population mean will fall between 2825 and 3191 80% of the time.

##Problem 2

For this problem we will add two additional seeds and execute 2 additional bootstraps to generate additional CI’s set for 80%. This will give us a better understanding of the true population mean. Seed 2 will be “0830”, seed 3 will be “3190”. We will discuss results after each code chunk execution.

#Second seed (0830), 1000 observations  
  
set.seed(0830)  
boots <- NULL  
for (i in 1:10000) {  
meanCollegeApps <- mean(sample(collegeApps,1000,replace = TRUE))  
boots<- c(boots,meanCollegeApps)  
}  
mylist<-boots  
  
# CI = 80% with new seed  
  
quantile(mylist,c(.1,.9))

## 10% 90%   
## 2846.634 3163.158

Using the second seed of “0830” to bootstrap 10,000 random samples, limiting inclusion to 1,000, we can confidently say that true population mean will fall between 2847 and 3163 80% of the time.

Now to look at a third seed.

#third seed (3190), 1000 observations  
start <- Sys.time()  
set.seed(3190)  
boots <- NULL  
for (i in 1:10000) {  
meanCollegeApps <- mean(sample(collegeApps,1000,replace = TRUE))  
boots<-c(boots,meanCollegeApps)  
}  
mylist<-boots  
  
#CI = 80% with third seed  
  
quantile(mylist,c(.1,.9))

## 10% 90%   
## 2850.162 3161.126

end <- Sys.time()  
end - start

## Time difference of 0.7276809 secs

After initiating a third random sample distribution using the seed “3190”, and calculating another CI at 80%, we can confidently say that the true population mean will fall between 2850 and 3161 80% of the time. Also included in the above chunk is a sys.time function that calculates the time required to execute the code within the chunk. For seed 3 with 1000 observations, we observe the time necessary to be .742801 seconds. We will compare this with later with seed 3 and 5000 observations.

Until now we have limited the random sample to only include 1000 observations. Next we will examine CI of 80% with “5000” observations included for all three seeds (2020,0830,3190). We will address the results at the end of analysis.

Seed 1 (2020), 5000 observations

set.seed(2020)  
boots <- NULL  
for (i in 1:10000) {  
meanCollegeApps <- mean(sample(collegeApps,5000,replace = TRUE))  
boots<- c(boots,meanCollegeApps)  
}  
  
mylist2020<-boots  
#CI=80%  
quantile(mylist2020,c(.1,.9))

## 10% 90%   
## 2930.169 3071.458

Seed 2 (0830), 5000 observations

set.seed(0830)  
boots <- NULL  
for (i in 1:10000) {  
meanCollegeApps <- mean(sample(collegeApps,5000,replace = TRUE))  
boots<- c(boots,meanCollegeApps)  
}  
  
mylist0830<-boots  
#CI=80%  
quantile(mylist0830,c(.1,.9))

## 10% 90%   
## 2931.789 3073.843

Seed 3 (3190), 5000 observations

start <- Sys.time()  
set.seed(3190)  
boots <- NULL  
for (i in 1:10000) {  
meanCollegeApps <- mean(sample(collegeApps,5000,replace = TRUE))  
boots<- c(boots,meanCollegeApps)  
}  
  
mylist3190<-boots  
#CI =80%  
quantile(mylist3190,c(.1,.9))

## 10% 90%   
## 2932.284 3072.757

end <- Sys.time()  
end - start

## Time difference of 2.196011 secs

After executing code for all three seeds, we observed that there was a difference in time necessary for the analysis. Specifically, using the sys.time() function returned a time difference in excess of 1.458441 seconds (2.201242 seconds - 0.742801 seconds) between a 1,000 sample and 5,000 sample. Additional time spent to run the larger sample negates the benefit derived from confidence gained from larger sample.

#Problem 3 We want to explore if there is a significant difference between the mean number of applications received among public and private schools within the “College” data.frame. We think the mean number of applications for public schools is higher.

This can be understood as: Public > Private. Null Hypothesis: Public-Private <= 0 Alternative hypothesis is Public-Private >0.

We have chosen a p-value significance indicator of .05.

For our first step, we must establish a new sample distribution. We will also define terms to be used in later analysis.

newSamp <- sample(College$Private,777)  
numPubPriv <- data.frame(numApps=College$Apps, PubPriv=College$Private)  
numPubPriv

## numApps PubPriv  
## 1 1660 Yes  
## 2 2186 Yes  
## 3 1428 Yes  
## 4 417 Yes  
## 5 193 Yes  
## 6 587 Yes  
## 7 353 Yes  
## 8 1899 Yes  
## 9 1038 Yes  
## 10 582 Yes  
## 11 1732 Yes  
## 12 2652 Yes  
## 13 1179 Yes  
## 14 1267 Yes  
## 15 494 Yes  
## 16 1420 Yes  
## 17 4302 Yes  
## 18 1216 Yes  
## 19 1130 Yes  
## 20 3540 No  
## 21 713 Yes  
## 22 7313 No  
## 23 619 Yes  
## 24 12809 No  
## 25 708 Yes  
## 26 1734 No  
## 27 2135 Yes  
## 28 7548 No  
## 29 662 Yes  
## 30 1879 Yes  
## 31 761 Yes  
## 32 948 Yes  
## 33 627 Yes  
## 34 602 Yes  
## 35 1690 Yes  
## 36 261 Yes  
## 37 1910 Yes  
## 38 2496 Yes  
## 39 990 Yes  
## 40 6075 Yes  
## 41 1163 Yes  
## 42 807 Yes  
## 43 632 Yes  
## 44 1220 Yes  
## 45 1320 Yes  
## 46 1208 No  
## 47 632 Yes  
## 48 519 Yes  
## 49 3466 Yes  
## 50 1858 Yes  
## 51 878 Yes  
## 52 202 Yes  
## 53 502 Yes  
## 54 1646 Yes  
## 55 805 Yes  
## 56 500 Yes  
## 57 6773 No  
## 58 377 Yes  
## 59 692 Yes  
## 60 20192 Yes  
## 61 3356 Yes  
## 62 9251 No  
## 63 443 Yes  
## 64 3767 Yes  
## 65 4186 Yes  
## 66 367 Yes  
## 67 1436 Yes  
## 68 392 Yes  
## 69 838 Yes  
## 70 7365 Yes  
## 71 12586 Yes  
## 72 1465 Yes  
## 73 6548 Yes  
## 74 860 Yes  
## 75 2362 Yes  
## 76 599 Yes  
## 77 1011 Yes  
## 78 563 Yes  
## 79 7811 No  
## 80 4540 No  
## 81 1784 Yes  
## 82 2087 Yes  
## 83 848 Yes  
## 84 2853 Yes  
## 85 1747 Yes  
## 86 100 Yes  
## 87 2694 Yes  
## 88 8728 Yes  
## 89 1160 Yes  
## 90 1096 Yes  
## 91 1616 Yes  
## 92 3877 Yes  
## 93 1257 No  
## 94 1083 Yes  
## 95 1754 Yes  
## 96 3847 Yes  
## 97 776 Yes  
## 98 1307 Yes  
## 99 369 Yes  
## 100 495 Yes  
## 101 601 Yes  
## 102 1283 Yes  
## 103 4158 No  
## 104 4681 No  
## 105 2785 No  
## 106 174 Yes  
## 107 1013 Yes  
## 108 959 Yes  
## 109 212 Yes  
## 110 342 Yes  
## 111 81 Yes  
## 112 880 Yes  
## 113 883 No  
## 114 1196 Yes  
## 115 1860 Yes  
## 116 2887 Yes  
## 117 460 Yes  
## 118 2174 Yes  
## 119 8065 No  
## 120 689 No  
## 121 1006 Yes  
## 122 604 Yes  
## 123 2848 Yes  
## 124 4856 Yes  
## 125 1432 Yes  
## 126 4772 No  
## 127 798 Yes  
## 128 946 Yes  
## 129 344 Yes  
## 130 457 Yes  
## 131 938 Yes  
## 132 511 Yes  
## 133 444 Yes  
## 134 983 Yes  
## 135 546 Yes  
## 136 141 Yes  
## 137 672 Yes  
## 138 2994 Yes  
## 139 7117 No  
## 140 2100 Yes  
## 141 3207 Yes  
## 142 9478 No  
## 143 314 Yes  
## 144 737 Yes  
## 145 6756 Yes  
## 146 281 Yes  
## 147 232 Yes  
## 148 688 Yes  
## 149 528 Yes  
## 150 3035 Yes  
## 151 440 Yes  
## 152 1538 Yes  
## 153 2967 Yes  
## 154 1576 Yes  
## 155 995 Yes  
## 156 866 Yes  
## 157 504 Yes  
## 158 585 Yes  
## 159 8587 Yes  
## 160 2373 Yes  
## 161 571 Yes  
## 162 967 No  
## 163 2762 Yes  
## 164 1994 Yes  
## 165 3014 Yes  
## 166 434 No  
## 167 1998 Yes  
## 168 793 Yes  
## 169 360 Yes  
## 170 604 Yes  
## 171 1011 Yes  
## 172 2799 Yes  
## 173 2153 Yes  
## 174 700 Yes  
## 175 13789 Yes  
## 176 1358 Yes  
## 177 9274 No  
## 178 3330 No  
## 179 379 Yes  
## 180 458 Yes  
## 181 2172 No  
## 182 5597 No  
## 183 486 Yes  
## 184 516 Yes  
## 185 1422 Yes  
## 186 2417 Yes  
## 187 1457 Yes  
## 188 245 Yes  
## 189 3624 Yes  
## 190 3151 Yes  
## 191 765 Yes  
## 192 8506 Yes  
## 193 1256 No  
## 194 659 Yes  
## 195 560 Yes  
## 196 1801 No  
## 197 4784 Yes  
## 198 1455 No  
## 199 1339 Yes  
## 200 1415 Yes  
## 201 1947 Yes  
## 202 3306 No  
## 203 1381 Yes  
## 204 11651 No  
## 205 291 Yes  
## 206 4200 Yes  
## 207 3440 No  
## 208 1801 No  
## 209 553 Yes  
## 210 804 Yes  
## 211 5187 Yes  
## 212 895 Yes  
## 213 346 Yes  
## 214 2161 Yes  
## 215 2464 Yes  
## 216 1110 Yes  
## 217 668 Yes  
## 218 809 Yes  
## 219 5653 No  
## 220 7875 Yes  
## 221 727 Yes  
## 222 11115 Yes  
## 223 7837 No  
## 224 3793 No  
## 225 348 Yes  
## 226 3596 Yes  
## 227 633 Yes  
## 228 1886 Yes  
## 229 674 Yes  
## 230 440 Yes  
## 231 1151 Yes  
## 232 548 Yes  
## 233 555 Yes  
## 234 5165 No  
## 235 780 Yes  
## 236 608 Yes  
## 237 510 Yes  
## 238 2039 Yes  
## 239 2491 Yes  
## 240 1202 Yes  
## 241 1709 Yes  
## 242 380 Yes  
## 243 3140 Yes  
## 244 1006 Yes  
## 245 817 Yes  
## 246 7178 Yes  
## 247 1006 Yes  
## 248 467 Yes  
## 249 1721 Yes  
## 250 2083 Yes  
## 251 13865 Yes  
## 252 1377 Yes  
## 253 817 Yes  
## 254 823 Yes  
## 255 920 Yes  
## 256 922 Yes  
## 257 2688 Yes  
## 258 7428 Yes  
## 259 602 Yes  
## 260 699 Yes  
## 261 1712 Yes  
## 262 949 Yes  
## 263 608 Yes  
## 264 450 Yes  
## 265 600 Yes  
## 266 723 Yes  
## 267 607 Yes  
## 268 894 Yes  
## 269 1756 Yes  
## 270 8681 No  
## 271 3050 Yes  
## 272 268 Yes  
## 273 1163 Yes  
## 274 5659 No  
## 275 16587 No  
## 276 735 Yes  
## 277 4892 Yes  
## 278 8427 No  
## 279 7259 Yes  
## 280 11223 No  
## 281 472 Yes  
## 282 2957 No  
## 283 605 Yes  
## 284 2421 Yes  
## 285 8474 Yes  
## 286 833 No  
## 287 313 Yes  
## 288 1005 Yes  
## 289 5880 No  
## 290 589 Yes  
## 291 3121 No  
## 292 584 Yes  
## 293 2212 Yes  
## 294 461 Yes  
## 295 1456 Yes  
## 296 355 Yes  
## 297 1040 Yes  
## 298 361 Yes  
## 299 2929 Yes  
## 300 4010 Yes  
## 301 544 Yes  
## 302 979 Yes  
## 303 497 Yes  
## 304 2336 No  
## 305 831 Yes  
## 306 1166 No  
## 307 1243 Yes  
## 308 1470 Yes  
## 309 1386 Yes  
## 310 6397 Yes  
## 311 979 Yes  
## 312 244 Yes  
## 313 477 Yes  
## 314 2774 Yes  
## 315 1154 Yes  
## 316 787 Yes  
## 317 1660 No  
## 318 810 Yes  
## 319 1561 Yes  
## 320 900 Yes  
## 321 3570 No  
## 322 2747 No  
## 323 1641 Yes  
## 324 2013 Yes  
## 325 5996 No  
## 326 2397 No  
## 327 4076 Yes  
## 328 3768 Yes  
## 329 1891 Yes  
## 330 3579 Yes  
## 331 1549 Yes  
## 332 1286 Yes  
## 333 1756 Yes  
## 334 535 No  
## 335 2939 Yes  
## 336 740 Yes  
## 337 874 Yes  
## 338 1004 Yes  
## 339 2432 Yes  
## 340 962 Yes  
## 341 3073 No  
## 342 824 Yes  
## 343 1611 Yes  
## 344 4731 Yes  
## 345 5152 Yes  
## 346 4226 Yes  
## 347 499 Yes  
## 348 4350 No  
## 349 478 Yes  
## 350 695 Yes  
## 351 941 Yes  
## 352 1464 Yes  
## 353 549 Yes  
## 354 1107 Yes  
## 355 6411 Yes  
## 356 233 No  
## 357 1002 Yes  
## 358 578 Yes  
## 359 420 Yes  
## 360 2286 Yes  
## 361 1557 Yes  
## 362 857 Yes  
## 363 1981 Yes  
## 364 1584 No  
## 365 1742 Yes  
## 366 9239 No  
## 367 18114 No  
## 368 2618 No  
## 369 331 Yes  
## 370 6011 No  
## 371 610 Yes  
## 372 1444 Yes  
## 373 905 Yes  
## 374 1217 Yes  
## 375 594 Yes  
## 376 4255 No  
## 377 480 No  
## 378 1576 No  
## 379 1310 Yes  
## 380 601 Yes  
## 381 2707 Yes  
## 382 572 No  
## 383 3500 No  
## 384 5220 No  
## 385 263 Yes  
## 386 2442 No  
## 387 1232 Yes  
## 388 3708 Yes  
## 389 586 Yes  
## 390 882 Yes  
## 391 1800 Yes  
## 392 279 Yes  
## 393 235 Yes  
## 394 368 Yes  
## 395 325 Yes  
## 396 1321 Yes  
## 397 1170 Yes  
## 398 657 Yes  
## 399 1310 Yes  
## 400 510 Yes  
## 401 2519 Yes  
## 402 2225 No  
## 403 1109 Yes  
## 404 513 Yes  
## 405 947 Yes  
## 406 1879 No  
## 407 787 No  
## 408 13594 Yes  
## 409 872 Yes  
## 410 2220 Yes  
## 411 1563 No  
## 412 4809 No  
## 413 10634 No  
## 414 812 Yes  
## 415 1127 Yes  
## 416 2968 No  
## 417 465 Yes  
## 418 6040 No  
## 419 11901 Yes  
## 420 5891 No  
## 421 10706 No  
## 422 2729 No  
## 423 616 Yes  
## 424 860 Yes  
## 425 12289 Yes  
## 426 1743 Yes  
## 427 379 Yes  
## 428 3041 No  
## 429 4778 Yes  
## 430 2324 Yes  
## 431 792 Yes  
## 432 2936 Yes  
## 433 11023 No  
## 434 2190 Yes  
## 435 758 Yes  
## 436 776 Yes  
## 437 4522 No  
## 438 1496 Yes  
## 439 910 Yes  
## 440 2308 Yes  
## 441 8256 Yes  
## 442 1603 Yes  
## 443 940 Yes  
## 444 943 Yes  
## 445 944 No  
## 446 19315 No  
## 447 3821 Yes  
## 448 701 No  
## 449 838 Yes  
## 450 1538 Yes  
## 451 692 Yes  
## 452 663 Yes  
## 453 404 Yes  
## 454 1133 Yes  
## 455 809 Yes  
## 456 875 Yes  
## 457 1132 Yes  
## 458 2405 No  
## 459 1082 Yes  
## 460 13218 Yes  
## 461 5139 Yes  
## 462 21804 No  
## 463 516 Yes  
## 464 1025 Yes  
## 465 3712 Yes  
## 466 5702 No  
## 467 2088 No  
## 468 1771 Yes  
## 469 696 Yes  
## 470 1966 Yes  
## 471 427 Yes  
## 472 4996 Yes  
## 473 2302 Yes  
## 474 3586 Yes  
## 475 587 Yes  
## 476 484 Yes  
## 477 2227 Yes  
## 478 935 Yes  
## 479 560 Yes  
## 480 3304 Yes  
## 481 1777 Yes  
## 482 434 Yes  
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## 484 48094 No  
## 485 3366 No  
## 486 5785 No  
## 487 2307 Yes  
## 488 897 Yes  
## 489 2095 Yes  
## 490 3971 No  
## 491 213 Yes  
## 492 1046 Yes  
## 493 933 Yes  
## 494 920 Yes  
## 495 833 Yes  
## 496 2519 Yes  
## 497 292 Yes  
## 498 3294 Yes  
## 499 888 Yes  
## 500 876 Yes  
## 501 150 Yes  
## 502 1910 Yes  
## 503 2248 Yes  
## 504 1606 Yes  
## 505 700 Yes  
## 506 785 Yes  
## 507 489 Yes  
## 508 335 Yes  
## 509 4216 No  
## 510 1680 Yes  
## 511 9402 No  
## 512 4019 Yes  
## 513 1380 Yes  
## 514 1109 Yes  
## 515 584 Yes  
## 516 855 Yes  
## 517 1183 Yes  
## 518 2115 Yes  
## 519 4576 Yes  
## 520 936 Yes  
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## 522 540 Yes  
## 523 2961 Yes  
## 524 464 Yes  
## 525 1003 Yes  
## 526 1016 Yes  
## 527 437 Yes  
## 528 4293 Yes  
## 529 2925 Yes  
## 530 2807 No  
## 531 2281 No  
## 532 818 No  
## 533 385 Yes  
## 534 2540 No  
## 535 4301 Yes  
## 536 1093 Yes  
## 537 6118 No  
## 538 1047 No  
## 539 321 Yes  
## 540 213 Yes  
## 541 1244 Yes  
## 542 283 Yes  
## 543 3713 Yes  
## 544 372 Yes  
## 545 1489 Yes  
## 546 323 Yes  
## 547 1368 Yes  
## 548 2753 Yes  
## 549 191 Yes  
## 550 2643 Yes  
## 551 1340 No  
## 552 1243 Yes  
## 553 1334 Yes  
## 554 651 Yes  
## 555 861 Yes  
## 556 450 Yes  
## 557 1557 Yes  
## 558 1768 Yes  
## 559 4019 No  
## 560 3646 Yes  
## 561 13528 No  
## 562 14463 No  
## 563 15039 No  
## 564 12512 No  
## 565 7294 No  
## 566 8000 No  
## 567 5318 No  
## 568 7888 No  
## 569 4877 No  
## 570 8598 No  
## 571 8399 No  
## 572 5549 No  
## 573 3150 No  
## 574 2119 No  
## 575 2096 Yes  
## 576 462 Yes  
## 577 10477 Yes  
## 578 257 Yes  
## 579 4414 Yes  
## 580 1769 Yes  
## 581 232 Yes  
## 582 14474 No  
## 583 529 No  
## 584 4095 Yes  
## 585 497 Yes  
## 586 4345 No  
## 587 592 Yes  
## 588 1500 No  
## 589 1154 Yes  
## 590 845 Yes  
## 591 759 Yes  
## 592 5042 No  
## 593 1262 Yes  
## 594 3058 Yes  
## 595 247 Yes  
## 596 222 Yes  
## 597 2425 Yes  
## 598 7033 Yes  
## 599 626 Yes  
## 600 2267 Yes  
## 601 484 Yes  
## 602 3495 Yes  
## 603 4800 No  
## 604 1797 No  
## 605 3235 No  
## 606 19873 No  
## 607 15698 No  
## 608 6986 No  
## 609 682 Yes  
## 610 6348 Yes  
## 611 6855 No  
## 612 9735 No  
## 613 681 Yes  
## 614 6361 Yes  
## 615 14446 Yes  
## 616 2974 Yes  
## 617 927 Yes  
## 618 576 Yes  
## 619 2096 Yes  
## 620 12445 No  
## 621 11220 No  
## 622 5081 Yes  
## 623 3580 No  
## 624 14939 No  
## 625 8384 No  
## 626 1487 Yes  
## 627 8579 No  
## 628 1597 Yes  
## 629 4777 No  
## 630 1208 No  
## 631 441 No  
## 632 461 No  
## 633 4269 No  
## 634 14292 No  
## 635 14438 No  
## 636 3347 No  
## 637 7122 Yes  
## 638 19152 No  
## 639 4192 No  
## 640 1458 No  
## 641 11054 No  
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## 643 6574 No  
## 644 1877 No  
## 645 1618 No  
## 646 452 Yes  
## 647 1351 No  
## 648 6277 No  
## 649 1209 Yes  
## 650 9750 No  
## 651 1757 No  
## 652 14596 No  
## 653 5803 No  
## 654 5191 No  
## 655 6071 No  
## 656 2777 No  
## 657 1800 No  
## 658 4418 No  
## 659 5530 No  
## 660 4144 No  
## 661 7700 Yes  
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## 663 8631 No  
## 664 12394 Yes  
## 665 8586 No  
## 666 1758 Yes  
## 667 4044 Yes  
## 668 9643 No  
## 669 5892 Yes  
## 670 8766 Yes  
## 671 3934 Yes  
## 672 2306 Yes  
## 673 285 No  
## 674 4471 Yes  
## 675 848 No  
## 676 7693 No  
## 677 7589 No  
## 678 12229 Yes  
## 679 1401 No  
## 680 2379 No  
## 681 2850 No  
## 682 2057 Yes  
## 683 374 Yes  
## 684 7473 No  
## 685 3281 No  
## 686 14752 No  
## 687 4217 No  
## 688 974 Yes  
## 689 2459 Yes  
## 690 1445 Yes  
## 691 1712 Yes  
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## 693 7663 No  
## 694 15849 No  
## 695 12749 No  
## 696 1558 No  
## 697 2593 No  
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## 699 4400 No  
## 700 2409 No  
## 701 14901 No  
## 702 5244 No  
## 703 2029 No  
## 704 663 Yes  
## 705 1399 Yes  
## 706 325 Yes  
## 707 368 No  
## 708 2075 Yes  
## 709 7791 Yes  
## 710 3550 Yes  
## 711 7759 Yes  
## 712 4963 No  
## 713 2996 No  
## 714 15712 No  
## 715 1847 Yes  
## 716 1470 Yes  
## 717 647 Yes  
## 718 1465 Yes  
## 719 800 Yes  
## 720 1416 Yes  
## 721 5661 Yes  
## 722 1092 Yes  
## 723 440 Yes  
## 724 1231 Yes  
## 725 1305 Yes  
## 726 3315 Yes  
## 727 1209 Yes  
## 728 6540 No  
## 729 7654 Yes  
## 730 1373 No  
## 731 1190 Yes  
## 732 280 Yes  
## 733 665 Yes  
## 734 2895 Yes  
## 735 318 Yes  
## 736 1480 Yes  
## 737 980 Yes  
## 738 4772 Yes  
## 739 6502 No  
## 740 1164 No  
## 741 1566 Yes  
## 742 3224 No  
## 743 1205 Yes  
## 744 9167 No  
## 745 1650 Yes  
## 746 2702 No  
## 747 5548 No  
## 748 3100 No  
## 749 662 Yes  
## 750 996 Yes  
## 751 917 Yes  
## 752 950 No  
## 753 1432 Yes  
## 754 1738 Yes  
## 755 903 Yes  
## 756 1861 Yes  
## 757 1681 Yes  
## 758 1121 Yes  
## 759 2139 Yes  
## 760 1631 Yes  
## 761 1658 Yes  
## 762 663 Yes  
## 763 469 Yes  
## 764 4186 Yes  
## 765 167 Yes  
## 766 1239 Yes  
## 767 3325 No  
## 768 2320 No  
## 769 152 Yes  
## 770 1979 Yes  
## 771 1501 Yes  
## 772 2768 Yes  
## 773 2197 No  
## 774 1959 Yes  
## 775 2097 Yes  
## 776 10705 Yes  
## 777 2989 Yes

tapply(numPubPriv$numApps, numPubPriv$PubPriv, mean)

## No Yes   
## 5729.920 1977.929

According to the above code, we have calculated the means of: Public colleges applications across all public colleges as 5730. Private colleges applications across all private colleges as 1978

In our next chunk, we will label the means listed above as “newPubMeans” and “newPrivMeans” representing public and private respectively.

newMeans <- tapply(numPubPriv$numApps,numPubPriv$PubPriv, mean)  
newPubMeans <- newMeans[1]  
newPrivMeans <-newMeans[2]

Next we will calculate the difference of these means.

newPubMeans - newPrivMeans

## No   
## 3751.991

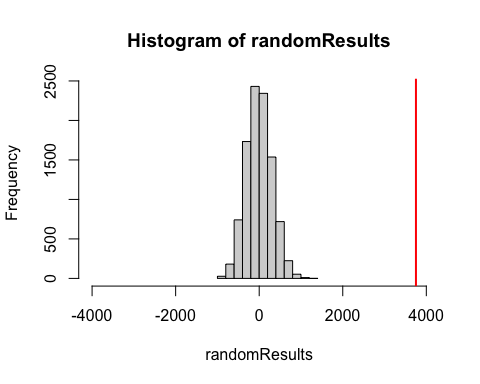
We have identified the mean difference between public and private college applications as 3751.991 or 3752.

Next we created another random sample based on our true population using the seed of 42, generating 10,000 observations and including 777 of them. This bootstraping will be named “randomResults”.

set.seed(42)  
randomResults <- NULL  
for(i in 1:10000){  
newSample <- sample (College$Private,777)  
numPubPriv <- data.frame(numApps=College$Apps, PubPriv=newSample)  
newMeans <-tapply(numPubPriv$numApps,numPubPriv$PubPriv, mean)  
randomResults <- c(randomResults, newMeans[1]-newMeans[2])  
}

After generating the randomResults sample, we will generate a histogram with a line to indicate the difference of means in comparison to the randomResults histogram.

hist(randomResults, xlim=c(-4000,4000))  
abline(v=newPubMeans - newPrivMeans, col="red", lwd=2)

 We observe that the observations included in the “randomResults” sample are displayed in a normal distribution (similar to a bell curve) centered around zero. The red line indicates the difference in means (3752) of the two subsets of public college applications and private college applications. Based on the visual representation, and understanding that our p-value should indicate the probability of occurrences above (or to the right of) the representation of mean differences demarcation line (in red), we can make the assumption that the p-value will be zero.

However, making an assumption is not a best practice or good habit for data scientists, therefore we will test the p-value below.

greaterThanOrig <- sum(randomResults > (newPubMeans - newPrivMeans))  
sum(greaterThanOrig)/10000

## [1] 0

As expected, the results of the above formula, wherein occurrences within the randomResults sample occur greater than the different of the mean for public college applications and the mean of private college applications. As such: p=0 p=0<.05 Because the p value is less than the reasonable alpha of .05, we reject the Null Hypothesis because public colleges receive less than or equal applications than private colleges.