HW 1 Submission

Chapter 2, exercise 1 (see next page for summary output)

There are several different asset classes or "groupings" in this analysis: (note: plots were not used for this commentary; only summaries were used to generate this commentary)

1. Fixed-Income (US-Treasury Rates (3-month, 2-year, 10-year, and 30-year) and Moody's Yield on Seasoned US-Corporate Bonds (BAA))
    a. Using the summary function alone, these fixed-income instruments would appear to be relatively stable, as the Interquartile Range is fairly narrow and the distance between (1Q, Mean) and (3Q, Mean) is roughly the same size. There are outliers, however, as can be seen in the Max. for these instruments (between 12.04 and 16.95).
2. Real Estate (Real Estate Indices (US/Canada) and RE investment/trust firms)
    a. Similar to the fixed income asset class, Real Estate tends to stay in a narrow interquartile range and is balanced pretty evenly around the mean for each instrument. There are very nasty outliers however; for example: the Canadian Apartments REIT has an interquartile range ~14.6 (1Q at 10.39 and 3Q at 24.97), with a mean of 18.95. The max, however, is a whopping 48.99, which is nearly 2.5x the average price!
3. Commodities
    a. In contrast to the previous two asset classes, commodities aren't very stable at all. These instruments have a wide interquartile range relative to their mean, and the distance between their min/max and mean is much larger still! As a result, I've concluded that these instruments have wild and dramatic price movements.
4. Global Equity Indices
    a. Somewhat similar to commodities, these instruments tend to vary wildly; the IQR of these instruments tends to be wide and left or right-leaning when compared to the mean.
5. Foreign-Exchange
    a. The summary data of the FX asset class had some very interesting results. Using the same analysis methodology as before, I would have easily concluded that FX is a fairly stable asset class (aside from USDJPY, it would seem). The narrow IQR and equally-balanced mean (relative to 1Q and 3Q) are what initially led me to this conclusion. However, after generating the plots (more on that in exercise-2), I was very surprised to find that these instruments move around quite often, much more than I had originally thought.

```
> summary(ust.raw)
     Index               UST3M            UST2Y            UST10Y           UST30Y
 Min.   :1962-01-02  Min.   : 0.000  Min.   : 0.160  Min.   : 1.370  Min.   : 2.110
 1st Qu.:1976-03-21  1st Qu.: 0.950  1st Qu.: 1.870  1st Qu.: 4.140  1st Qu.: 4.420
 Median :1990-06-05  Median : 4.240  Median : 5.380  Median : 5.950  Median : 6.680
 Mean   :1990-05-26  Mean   : 3.962  Mean   : 5.368  Mean   : 6.201  Mean   : 6.859
 3rd Qu.:2004-08-04  3rd Qu.: 5.870  3rd Qu.: 7.760  3rd Qu.: 7.820  3rd Qu.: 8.690
 Max.   :2018-09-27  Max.   :15.490  Max.   :16.950  Max.   :15.840  Max.   :15.210
                     NA's   :4983    NA's   :3592                    NA's   :4764
> summary(corpbond.raw)
     Index              USBaaCorp
 Min.   :1986-01-02  Min.   : 4.150
 1st Qu.:1993-08-23  1st Qu.: 6.210
 Median :2001-04-27  Median : 7.610
 Mean   :2001-05-08  Mean   : 7.583
 3rd Qu.:2009-01-22  3rd Qu.: 8.760
 Max.   :2016-10-07  Max.   :12.040
> summary(re.raw)
     Index               DJUSRE           NLY              EqRes            CdnApt
 Min.   :2007-01-02  Min.   :252.1   Min.   : 3.222  Min.   :10.63   Min.   : 6.944
 1st Qu.:2009-12-07  1st Qu.:288.9   1st Qu.: 5.836  1st Qu.:27.98   1st Qu.:10.390
 Median :2012-11-12  Median :303.3   Median : 7.042  Median :42.37   Median :17.458
 Mean   :2012-11-13  Mean   :300.8   Mean   : 6.930  Mean   :42.82   Mean   :18.932
 3rd Qu.:2015-10-21  3rd Qu.:315.5   3rd Qu.: 8.053  3rd Qu.:59.31   3rd Qu.:24.965
 Max.   :2018-09-28  Max.   :336.9   Max.   :11.075  Max.   :69.44   Max.   :48.998
                     NA's   :1851    NA's   :52      NA's   :52      NA's   :61
> summary(commodities.raw)
     Index               GSCI            Corn            Soybeans          Copper
 Min.   :1959-07-01  Min.   :283.1   Min.   :100.7   Min.   : 204.4  Min.   :0.269
 1st Qu.:1974-05-21  1st Qu.:371.7   1st Qu.:175.5   1st Qu.: 461.2  1st Qu.:0.599
 Median :1989-03-27  Median :403.4   Median :245.0   Median : 595.0  Median :0.806
 Mean   :1989-03-17  Mean   :401.2   Mean   :266.5   Mean   : 646.0  Mean   :1.259
 3rd Qu.:2004-01-29  3rd Qu.:442.0   3rd Qu.:329.1   3rd Qu.: 785.4  3rd Qu.:1.368
 Max.   :2018-09-28  Max.   :494.4   Max.   :831.2   Max.   :1771.0  Max.   :4.623
                     NA's   :14570   NA's   :63      NA's   :61      NA's   :152
      Rebar              WTI             USNatgas
 Min.   :1580    Min.   : 10.42  Min.   : 1.046
 1st Qu.:2242    1st Qu.: 19.87  1st Qu.: 2.204
 Median :3046    Median : 29.61  Median : 3.033
 Mean   :3002    Mean   : 42.66  Mean   : 3.820
 3rd Qu.:3708    3rd Qu.: 61.51  3rd Qu.: 4.729
 Max.   :4780    Max.   :145.29  Max.   :15.378
 NA's   :13775   NA's   :6062    NA's   :7840
```

```
> summary(eqtidx.raw)
     Index               SP500            R2000            TSX              IPC
 Min.   :2007-01-02  Min.   : 676.5  Min.   : 343.3  Min.   : 7567   Min.   :16891
 1st Qu.:2009-12-09  1st Qu.:1277.7  1st Qu.: 725.7  1st Qu.:12224   1st Qu.:31784
 Median :2012-11-13  Median :1515.7  Median : 848.5  Median :13430   Median :40222
 Mean   :2012-11-15  Mean   :1674.7  Mean   : 970.6  Mean   :13335   Mean   :38300
 3rd Qu.:2015-10-22  3rd Qu.:2076.3  3rd Qu.:1188.4  3rd Qu.:14696   3rd Qu.:44895
 Max.   :2018-09-28  Max.   :2930.8  Max.   :1740.8  Max.   :16567   Max.   :51713
                     NA's   :102     NA's   :102     NA's   :110     NA's   :120
     FTSE100            ESTX50           SMI             HangSeng          STI              NK225
 Min.   :3512    Min.   :1810    Min.   :4308    Min.   :11016   Min.   :1457    Min.   : 7055
 1st Qu.:5664    1st Qu.:2702    1st Qu.:6440    1st Qu.:20629   1st Qu.:2854    1st Qu.: 9866
 Median :6242    Median :3022    Median :7929    Median :22520   Median :3097    Median :14486
 Mean   :6165    Mean   :3088    Mean   :7604    Mean   :22605   Mean   :3026    Mean   :14411
 3rd Qu.:6753    3rd Qu.:3447    3rd Qu.:8763    3rd Qu.:24036   3rd Qu.:3280    3rd Qu.:17860
 Max.   :7878    Max.   :4558    Max.   :9612    Max.   :33154   Max.   :3876    Max.   :24124
 NA's   :91      NA's   :169     NA's   :112     NA's   :164     NA's   :132     NA's   :181
> summary(fx.raw)
     Index               USDJPY           USDEUR           USDCAD           AUDNZD
 Min.   :1976-08-02  Min.   : 3346   Min.   :0.830   Min.   :0.6190  Min.   :1.008
 1st Qu.:1987-03-17  1st Qu.: 6498   1st Qu.:1.093   1st Qu.:0.7344  1st Qu.:1.086
 Median :1997-10-22  Median : 8367   Median :1.230   Median :0.8076  Median :1.133
 Mean   :1997-10-09  Mean   : 7932   Mean   :1.209   Mean   :0.8108  Mean   :1.159
 3rd Qu.:2008-05-15  3rd Qu.: 9406   3rd Qu.:1.334   3rd Qu.:0.8665  3rd Qu.:1.243
 Max.   :2018-09-28  Max.   :13210   Max.   :1.596   Max.   :1.0837  Max.   :1.373
                     NA's   :84      NA's   :5740    NA's   :200     NA's   :6970
> 
```

Chapter 2, exercise 2

1. Fixed Income
    a. The short-term (3M and 2Y) tend to mimic each other, and the long-term (10Y and 30Y) tend to mimic each other closely as well, but by no means would I call these "stable." Since January'14, we've seen short-term rates rise from essentially zero (even slightly negative) to nearly 2% on the 3-month and over 2.5% on the 2-year.
    b. In addition, the 10 and 30-year rates have swung dramatically, falling 1.5-2.0% (respectively) to their lows midway through 2016. Rates have then dramatically risen through December 2017, with the 10-year returning to 3.0% and the 30-year rising to 3.0%, which is still almost a full percentage point lower than what it was at the beginning of 2014.
2. Foreign-Exchange
    a. These do not seem to follow much of a pattern at all. Each FX rate appears to follow a different path, but there are times when these paths have greater variance than what appears to be the "norm" for each rate. If there is any pattern that can be discerned, it may be that the FX for a given country does follow somewhat of a similar path (at least weakly) with FX rates of that country and other market participants; the USD-JPY/EUR/CAD plots are a good demonstration of this. While the trajectory of these rates are by no means identical, there is definitely a positive correlation here.
3. Real Estate
    a. These assets follow a similar path, but with varying degrees. EQR and NLY, both significantly involved in the US real estate market (Trust/Investment firms) appear to closely follow the DJUSRE Index (for obvious reasons).
    b. CdnApt (in Canada) resembles the DJUSRE but to a much lesser extent. It would appear that the downturns in the US Real Estate market have some degree of effect on the Canadian market, but the upswings in the Canadian RE market don't have any affect on the US market.
4. Equities
    a. These instruments seem to follow a somewhat similar path, but this is not always in the case. They follow a similar path especially during global crises, such as the downswing in all markets caused by events such as Brexit and the 2016 US Presidential Election (mainly events in the latter part of 2016).
    b. Overall, it appears that these instruments follow a path in terms of regions. For example, the US and Canadian indices seem to follow each other in a much closer fashion than the US and Asian market indices follow each other. Similarly, the Asian market Indices seem to follow each other in a "group" and the Euro Indices seem to follow each other in a "group" as well, meaning that if there is a downturn in one large market in Europe, one might expect to see a downturn in the other Euro Indices as well, etc.
5. Commodities
    a. Commodity prices do not seem to follow a cohesive path either; each individual commodity follows a different path than other commodities. There are, however, very apparent spikes in prices at different times for each commodity. One good example of dramatic upswings/downswings in price is in Rebar, from early 2016 towards the end of

2017. Another example that shows a different, but dramatic swing in price is in Copper, which moved from lows of 2.0 in early-mid 2016 to 2.5 at the end of 2016, with another large upswing to 3.0 in the middle of 2017.

   b. Note there appears to be a data error in GSCI, as most of the plot is missing data (all of 2014, and the second half of 2015, 2016, and 2017 is missing)
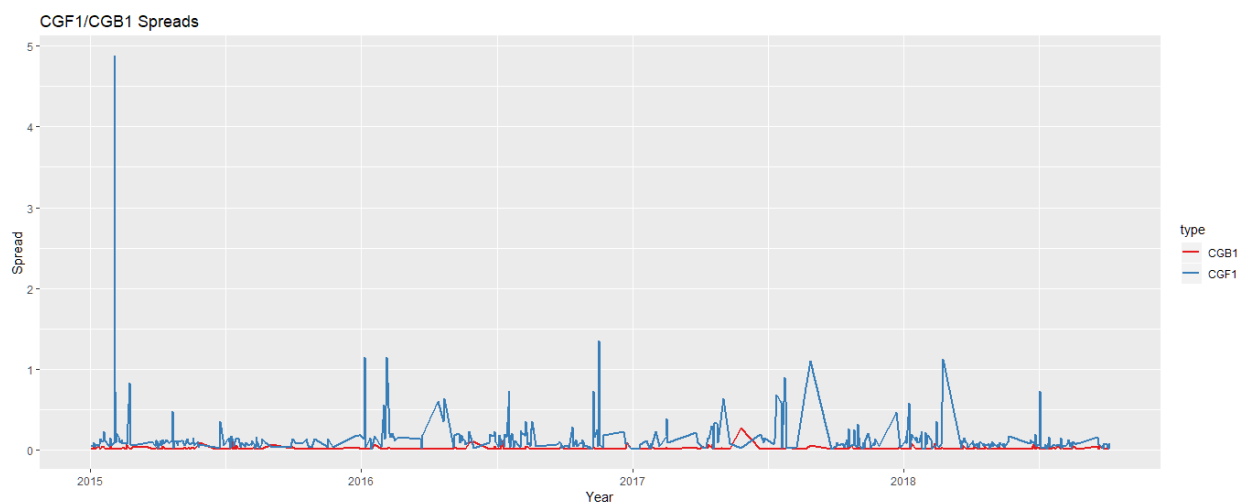
Chapter 2, exercise 3

Given the summary outputs of both the geometric index and equally-weighted portfolio returns, I would rather hold the equally-weighted portfolio. This is because the average return (1.0001) is higher (albeit, only slightly) than the average return of the geometric index.

```
> geo_idx <- ((1+r1)*(1+r2)*(1+r3)*(1+r4)*(1+r5))^(1/5)
> summary(geo_idx)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.9301  0.9874  0.9998  0.9995  1.0118  1.0649
> eq_port <- (1/5)*((1+r1)+(1+r2)+(1+r3)+(1+r4)+(1+r5))
> summary(eq_port)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.9306  0.9880  1.0004  1.0001  1.0124  1.0660
> any(eq_port > geo_idx)
[1] TRUE
> summary(eq_port) > summary(geo_idx)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   TRUE    TRUE    TRUE    TRUE    TRUE    TRUE
> |
```
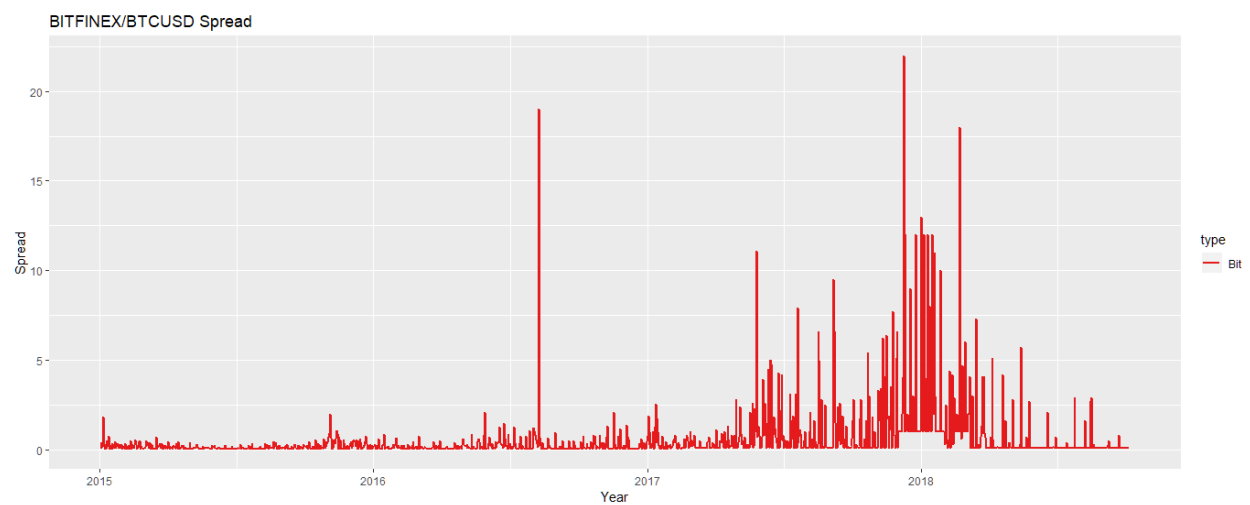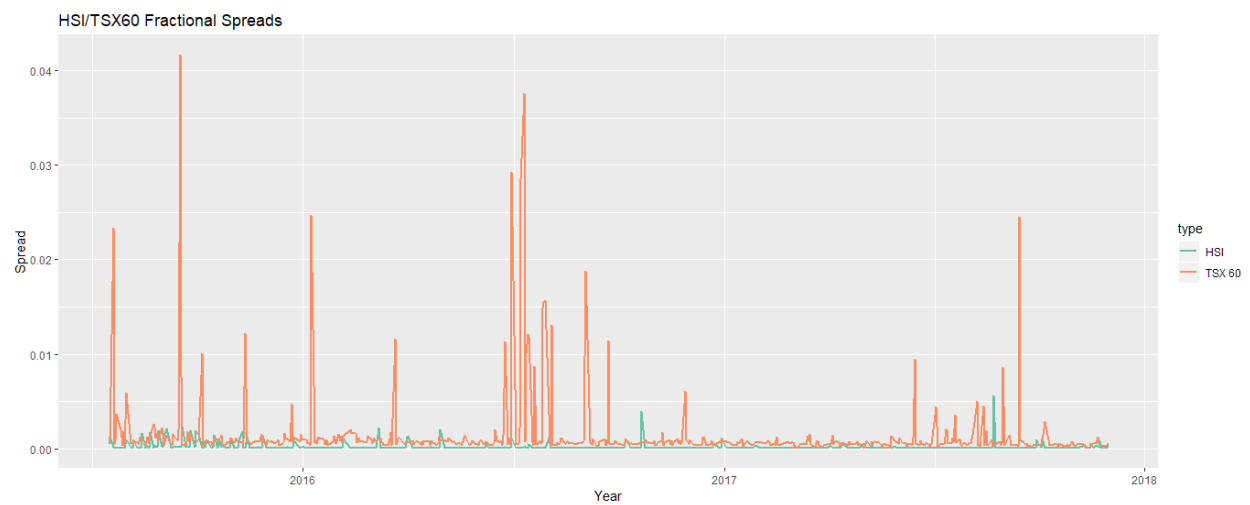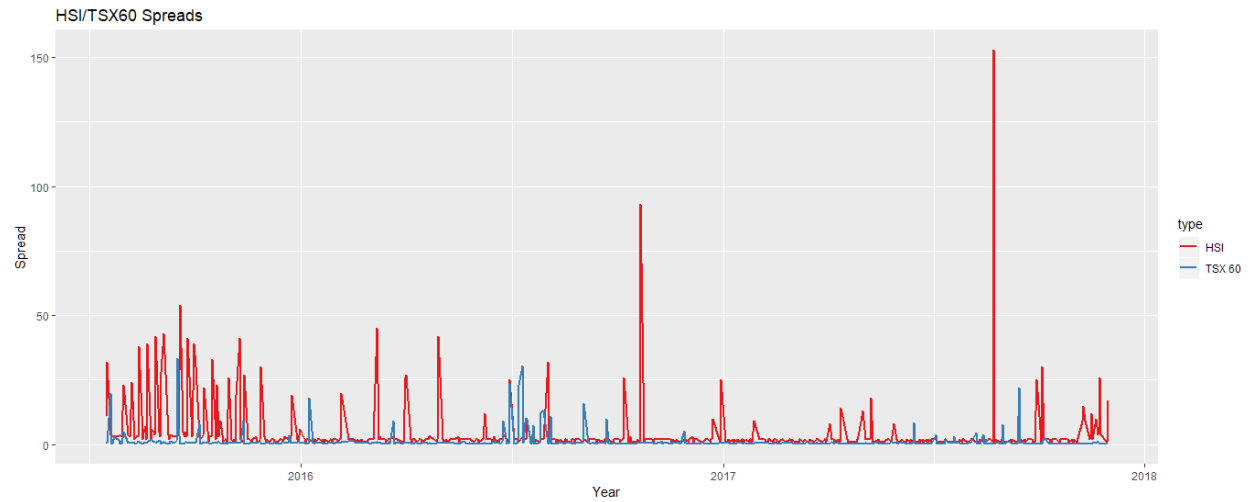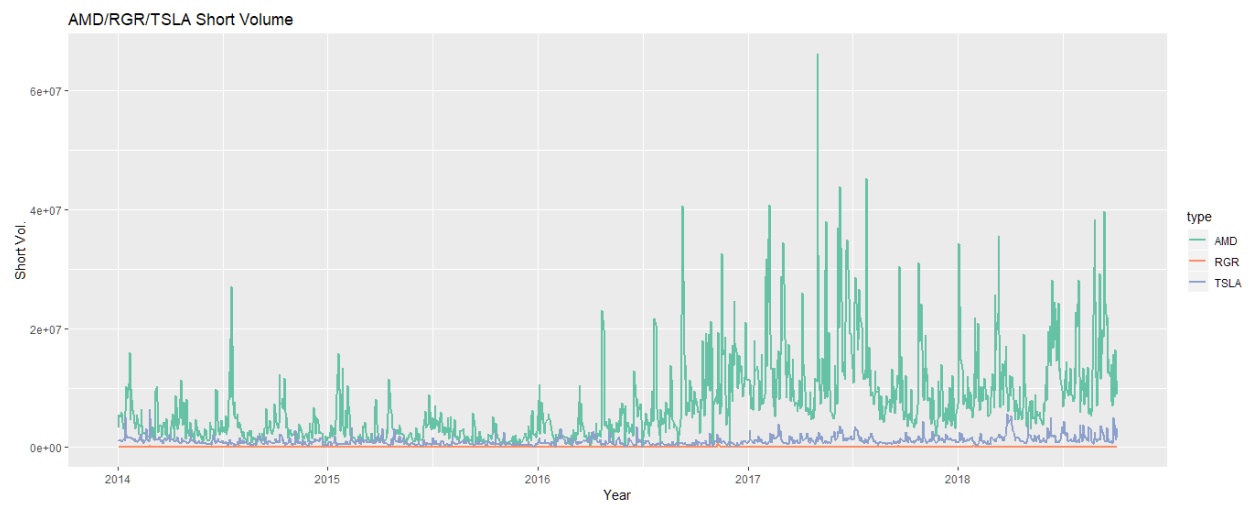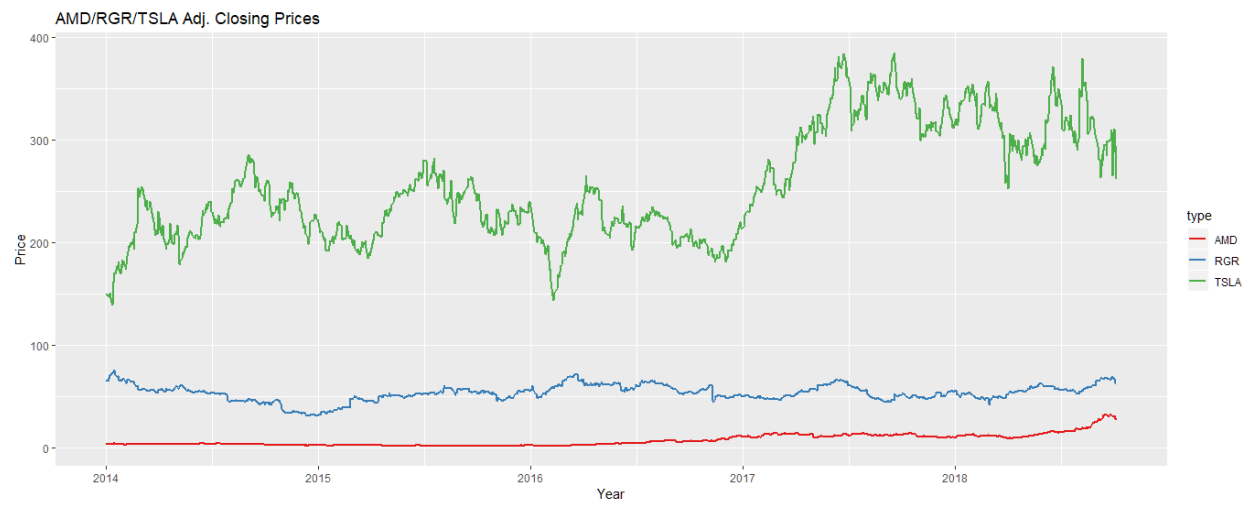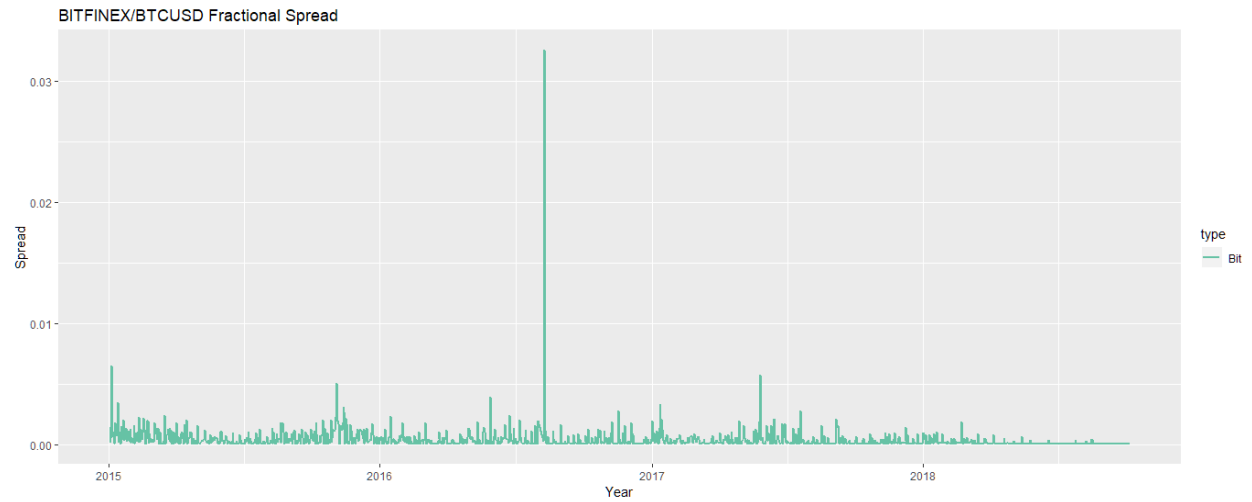
Chapter 2, exercise 4

The screenshot used in exercise 3 will help to answer this question. I generated two inequalities to determine if holding the equally-weighted portfolio is always better than holding the geometric index. I used the any() function to check all time periods ("steps") for eq_port > geo_idx. This function returned TRUE, meaning that for all of these periods, the eq_port returns were greater than that of the geometric index. In addition, we can see that this inequality is also TRUE for all of the summary statistics generated for both of these investment options; meaning that the min/max/mean are larger in the eq_port than that in the geometric index.

Chapter 3, exercise 1

CGF1/CGB1 Fractional Spreads

CU/AL/TN Spreads

CU/AL/TN Fractional Spreads

HSI/TSX60 Spreads

HSI/TSX60 Fractional Spreads

BITFINEX/BTCUSD Spread

BITFINEX/BTCUSD Fractional Spread

AMD/RGR/TSLA Adj. Closing Prices

AMD/RGR/TSLA Short Volume
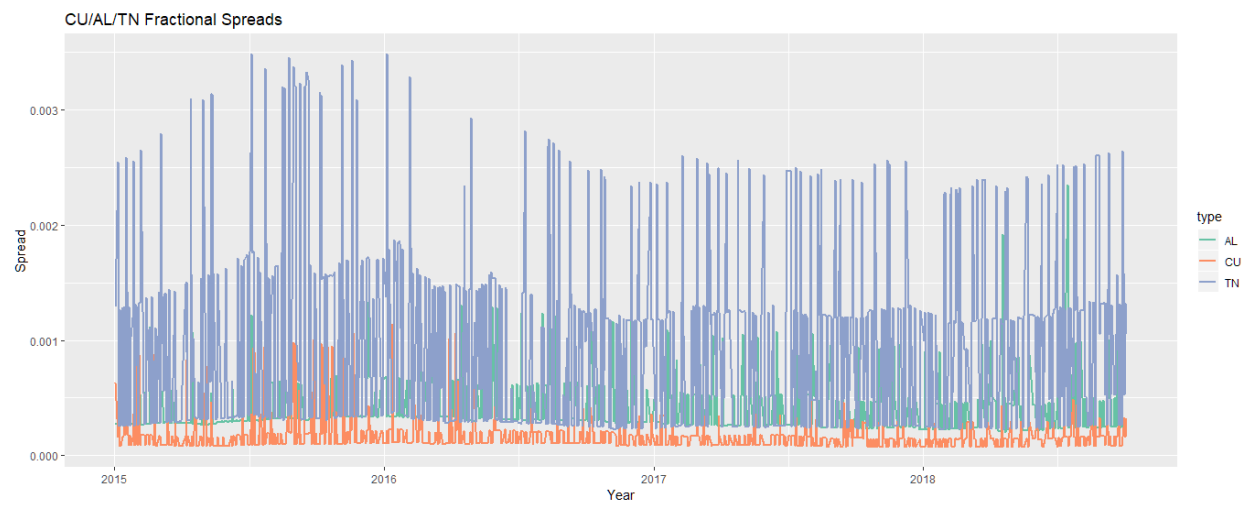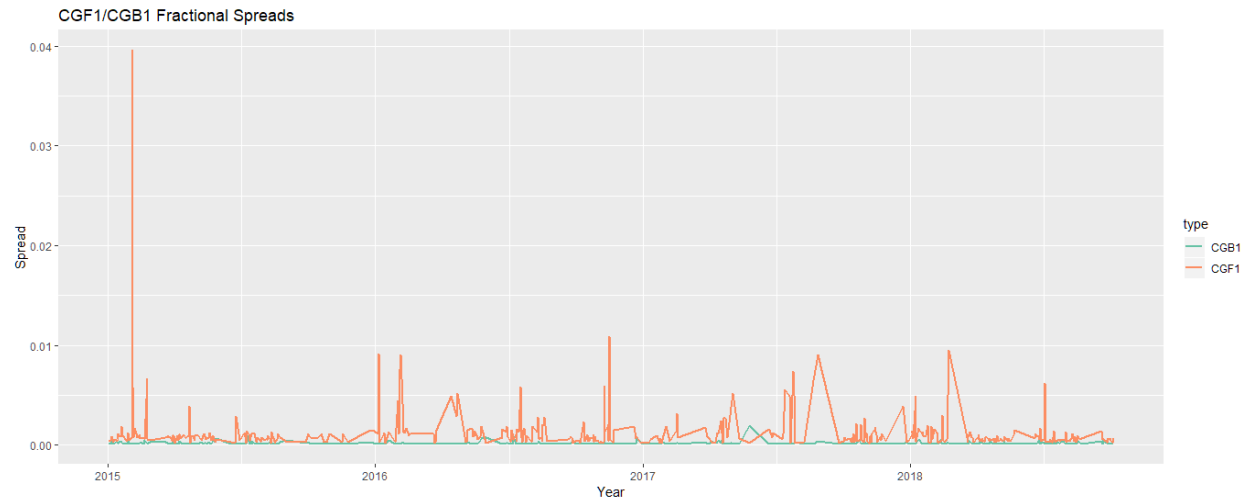
1. Fixed Income
   a. Spreads seem relatively stable and very narrow for the most part. There are certain times where the spreads jump wildly though, perhaps the Canadian government bond market reacting to events in the US or global markets?
2. Commodities
   a. The spreads for Copper and Aluminum futures on the LME are very narrow, usually 0.5 – 1.0 wide. This indicates that these markets are probably extremely liquid, as the spreads for these commodities rarely widens past 3.0. In contrast, Tin futures have extremely wide spreads, nearly 10 times that of CU/AL. Furthermore, Tin future spreads seem to jump frequently, bouncing around from 5.0 – 25.0, and even 50.0 many times. Either the market isn't very liquid, Tin futures may be subject to other supply/demand/pricing forces, or it could be that the contracts are quoted in a different degree of numerical precision.
3. Equities
   a. It's hard to make a judgement call on the equity index spreads here. In 2016, the HIS jumped wildly, bouncing from very narrow (5 – 25) to 50 very often. This tapered down for the majority of 2017, but there were two instances where the spread jumped over to over 100 points! This was probably due to events between the US/Asia, if I had to guess. The TSX is comparatively docile in contrast, spreads are for the most part narrow (good liquidity), and remaining stable throughout the analyzed time period.
4. FX/Crypto
   a. The spread Bitfinex/BTCUSD is exactly as I predicted. The spread became very active starting in the second half of 2017, which is around the same time that the "crypto-craze" became a global phenomenon; as the media and news outlets publicized it more and more, the stupidity just kept piling in, and wild swings in price/spread were caused by buying high, selling low, massive price manipulation, and enough counts of investor that it's probably classified as treasonous. The spreads have narrowed into 2018, and it is "All Quiet on the Crypto Front" as cryptocurrency has turned into the worst investment of 2018 by a long shot (worst investment quite possibly ever in my biased opinion.)

Chapter 3, exercise 2

1. Fixed Income
   a. The log spreads for fixed income look almost identical to the arithmetic spreads when plotted. There is not much of a difference in commentary here, besides the observation that the spread is exponentially smaller in number, but the width looks the same.
2. Commodities
   a. The logarithmic spreads of CU/AL/TN futures seem to be even more active than the arithmetic spreads. The AL/CU spreads have much more variation than in the previous exercise. TN seems to be just as active, but there are certain periods where the spread is within a given range (.0001 to .0015), disrupted by occasional "spikes" to .002 and above.
3. Equities

a. The equity indices are very surprising and a bit puzzling to me. The previous analysis of HSI and TSX60 seems to be completely reversed here: the log spreads of TSX60 have various spikes in width throughout the period (particularly in 2016), while the HSI remains very narrow (essentially 0) and barely moves! I'm not sure the exact reason for this, and I haven't been able to discover much through research but hopefully we'll discuss this anomaly in class.
4. FX/Crypto
   a. The fractional spreads in this asset class are essentially 0. This highly contrasts the activity that was seen in the arithmetic spreads.

Chapter 3, exercise 3

Comparing the summaries of spreads and fractional spreads, I've concluded that the logarithmic spreads are more well-behaved than the regular spreads. This seemed a little counter-intuitive to me at first: the spreads had larger "jumps" because the numbers were much larger, but I wasn't convinced that log spreads behaved better. To investigate further, I created inequalities for several of the securities and compared the variance of spreads to the variance of logarithmic spreads. This analysis proved my original conclusion to be correct: the variances of logarithmic spreads are smaller (more well-behaved) than the variances for arithmetic spreads.

Chapter 3, exercise 4

There appears to be a relationship between short volume and price in that the higher the short volume, the lower the stock price. For example, TSLA has essentially zero short volume and a stock price that is significantly higher than the prices of AMD and RGR. In contrast, AMD has had massive shorting activity throughout the years; AMD also has the lowest stock price of the three (by a significant amount), as expected according to my hypothesis on this relationship.
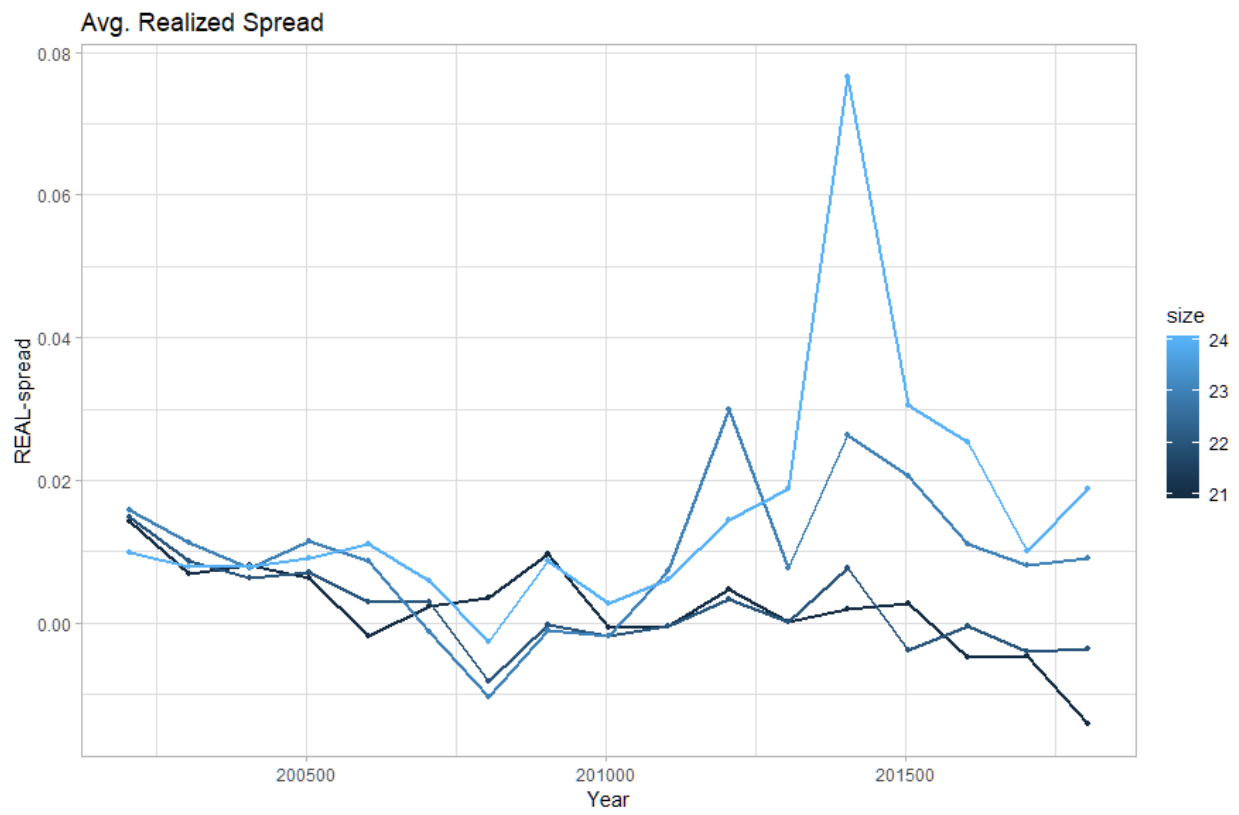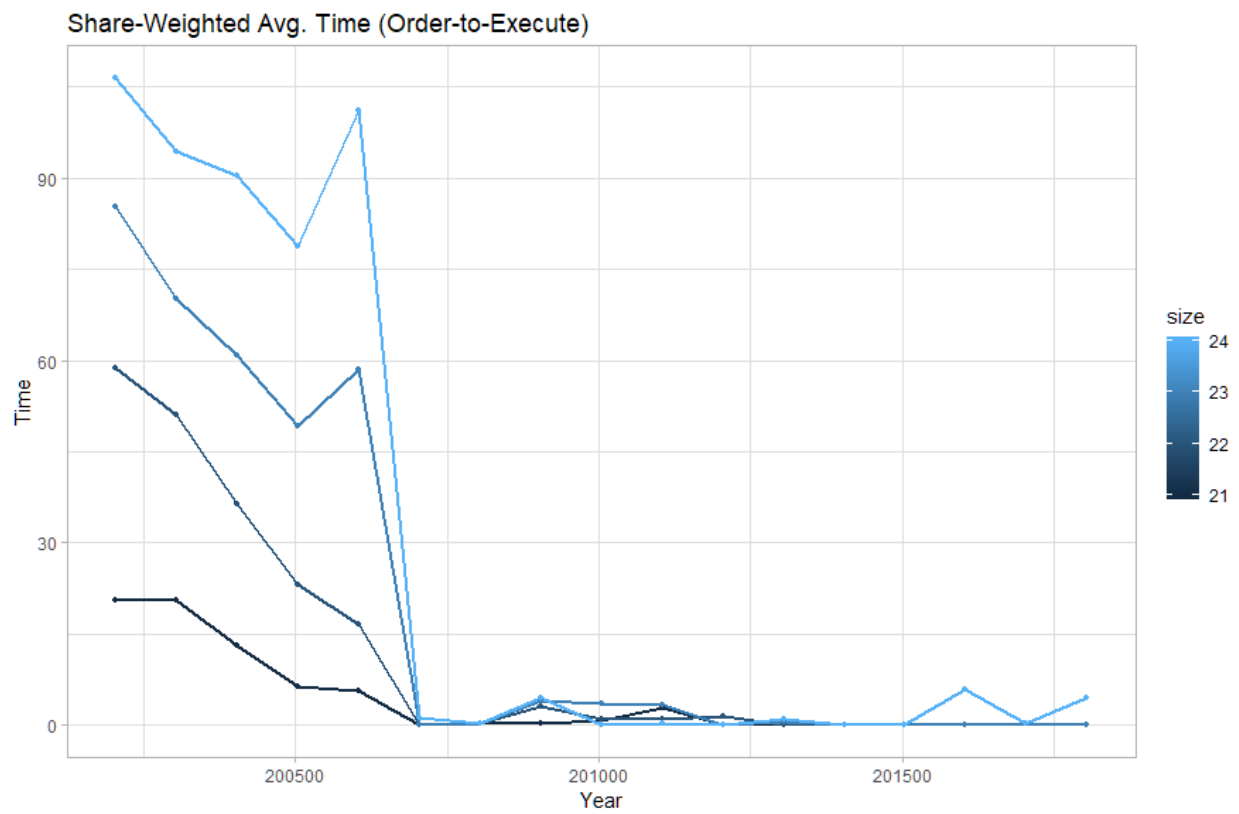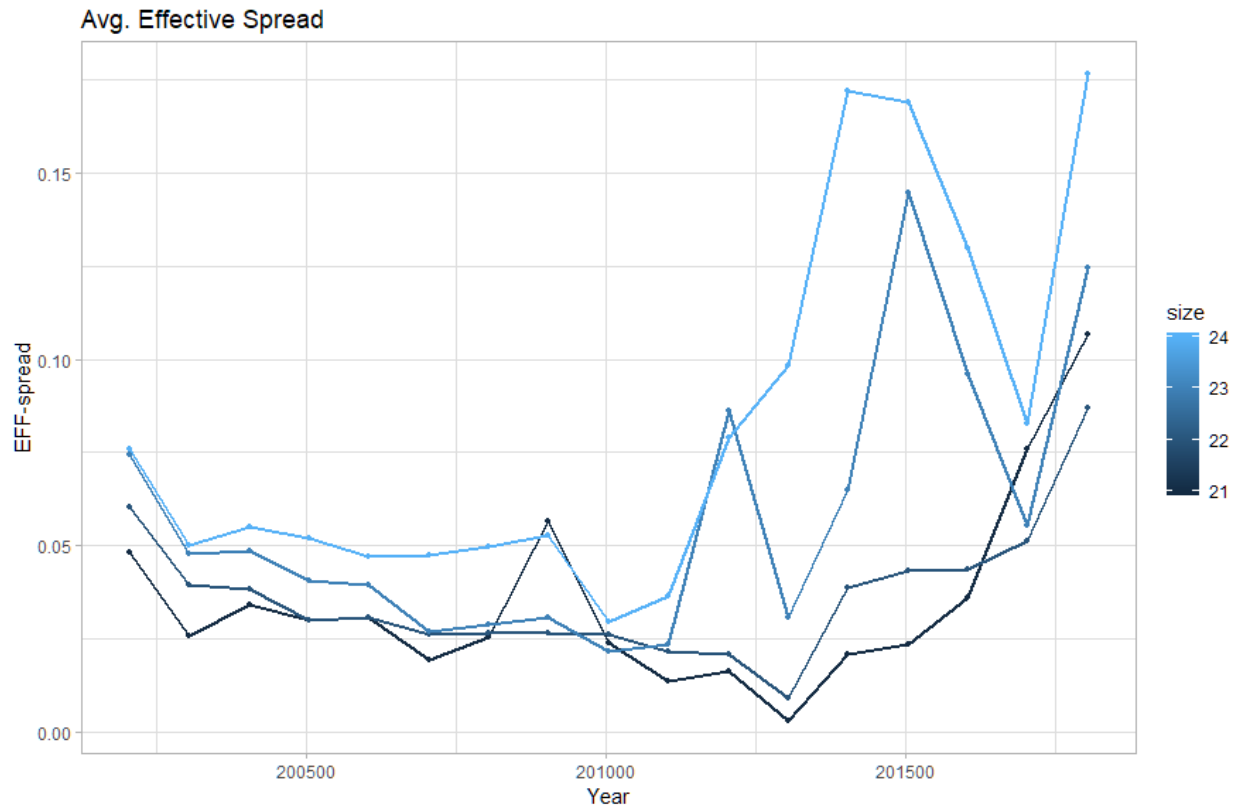
Chapter 4, exercise 1

Referring to figure 3, "*The distribution of price fractions across all inside quotes for 100 Nasdaq/NYSE/AMEX securities...*", I used Excel and calculated the probability of the random divergence from the uniform distribution of prices to be 0.005313, or .5313%.

Chapter 4, exercise 2

E(p) - E(p)' > 0, the antiderivative of this unconditional density shows the negative bias in prices because the increase in lambda * c is smaller than the point between (c to infinity) and lambda.

Chapter 4, exercise 3

Avg. Realized Spread

Avg. Effective Spread

Share-Weighted Avg. Time (Order-to-Execute)

1. Realized Spread

a. There isn't much I can tell from the Avg. Realized Spread, other than the increase in spread that happened between 2010 – 2015. It is apparent, however, that the largest group size (24) has a significantly higher spread than that of the smaller group sizes. This trend continues, with the group size of 23 having the second highest spread of the four.

b. Note: For all three charts, more data was plotted to help give a better overall picture of what's going on.

2. Effective Spread

a. Effective spreads can be viewed as an estimate of the execution costs paid by the trader, and the overall revenue that goes to the liquidity provider (market-makers, etc). This graph thus paints a good picture that the liquidity providers in the market have seen revenues increase dramatically since 2011. Unrelated to this analysis, the book *Flash Boys* by Michael Lewis can probably shine some light on this as well. I recall Lewis mentioning the different deals that exchanges were offering to traders and liquidity providers; some would incentivize liquidity providers by actually paying them to execute on their exchange, and others would do the opposite. (This did have uses for the exchange, regardless of whether they were paying people to play, or charging them)

3. Share-Weighted Avg. Time

a. This graph is the most dramatic of the entire chapter; it is very telling of the influence that technological innovation has had on the financial markets. Right around 2006-2007, the average order-to-execute time crashed through the floor, going from 30, 60, even 90 seconds to essentially 0 seconds basically overnight. There it has stayed; to look at the order-to-execute time since then (especially for HFT nowadays), this graph would need to be in microseconds (a case could be made for NANO-seconds too)